

CASE REPORT

Nagoya J. Med. Sci. **84**. 640–647, 2022
doi:10.18999/nagjms.84.3.640

Achieving good neurological outcome by combining decompressive craniectomy for acute subdural hematoma and transarterial embolization of intraperitoneal injured arteries for multiple severe trauma: a case report

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ABSTRACT

A 22-year-old woman jumped from the 4th floor of her apartment in an attempt to commit suicide. Whole-body computed tomography showed multiple injuries, including right acute subdural hematoma, left hemopneumothorax, several fractures, intraperitoneal hemorrhage, and spleen injury. Her consciousness deteriorated rapidly, and her right pupil was dilated. Furthermore, she had unstable vital signs including blood pressure of approximately 70/40 mmHg, pulse about 150/minute, respiratory rate 25/minute, and percutaneous oxygen saturation of 90% on 10 L oxygen. Intratracheal intubation and insertion of a thoracostomy tube were performed in the emergency room. Due to concomitant brain herniation and hemorrhagic shock, simultaneous decompressive craniectomy for acute subdural hematoma and transarterial embolization of intraperitoneal injured arteries were performed in our hybrid operating room. Despite rapid blood transfusions, the blood pressure did not increase. After starting embolization of the injured arteries of the spleen, the blood pressure increased, thereby making it possible to remove the acute subdural hematoma, and hemostasis was then achieved. Four hours later, the acute subdural hematoma and intracranial pressure increased again, and re-operation was performed in the normal operating room. Cranioplasty and clavicular fracture reduction were performed 14 days later. She recovered enough to talk and walk, and her consciousness stabilized. Interviews with her and her family by a psychiatrist determined that abnormal behaviors had first appeared 2 months earlier. She was diagnosed with acute and transient psychotic disorders, and treatment was started. The patient was discharged home 1 month later with mild disability of her higher-order brain function.

Keywords: traumatic brain injury, hemorrhagic shock, transarterial embolization, combining, hybrid

Abbreviations:

IVR: interventional radiology
TAE: transarterial embolization
TBI: traumatic brain injury

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Received: July 5, 2021; accepted: September 22, 2021

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INTRODUCTION

Outcomes of patients with concomitant traumatic brain injury (TBI) and hemorrhagic shock are extremely poor.¹⁻⁴ Hemorrhagic shock is mainly induced by internal hemorrhage due to severe trauma. Early hemorrhage control is essential to save hemorrhagic shock patients.^{2,4,5} Similarly, early efforts to decrease intracranial pressure of patients with TBI can improve functional outcomes.⁶⁻⁹ Hybrid operating rooms equipped with an angiographic fluoroscopy system are widely used in different surgical sub-specialties.¹⁰ The hybrid operating room makes it possible to perform immediate bleeding control using interventional radiology (IVR) and/or direct surgery. Recently, it has been reported that hybrid treatment using a combination of IVR and direct surgery can improve the outcomes of traumatic torso hemorrhage patients.²⁻⁵ Before the hybrid operation rooms were installed in many hospitals, only either treatment for TBI or hemorrhagic shock was performed first. Therefore, most patients with concomitant TBI and hemorrhagic shock induced by torso hemorrhage died. Now, it is possible to perform simultaneous craniotomy for TBI and IVR for torso hemorrhage in hybrid operating rooms, and the hybrid treatments can rescue some severe patients with concomitant TBI and hemorrhagic shock.

A case that was treated with a combination of decompressive craniectomy for acute subdural hematoma and transarterial embolization (TAE) of injured intraperitoneal arteries for severe trauma in a hybrid operating room, with a net result of achieving not only rescue but also a good neurological outcome, is presented.

CASE REPORT

A 22-year-old woman jumped from the 4th floor of her apartment in an attempt to commit suicide in front of her family. She was immediately transported to our hospital, and upon arrival, her Glasgow Coma Scale score was 11 (E3V3M5) with restlessness. Whole-body computed tomography demonstrated that there were multiple injuries including right acute subdural hematoma, left petrous fracture, left hemopneumothorax, several rib fractures, clavicular fracture, intraperitoneal hemorrhage, and injury of the spleen (Fig. 1).

There was rapid deterioration of her consciousness, with the Glasgow Coma Scale score decreasing to 9 (E2V2M5), in conjunction with dilation of her right pupil. Furthermore, her vital signs were unstable: blood pressure approximately 70/40 mmHg, pulse approximately 150/minute, respiratory rate 25/minute, and percutaneous oxygen saturation 90% on using 10-L oxygen. These findings were indicative of hemorrhagic shock. Intratracheal intubation and insertion of a thoracostomy tube were performed in the emergency room. Intraperitoneal hemorrhage was caused by the injured spleen, which was thought to be the main bleeding point. These conditions were concomitant with both brain herniation and hemorrhagic shock. Therefore, it was decided to perform a simultaneous decompressive craniectomy for acute subdural hematoma and TAE of the injured intraperitoneal arteries within the hybrid operating room. Blood pressure remained unstable and did not increase despite rapid transfusions using fresh frozen plasma and mannitol adenine phosphate. After craniotomy, the dura mater was not opened until the blood pressure became greater than 90 mmHg. Abdominal angiography was performed concurrently, with embolization of the injured arteries of the spleen (Fig. 2).

