CASE RECORDS of the MASSACHUSETTS GENERAL HOSPITAL

Case 39-2019: A 57-Year-Old Woman with Hypotension and Trauma after a Motorcycle Accident

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PRESENTATION OF CASE

Dr. Jordan P. Bloom (Surgery): A 57-year-old woman was evaluated at this hospital after a motorcycle accident.

The patient was the helmeted operator of a motorcycle traveling at 64 km per hour that collided head on with a car coming from the opposite direction. The patient's body was launched over the motorcycle handlebars; her helmet remained intact. Emergency medical services personnel and an advanced response team found the patient lying in the prone position, where she was noted to be confused and to have repetitive speech. She reported pain in the left hip, weakness in the left leg, and difficulty breathing. The heart rate was 118 beats per minute, the blood pressure 78/48 mm Hg, the respiratory rate 46 breaths per minute, and the oxygen saturation 97% while she was receiving oxygen through a nonrebreather face mask at a rate of 15 liters per minute. The Glasgow Coma Scale (GCS) score was 8 (on a scale of 3 to 15, with lower scores indicating greater alteration of consciousness), and the pupils were unequal (the left was 3 mm in diameter, and the right was 4 mm) but reactive. The hands and feet were cool with weak pulses. The pelvis appeared grossly deformed; the patient was immobilized with a pelvic binder, a cervical collar, and a backboard. Intraosseous access was established in the left humerus, and two peripheral intravenous catheters were inserted in the right arm; intravenous fluid and phenylephrine boluses were administered. Owing to the patient's altered mental status and the development of hypopnea, the trachea was intubated after rapid-sequence induction with etomidate and succinylcholine.

The patient was transported by helicopter directly to the emergency department of this hospital. During transport, 2 liters of normal saline, 2 units of packed red cells, fentanyl, ketamine, rocuronium, and phenylephrine were administered intravenously; an intravenous bolus of 3% hypertonic saline was also administered because of concerns about intracranial injury.

On the patient's arrival at this hospital, the temperature was 35.6°C, the heart rate 101 beats per minute, and the blood pressure in the left arm 60/40 mm Hg. The height was 165 cm and the weight 80 kg. The oxygen saturation was 100% while the patient was receiving oxygen through a mechanical ventilator (respiratory rate, 18 breaths per minute; tidal volume, 370 ml; positive end-expiratory pressure, 5 cm of water; fraction of inspired oxygen, 1.0). The neurologic examination was limited owing to the administration of an anesthetic agent; the GCS score was 3T (the suffix "T" indicates that the trachea was intubated). There was palpable deformity of the left clavicle, but there was no evidence of trauma to the head, arms, or back. The neck was supple, and the trachea was positioned in the midline. Carotid and femoral pulses were symmetric and weakly palpable. Breath sounds were slightly diminished at the base of the left lung, and there was no evidence of rib fractures or flail chest. The abdomen was soft but was not distended. A 5-cm laceration with active bleeding extended from the pubic symphysis to the left labium majus. The pelvis was grossly unstable, with a pelvic binder in place. There were marked ecchymoses and gross deformity of the left thigh; on the upper medial left thigh, there was a circular wound measuring 2 cm in diameter, with active bleeding. The lengths of the right and left legs appeared equal, and the compartments of both legs were soft. The remainder of the examination was normal.

Laboratory test results are shown in Table 1. Focused assessment with sonography for trauma (FAST) did not reveal fluid in the pericardial, hepatorenal, splenorenal, or suprapubic recesses. Because the patient had persistent hypotension, a catheter was inserted in the left subclavian vein, and 8 units of packed red cells and one dose of tranexamic acid were prepared for intravenous infusion.

Emergency management decisions were made, and therapeutic procedures were performed.

DISCUSSION OF INITIAL MANAGEMENT

Dr. David R. King: I was involved in the care of this patient. When I first evaluated her in the emergency department, it was clear that she was dying, and cardiac arrest appeared imminent, given that she was in hemorrhagic shock. Hemorrhage is the most common cause of preventable death after a traumatic event. Imaging studies obtained in this patient showed a complex pelvic fracture and suggested that the retroperitoneum was the likely source of exsanguination (Fig. 1A). In order to keep this patient alive long enough to have the opportunity to explore and definitively control the presumed sites of exsanguination (i.e., the pelvis and thigh), stabilization of her hemodynamics would serve as a stopgap measure until surgical control of the bleeding could be established. Our goal was to immediately control internal bleeding from the noncompressible sites.

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a minimally invasive endovascular technique that can temporarily control life-threatening traumatic truncal hemorrhage occurring below the diaphragm. REBOA prevents aortic blood flow to the affected area, thus serving as a control measure until the implementation of definitive surgical management.[1,2] In some cases, REBOA may be an alternative to resuscitative thoracotomy and aortic cross-clamping.[3] Although REBOA is still considered to be an emerging intervention for traumatic torso exsanguination, many trauma centers have adopted this technique in select patients.[3-5] We chose to perform REBOA in this patient in the emergency department, given the immediate need to control infradiaphragmatic exsanguination.

Before an aortic occlusion balloon can be inflated, reasonable efforts must be made to rule out life-threatening hemorrhage in cavities proximal to the proposed location of the balloon. Given that the likely location of hemorrhage in this patient was in the pelvis, the endovascular balloon was planned to be positioned just above the aortic bifurcation (zone III of the aorta). However, if the patient's FAST examination had shown hemoperitoneum, then positioning the balloon in zone I (descending aorta proximal to the celiac artery) would have been appropriate.[6-8] The presence of clinically significant hemothorax or hemopericardium on FAST examination or chest radiography represents a contraindication for REBOA. REBOA is not a substitute for emergency anterolateral thoracotomy for penetrating chest injuries. In this patient, bleeding into the pericardium, pleural spaces, and intraperitoneal space was ruled out with the use of bedside ultrasonography and chest radiography.

Early femoral arterial access for REBOA has

Table 1. Laboratory Data.*

Variable	Reference Range†	On Arrival at Emergency Department
Hemoglobin (g/dl)	12.0–16.0	15.8
Hematocrit (%)	36.0–46.0	47.6
Red-cell count (per μl)	4,000,000–5,200,000	5,220,000
White-cell count (per μl)	4500–11,000	15,800
Platelet count (per μl)	150,000–400,000	104,000
Sodium (mmol/liter)	135–145	143
Potassium (mmol/liter)	3.4–5.0	5.3
Chloride (mmol/liter)	98–108	114
Carbon dioxide (mmol/liter)	23–32	9
Urea nitrogen (mg/dl)	8–25	17
Creatinine (mg/dl)	0.60–1.50	1.20
Glucose (mg/dl)	70–110	449
Phosphorus (mg/dl)	2.6–4.5	6.1
Calcium (mg/dl)	8.5–10.5	6.6
Ionized calcium (mmol/liter)	1.14–1.30	0.88
Magnesium (mg/dl)	1.7–2.4	1.6
Total protein (g/dl)	6.0–8.3	2.6
Albumin (g/dl)	3.3–5.0	1.6
Globulin (g/dl)	1.9–4.1	1.0
Alanine aminotransferase (U/liter)	7–33	22
Aspartate aminotransferase (U/liter)	9–32	47
Alkaline phosphatase (U/liter)	30–100	35
Total bilirubin (mg/dl)	0.0–1.0	0.2
Direct bilirubin (mg/dl)	0.0–0.4	<0.2
Lipase (U/liter)	13–60	96
Prothrombin time (sec)	11.5–14.5	22.7
International normalized ratio	0.9–1.1	1.9
Partial-thromboplastin time (sec)	22.0–35.0	89.6
Lactate (mmol/liter)	0.5–2.2	5.8
Venous blood gases		
pH	7.30–7.40	7.04
Partial pressure of carbon dioxide (mm Hg)	38–50	48
Partial pressure of oxygen (mm Hg)	35–50	197
Base excess (mmol/liter)	0.0–3.0	−18.2
Arterial blood gases‡		
Fraction of inspired oxygen		1.0
pH	7.35–7.45	7.16
Partial pressure of carbon dioxide (mm Hg)	35–42	45
Partial pressure of oxygen (mm Hg)	80–100	554
Base excess (mmol/liter)	0.0–3.0	−12.9