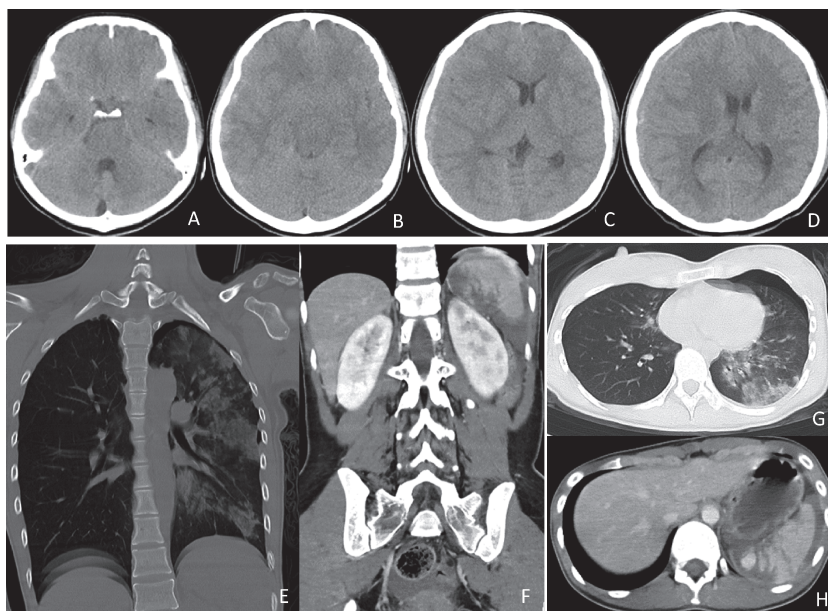


Fig. 1 Computed Tomography (CT) before the operation
Fig. 1A–D: Head CT shows right acute subdural hematoma and indicates increasing intracranial pressure.
Fig. 1E–H: Body CT shows left hemopneumothorax, intraperitoneal hemorrhage, and injury of the spleen.

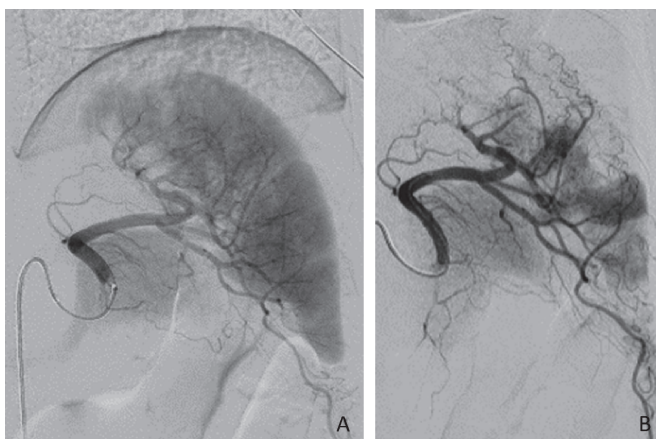


Fig. 2 Abdominal angiography
Fig. 2A: This angiography shows pre transarterial embolization (TAE) view.
Fig. 2B: This angiography shows post TAE view decreasing flow in the spleen.

Subsequently, after the blood pressure rose, the dura mater was opened, and the acute subdural hematoma was successfully removed. After the operation, her right dilated pupil improved and regained normal size, and computed tomography showed decreased intracranial pressure (Fig. 3A–C). However, four hours later, anisocoria once again appeared, and computed tomography showed that the acute subdural hematoma and intracranial pressure were both increasing (Fig.

3D–F). Sources of rebleeding were identified in our normal operating room as being from the contusion of her right temporal lobe and some of the bridging veins of her skull base. Thus, we then performed partial lobectomy of the middle and inferior temporal gyri, and complete hemostasis of the bleeding from the bridging veins (Fig. 3G–I).

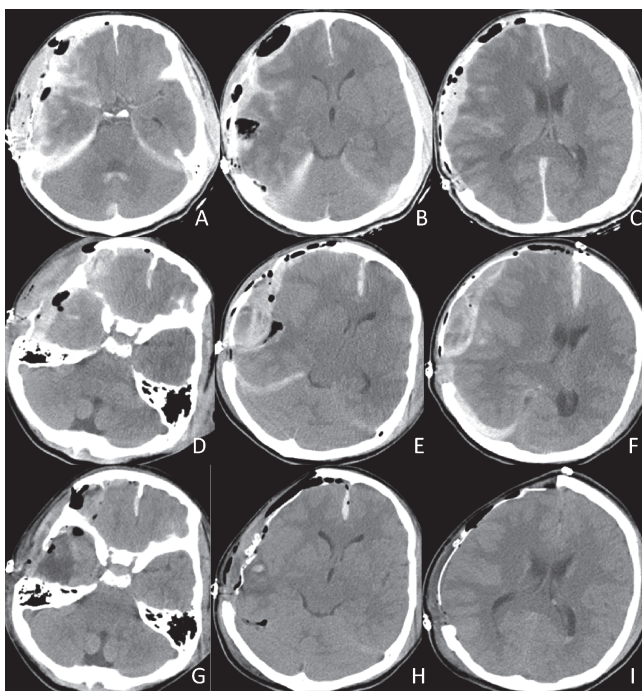


Fig. 3 Computed Tomography (CT) after the operation

- Fig. 3A–C:** CT shows decreasing hematoma and intracranial pressure after the first operation with residual contrast agent effect.
- Fig. 3D–F:** Four hours after the first operation, CT once again reveals increasing acute subdural hematoma and intracranial pressure.
- Fig. 3G–I:** After the second operation, CT demonstrates disappearance of the hematoma, decreasing intracranial pressure, and partial lobectomy of the right middle and inferior temporal gyri.

The tracheal tube was extubated 2 days later, with cranioplasty and clavicular fracture reduction performed 14 days later. In addition to recovering enough to talk and walk, her overall awareness and consciousness stabilized. A psychiatrist interviewed both the patient and her family and found that some of her abnormal behaviors began appearing about 2 months earlier. She was thus diagnosed as having acute and transient psychotic disorders, and appropriate drug treatment was started. The patient was discharged home 1 month later with mild disability of her higher-order brain function and left facial palsy. Assessments of her higher-order brain function at 1 month were as follows: Wechsler Adult Intelligence Scale III: verbal IQ: 93, performance IQ: 83, and Mini Mental State: 30/30.

DISCUSSION

TBI and hemorrhage are still the main causes of trauma deaths.¹¹ TBI is the leading cause of morbidity and mortality in patients following injury, followed by hemorrhage. Hemorrhage and TBI are reciprocally harmful. TBI leads to worse coagulopathy, which impairs hemostasis of hemorrhagic injuries. Hemorrhagic shock causes decreased cerebral blood flow and hypoxemia, which results in worse neurological outcomes.¹² Patients with concomitant TBI and hemorrhagic shock have the worst coagulopathy, as evidenced by higher activated prothrombin time and lower platelet counts, along with increased mortality.¹ The clinical course of concomitant hemorrhagic shock, which requires a bleeding control procedure, and severe TBI, which requires decompression of the intracranial pressure, remains unclear.¹⁴ The reason for this is that, in most of these cases, the vital signs are so poor that it is not possible to perform examinations and treatments, or that death rapidly occurs despite therapeutic interventions. Kinoshita et al previously reviewed the data of 2686 multiple blunt trauma patients over an 8-year period. Their results showed that the numbers and rates of the selected therapy were: cardiopulmonary arrest on arrival (235, 8.7%), bleeding control procedure only (163, 6.1%), intracranial surgery only (122, 4.5%), both procedures but separately performed (14, 0.52%), and concurrent bleeding control with intracranial pressure monitoring (10, 0.37%).⁴

In patients with TBI, it has been reported that the duration of the brain herniation or intracranial hypertension is associated with worse functional outcomes.⁶⁻⁹ Thus, early efforts to decrease intracranial pressure can improve clinical outcomes. It has been demonstrated that shorter time intervals between the injury and intracranial surgery are associated with better outcomes in patients with TBI.⁶⁻⁹ Hemorrhagic shock is primarily induced by torso hemorrhage associated with severe trauma, with most of these cases being potentially preventable deaths. Thus, identifying ongoing hemorrhage and achieving hemostasis as rapidly as possible are essential for improving outcomes.^{2,3,5} IVR can play a unique diagnostic and therapeutic role in the management of acute severe trauma. IVR allows for a more rapid and less invasive procedure for controlling hemorrhage than direct surgery. TAE is currently a well-established and effective means of dealing with arterial hemorrhage in trauma patients.¹³ In cases of concomitant brain herniation and hemorrhagic shock, the simultaneous use of both decompressive craniectomy and a hemorrhage control procedure is needed to rescue a patient.