* To convert the values for urea nitrogen to millimoles per liter, multiply by 0.357. To convert the values for creatinine to micromoles per liter, multiply by 88.4. To convert the values for glucose to millimoles per liter, multiply by 0.05551. To convert the values for phosphorus to millimoles per liter, multiply by 0.3229. To convert the values for calcium to millimoles per liter, multiply by 0.250. To convert the values for magnesium to millimoles per liter, multiply by 0.4114. To convert the values for bilirubin to micromoles per liter, multiply by 17.1. To convert the values for lactate to milligrams per deciliter, divide by 0.1110.

† Reference values are affected by many variables, including the patient population and the laboratory methods used. The ranges used at Massachusetts General Hospital are for adults who are not pregnant and do not have medical conditions that could affect the results. They may therefore not be appropriate for all patients.

‡ Arterial blood gases were measured 10 minutes after the patient arrived at the emergency department.

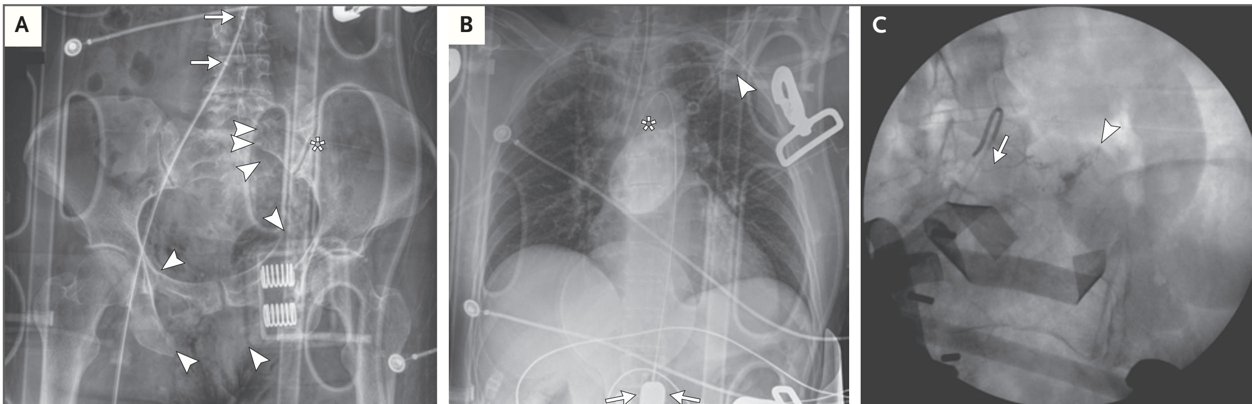


Figure 1. Initial Imaging Studies and REBOA Catheter Placement.

A portable pelvic radiograph (Panel A) shows multiple fractures (arrowheads) of the bilateral superior and inferior pubic rami and the left transverse process of L5, as well as a vertical fracture through the left hemisacrum. There is widening of the left sacroiliac joint (asterisk) that raises concern for ligamentous injury. The resuscitative endovascular balloon occlusion of the aorta (REBOA) catheter, which had been placed through the right femoral artery, is also noted, with metallic markers (arrows) indicating the superior and inferior position of the deflated balloon. Trauma equipment and monitoring lines are also seen. A portable chest radiograph (Panel B) shows the endotracheal tube terminating at the origin of the right main-stem bronchus, a left clavicle fracture (arrowhead), and mild bilateral hilar fullness and pulmonary vascular indistinctness that are consistent with mild pulmonary edema. The aortic occlusion balloon, which is filled with contrast material, is partially seen at the inferior edge of the radiograph (arrows). The wire over which the balloon catheter is placed courses upward in the aorta and terminates in the ascending portion of the aorta (asterisk). Trauma equipment, monitoring lines, and a defibrillator pad are also seen. An intraoperative arteriogram (Panel C) shows active extravasation (arrow) from the last left lumbar artery (arrowhead); radiodense surgical material overlies the pelvis.

been associated with improved survival after trauma.[9] In this patient, percutaneous access to the right common femoral artery had been obtained during the primary trauma survey and FAST examination, thus shortening the time from her arrival at the hospital to aortic occlusion and cessation of hemorrhage. Initially, the access had been obtained with a micropuncture needle, because the patient was hypotensive and there was no palpable femoral pulse to use as an anatomical landmark. Access was increased (also referred to as "upsized") serially to accommodate the REBOA balloon (Fig. 1A).

Immediately before the balloon was inflated, and despite transfusion with multiple units of blood product, the blood-pressure cuff (placed on the left brachium) displayed a blood pressure of 44/28 mm Hg. A 10-French aortic occlusion balloon catheter was advanced over a guidewire into aortic zone III and inflated with radiopaque contrast material. After balloon occlusion of the distal infrarenal aorta, the blood pressure rose to 168/88 mm Hg. A radiograph of the pelvis confirmed the presence of a complex pelvic fracture as well as the proper placement of the guidewire in the aorta. A portable chest radiograph showed REBOA in zone III; the termination of the endotracheal tube at the origin of the right main-stem bronchus was also noted (Fig. 1B). The endotracheal tube was repositioned 2 cm more proximally within the trachea and resecured. The patient was transported immediately to the operating room while receiving rapid infusions of warmed packed red cells (which had not been cross-matched) and thawed plasma; the REBOA catheter was in place.

After aortic occlusion is achieved and hemorrhage is temporarily controlled, rapid surgical intervention is still needed, since safe abdominal, pelvic, and lower-leg ischemic time after REBOA is estimated to be no more than 30 minutes.[1,10] REBOA provides a key temporary hemodynamic and hemorrhagic control that allows patients to survive long enough to receive definitive surgical and hemostatic intervention while perfusion is maintained above the level of aortic occlusion.

DISCUSSION OF INTRAOPERATIVE MANAGEMENT

Dr. Jerome C. Crowley: The intraoperative anesthetic management plan for a severely injured patient is complex and must be individualized on the basis of the patient's pathophysiological characteristics. The moment a patient arrives in the operating room, expert management by the anesthesia team is necessary to improve the likelihood of a good outcome as well as to aid the surgery team in their ability to obtain hemostasis and correct the underlying injury. In effect, comprehensive critical care starts in the operating room.

When this patient arrived in the operating room, her trachea had already been intubated and an inflated aortic resuscitation balloon was in place. Additional tasks were accomplished quickly; these included verification of the airway by means of continuous monitoring of end-tidal carbon dioxide, confirmation of adequate vascular access to accommodate rapid administration of large volumes of resuscitation fluids, and placement of an intraarterial catheter for continuous blood-pressure monitoring and to allow for real-time laboratory testing and dose adjustment of vasoactive medications. Immediate requisition of blood products is also critical for patients who have had major trauma. Emergency medications suited to any critically ill patient should be readily available. Finally, the depth of anesthesia in a critically injured patient can be adjusted on the basis of the patient's hemodynamic status. Since even anesthetic agents that do not directly suppress the cardiovascular system are likely to decrease the blood pressure by reducing sympathetic stimulation, we used electroencephalography to aid in monitoring and adjusting the depth of anesthesia in order to avoid the induction of unnecessarily deep anesthesia.[11] A transesophageal echocardiographic probe was placed to help guide decision making regarding the administration of vasopressor agents and fluids, to help identify the development of vasodilatory shock resulting from hypovolemic shock, and to identify any preexisting or developing structural cardiac anomalies.

Dr. King: In the operating room, in preparation for surgery, the patient's body was draped from the sternal notch downward. Given the likelihood of exsanguination in the pelvis, a Pfannenstiel–Kerr incision was made to access the retropubic space of Retzius and the preperitoneal–pelvic space; massive hemorrhage was identified and controlled with preperitoneal pelvic packing posteriorly toward the sacrum. After pelvic packing was completed, the patient was no longer dependent on volume expansion, so the resuscitative endovascular balloon was slowly deflated after 22 minutes of ischemic time. As expected, hypotension recurred during the deflation of the balloon.