Hybrid operating rooms furnished with angiographic equipment offer opportunities for identifying and controlling sources of hemorrhage with angiographic techniques, in addition to performing direct surgery. Hybrid treatments that combine direct surgery and IVR within the operating room or emergency department can effectively reduce iatrogenic damage and help preserve organ functions and tissue planes.²⁻⁵ Furthermore, the endovascular method can expedite access to vessels with minimal exposure, avoid complex dissections, and decrease procedure times.³ These hybrid treatments are mainly performed for abdominal bleeding control.²⁻⁵ The combination of procedures used for direct surgery and IVR include preperitoneal pelvic packing and pelvic artery embolization, perihepatic packing and hepatic artery/portal vein embolization, and splenectomy and renal artery embolization.²⁻⁵ However, even when using these hybrid treatments, it remains challenging when trying to treat patients with concomitant TBI and hemorrhagic shock. There have been a few reports of using a combination of both craniotomy and IVR.^{2,3} Kataoka et al reported¹³ patients who underwent hybrid treatment using a mobile digital subtraction angiography device in an emergency department. One case underwent combined decompressive craniotomy and embolization for the renal artery and portal vein. Although the patient survived, the neurological outcome was not reported.³ Jang et al also reported seven patients who underwent hybrid treatments in a hybrid operating room.² Two of the patients underwent combined craniectomy and

TAE/angiography, but both died.

The disadvantages of combining direct surgery and IVR in a hybrid operating room have been previously described.^{2,3,10} In these operating rooms, many special staff are required including a surgeon, interventional radiologist, anesthesiologist, radiological engineer, and nurse. In addition, there is a risk of radiation exposure for the surgical team, and there are issues with the cost-effectiveness of the hybrid operating room. Moreover, since hybrid operating rooms are not designed for neurosurgery, there were several specific problems when performing the combined craniotomy and IVR. First, there is limited movement of the operating table, because it only moves up and down. The head side cannot be separately raised up, and the flat table can induce bleeding from veins. Second, not all shadowless lamps were able to reach the head side because of the angiographic fluoroscopy apparatus. In our operating room, due to only one shadowless lamp being able to provide illumination, the operating field brightness was not sufficient to make it possible to observe the skull base side, where there were some bleeding veins (Fig. 4). Third, the angiographic fluoroscopy apparatus is so close to the neurosurgeons that this increases the radiation exposure (Fig. 4). Fourth, the space around the head side was more confined than that found for the IVR side. As a result, the staff and surgical equipment were all crowded together in a very small space (Fig. 4).



Fig. 4 Intraoperative photographs during the performance of the simultaneous craniectomy and interventional radiology (IVR) in the hybrid operating room

- Fig. 4A:** This picture shows the head side view. Space for the head side is more confined than that available for the IVR side. One of the shadowless lamps reaches the head side (long arrows). The angiographic fluoroscopy apparatus is so close to neurosurgeons that this increases the radiation exposure (arrowhead).
- Fig. 4B:** This picture shows the IVR side view. The other shadowless lamp is not able to reach because of the impediment of the angiographic fluoroscopy apparatus (short arrows).

The current case is the first report of achieving a good neurological outcome using a combined decompressive craniectomy and TAE of injured intraperitoneal arteries for multiple trauma. However, there were two fortunate aspects that helped achieve the good outcomes in the present case. First, the hemorrhagic shock was induced by only a spleen injury, without either pelvic or hepatic injuries causing major bleeding issues.^{2,3} Therefore, this made it possible to rapidly

control the bleeding and increase the blood pressure by performing TAE. Second, the origins of acute subdural hemorrhage were the right temporal contusion and some of the bridging veins, with most of the remaining brain intact. Rapid decompression craniectomy was able to avoid secondary brain damage with the exception of the right partial temporal lobectomy.

Before hybrid treatments become available, patents with concomitant TBI and hemorrhagic shock induced by torso hemorrhage were treated for TBI or hemorrhagic shock separately. It is well known that blood pressure is rapidly decreased at the time of performing decompression of intracranial pressure by craniotomy. When the craniotomy is selected as initial treatment for TBI in cases with hemorrhagic shock, blood pressure falls with the craniotomy, and the procedure cannot be performed. On the other hand, when procedures for hemostasis are selected as initial treatments for hemorrhagic shock in cases with brain herniation, poor neurological outcomes are inescapable because of severe brain damage, even if craniotomy is performed later. We suggest that the indications for simultaneous treatment with craniotomy for TBI and IVR for torso hemorrhage are concomitant 1) urgent brain herniation with unilateral pupil dilation, and 2) hemorrhagic shock class IV, such as decreasing systolic blood pressure, pulse \geq 140/minute, and a shock index (pulse/systolic blood pressure) \geq 2.0.

CONFLICT OF INTEREST

The authors declare no conflicts of interest associated with this manuscript.

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