Dr. Crowley: Management of anesthesia in patients who undergo REBOA is similar to that in patients with an aortic cross clamp; during deflation of the balloon, it is imperative that treatments are available to manage the acute drop in afterload, the increase in the potassium level, and the concomitant washout acidosis resulting from ischemia in the lower legs.[12] These treatments include vasoconstrictors, inotropic agents, calcium chloride, sodium bicarbonate, and insulin. Although the use of vasoconstrictors such as norepinephrine and vasopressin is controversial, this treatment was necessary for this patient in order to maintain an adequate perfusion pressure during the surgical procedure.[9] The patient was already receiving high-dose vasopressors when she arrived in the operating room; when she left the operating room, she was receiving low-dose vasopressors. In cases of hemorrhagic shock, anesthesiologists should be prepared to increase blood pressure with vasoactive agents, particularly since mixed shock states may develop.[13]

Dr. King: Additional bleeding from the lacerations to the labia, left groin, and left thigh was controlled with the use of advanced topical hemostatic gauze. As part of the management plan for comprehensive control of the patient's internal pelvic bleeding, external fixation of the pelvis was performed with the aid of intraoperative fluoroscopy. During the external fixation procedure, profound coagulopathy and hypotension developed; simultaneously, blood began to emanate from external lacerations that had previously been hemostatic.

Dr. Crowley: The next phase of the intraoperative management of this patient's condition involved ongoing resuscitation for massive bleeding and the developing coagulopathy. Continued transfusion of blood products, ideally in a balanced ratio, with the goal of hemodynamic stability is imperative; for this patient, transfusion included 30 units of packed red cells, 20 units of fresh-frozen plasma, and 6 units of pooled platelets.[14,15] The availability of laboratory results often lags behind clinical condition, and waiting for results may be detrimental to patient outcomes. Communication with the surgical team is critical to assess the clinical hemostasis and to inform the decision to aggressively continue transfusion with fresh-frozen plasma.

Dr. King: The patient subsequently underwent surgical exploration of the left groin and repair of laceration of the left common femoral vein. Hypotension recurred; therefore, the patient was continuously evaluated for the development of other shock states, such as cardiogenic or distributive shock, in conjunction with monitoring of anesthesia, since the presence of other shock states can confound the management of what is presumed to be hypovolemic shock.[16] Given the possibility that the patient had an injury that we had missed that was causing ongoing hypotension, an exploratory laparotomy was performed; clinically significant hemoperitoneum was noted, but neither a solid-organ injury nor a visceral source of hemorrhage was identified. Hemoperitoneum had resulted from rupture of the pelvic hematoma into the intraperitoneal space. The pelvic hematoma was evacuated, followed by ligation of the hypogastric arteries, ligation of a left external iliac vein injury, and temporary abdominal closure. Ultimately, a posterior sacral screw was placed, and fasciotomies of the left lower leg were performed after the leg was noted to be extremely tense. While the patient was still in the operating room, an angiogram was obtained, and lumbar artery angioembolization was performed to manage ongoing bleeding that could not be effectively controlled surgically.

Dr. Nathan E. Frenk: An arteriogram was obtained, with access through the right common femoral artery. Because the internal iliac arteries were known to have been ligated, investigation of additional sources of bleeding was performed. An arteriogram of the last lumbar artery on the left side showed active extravasation (Fig. 1C), which was successfully embolized with Gelfoam slurry. Arteriograms of the celiac, superior mesenteric, inferior mesenteric, common iliac, and external iliac arteries did not show additional bleeding.

DISCUSSION OF POSTOPERATIVE MANAGEMENT

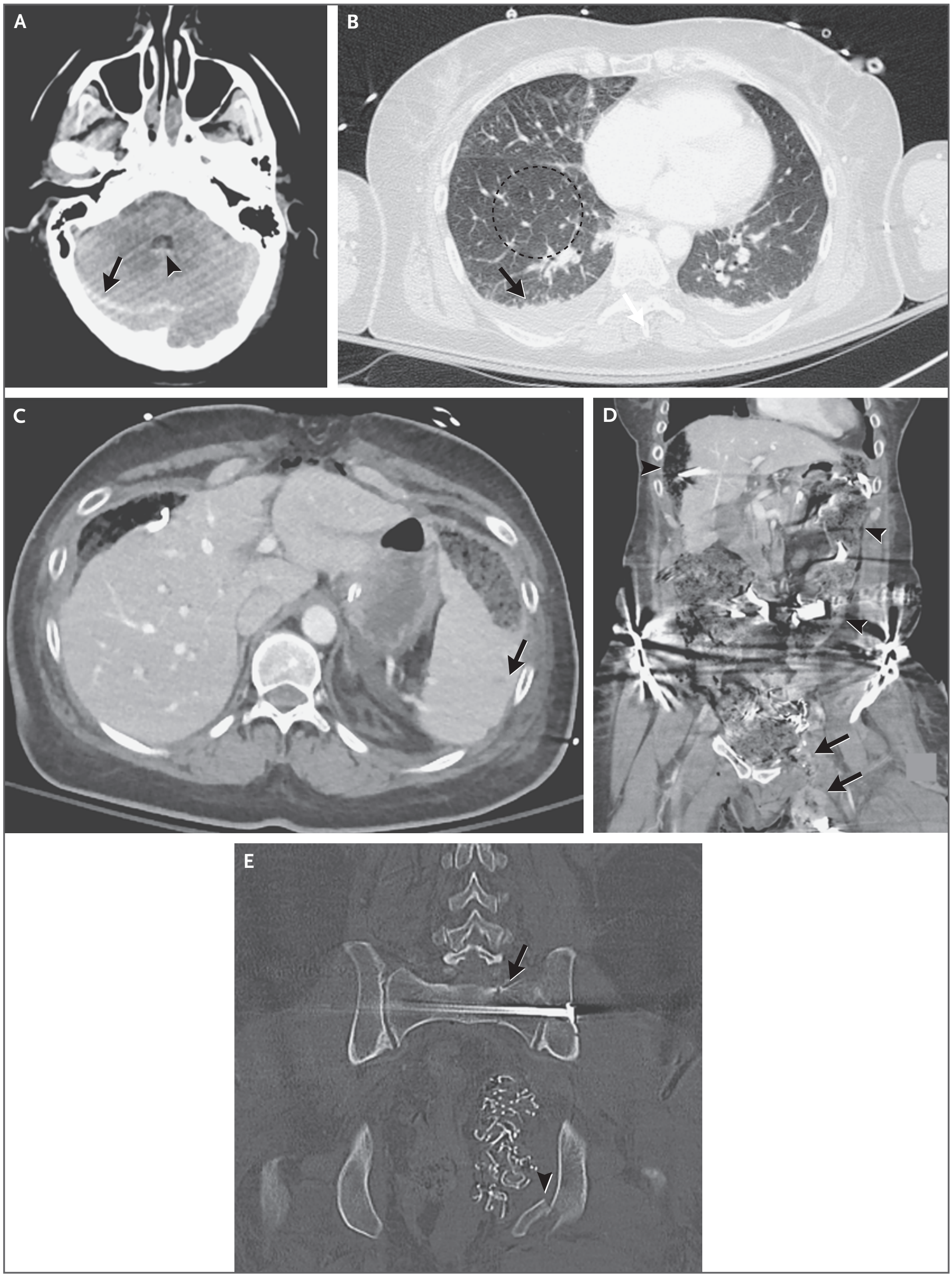
Dr. Frenk: After the initial surgery, computed tomography (CT) of the head was performed without the administration of contrast material, and CT of the neck, chest, abdomen, and pelvis was performed after the administration of contrast material. CT of the head revealed subarachnoid hemorrhage, trace blood in the fourth ventricle, and a small subdural hematoma, but no fractures or hydrocephalus were identified (Fig. 2A). CT of the chest revealed a left clavicular fracture, small bilateral pleural effusions, and mild pulmonary edema but no evidence of pneumothorax or vascular injury (Fig. 2B). CT of the abdomen and pelvis revealed a small laceration in the spleen, urine leak consistent with a bladder injury, and left pelvic fractures (Fig. 2C through 2E).

Dr. Haytham M.A. Kaafarani: Acute ischemia in the right lower leg developed in the patient in the intensive care unit immediately after surgery. The ischemia — a well-described complication of REBOA — resolved after removal of the right femoral catheter. The patient underwent multiple surgeries over the course of the next 10 weeks to repair the injured bladder and the fractured pelvis; resection of ischemic bowel was also performed. She later underwent multiple extensive reconstructive surgeries to address her open pelvic wound and the wound in her left lower leg and to cover her exposed femoral vessels and bladder. She also had acute kidney injury, without prompt recovery, rendering her dependent on dialysis. The patient's postoperative course was complicated, with a 73-day hospital stay, of which 64 days were spent in the surgical intensive care unit. After discharge from this hospital, she spent more than 200 days in rehabilitation; during that time, she had 5 hospital readmissions and 45 visits to specialty clinics. Her postoperative care involved the multidisciplinary efforts of 36 surgeons and surgical residents — representing 6 surgical specialties — who performed 33 operations, as well as the expertise of nurses and consultants from nephrology, infectious diseases, interventional radiology, physical medicine and rehabilitation, and nutrition.

One year after discharge, the patient had made great progress with physical therapy and had regained partial ambulatory function with the use of a walker to the point of enjoying outdoor activities, especially golf. She eventually underwent a left below-knee amputation, was fitted for a prosthesis, and was undergoing evaluation for kidney transplantation. Eighteen months after discharge, kidney function had recovered, and she no longer required hemodialysis.

PATIENT PERSPECTIVE

The Patient: I don't remember anything. The day before the accident, my husband and I were celebrating our wedding anniversary with a trip to



northern New England. The accident happened on our way home, less than a half mile from our house. I do not remember that day at all; I do not remember the drive back or the accident. I remember waking up some time later. I was in the hospital for a couple months, and I spent 7 months undergoing occupational and physical therapy.

When I came home, the first 2 weeks were utter chaos; we didn't know what we were doing, how to do it, or how to go about it. Of course,

Figure 2 (facing page). Postoperative Imaging Studies.
CT of the head (Panel A), performed without the administration of contrast material, reveals blood in the fourth ventricle (arrowhead) and a small subdural hematoma along the cerebellar tentorium (arrow). Subarachnoid hemorrhage is also present (not shown). Contrast-enhanced CT of the chest (Panel B) reveals small bilateral pleural effusions (arrow) and interlobar septal thickening consistent with mild interstitial pulmonary edema (circle). A nondisplaced left clavicular fracture is also present (not shown). An axial, contrast-enhanced CT scan of the abdomen and pelvis (Panel C) shows a small splenic laceration (arrow). Coronal reformatted images from contrast-enhanced CT of the abdomen and pelvis (Panels D and E) show surgical packing material (Panel D, arrowheads), as well as urine leak (which appears hyperintense owing to excretion of the contrast material) that extends from the pelvis to the thigh (Panel D, arrows) and, in Panel E, fractures of the left hemisacrum (arrow) (after fixation with screws) and left pubis (arrowhead); fracture of the left transverse process of L5 is also present (not shown).

using a stair lift and just figuring out how to get around the house with a wheelchair and walker and other accessories was something I had to learn. Everything must be planned out, and when I go out, even just to go out to eat, we have to plan: Do I have my wheelchair? Do I have my water? Do I have my supplies? My husband and I have really had to come up with plans and procedures.

I have an incredible support group. I have so many friends and family members supporting me through this whole thing. I feel pretty good, but as far as my emotional health goes, I have good days and bad days. I do have days when I just want to cry all day. I do have those days, but I talk to somebody about it. I talk to my daughter. I talk to my husband a lot. I probably will seek some professional help at some point if I need it.

I have set goals for myself, and I'm trying to reach them. I work hard. Life is a struggle for all of us, and my struggles are just different. Right now, my purpose is to get as physically healthy as I can, and that includes just walking. I'm looking forward to the process of getting a leg prosthesis and being able to walk and go hiking and biking and swimming and all those things.

I don't know why I'm alive, so I'm hoping at some point that I'll figure that out and that I'll have a purpose for continuing.

Dr. King: Sometimes we are not meant to understand why things happen in the moment. I have no doubt that you will find your purpose.

FINAL DIAGNOSIS

Control of hemorrhage with the use of resuscitative endovascular balloon occlusion of the aorta.

This case was presented at Surgery Grand Rounds.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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