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Life-Threatening Hemorrhage: Use of Resuscitative Endovascular Balloon Occlusion of the Aorta after Elective Laparoscopic Hiatal Hernia Repair

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Background	Resuscitative endovascular balloon occlusion of the aorta (REBOA) utilizes an intra-aortic balloon catheter to control sub-diaphragmatic hemorrhage. Recently its use has expanded from military/domestic trauma to non-traumatic hemorrhage or shock. Serious complications and death can arise from prolonged ischemia distal to aortic occlusion, and particular REBOA strategies may help avoid ischemic injuries.
Summary	The present case describes a 72-year-old woman who rapidly developed hypotension and altered mental status shortly after completing laparoscopic hiatal hernia repair. Given intraoperative concern for an aortic injury, a REBOA catheter was placed while the patient was being prepped for re-exploration. The balloon slowed hemorrhage so the operative field could be laparoscopically cleared and allowed anesthesia to deliver blood and resuscitative products. Invasive blood pressure monitoring was used to guide partial aortic occlusion and intermittent balloon to minimize distal ischemia. Despite massive blood loss, the patient suffered no evidence of ischemic organ injury and was discharged home on postoperative day two.
Conclusion	REBOA is a powerful tool when effectively utilized in special emergencies. As in this case, it may be used to decrease morbidity when facing life-threatening postoperative hemorrhage. It allows rapid control of blood loss which gives the operating surgeon time to gain adequate exposure and isolate the source. Care must be taken to minimize visceral ischemia with techniques such as partial occlusion and intermittent balloon deflation.
Key Words	REBOA; partial occlusion; intermittent deflation; ischemia; postoperative hemorrhage; laparoscopic

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Case Description

The patient is a 72-year-old woman with no significant medical history, seen in the clinic with complaints of heartburn, intermittent nausea, and chest discomfort. She had a prior upper endoscopy for these complaints, which was normal other than a 5 cm hiatal hernia. Additional workup included high-resolution manometry, which found normal esophageal motility and lower esophageal sphincter function.

She was taken to the operating room for laparoscopic hiatal hernia repair. Upon exploration, a type III hiatal hernia was found with a 6 cm hiatal defect. The crural and gastric dissections proceeded uneventfully, and the hernia sac was resected. A biologic mesh was prepared for posterior cruroplasty. A small amount of blood welled up in the mediastinum during placement of the first most posterior stitch. There was concern for an aortic needle injury, but after a period of close inspection and observation, there was no further accumulation of blood, and the surgery was resumed. The cruroplasty and fundoplication were completed without incident, and after a final inspection, ports were removed and skin incisions closed. Leaving the OR, the patient's blood pressure was 130/90.

Thirty minutes later, in the post-anesthesia care unit (PACU), the patient's blood pressure had fallen to 77/40. There was renewed concern for an aortic injury, and the patient was immediately taken back for laparoscopic exploration. En route, the in-house trauma/acute-care surgeon was asked to come to the OR with a REBOA kit. While the patient was prepped and intubated, internal jugular central access and radial artery invasive blood pressure monitoring was gained by anesthesia. The trauma surgeon placed the REBOA sheath in the right femoral artery. Skin incisions were opened and ports replaced. A large volume of blood and clot was encountered and suctioned. As the hiatus came into view, ongoing hemorrhage continued at the same rate it could be suctioned from the abdomen. The REBOA catheter was inserted to above the level of the hiatus, estimated by measuring from the femoral sheath to 10 cm above the sternal notch. The balloon was slowly inflated until the patient's radial systemic pressure exceeded 100 and hemorrhage slowed.

In a stepwise fashion, blood and clot were cleared from the hiatus, and the crural repair was taken down. The balloon was intermittently let down during this process to allow visceral perfusion and adjust to ongoing resuscitation. The aorta and mediastinum were carefully inspected, and no bleeding was found. The balloon was again let down, and blood was noted to be originating from screen right; attention was turned to the left upper quadrant, and the residual clot was suctioned. A briskly bleeding short gastric artery was found, which was ligated with an energy device. The crura were reapproximated, ports removed, and skin incisions closed. The REBOA catheter was partially inflated (approximately 5 ml) for 20 minutes and was let down four times for less than 60 seconds. Estimated blood loss approached 3 liters, the majority of which was initially suctioned from the abdomen at the beginning of the case.

In PACU, the patient received a one-liter bolus. Intraoperatively products were six units of packed red blood cells, two units each of plasma, platelets and cryoprecipitate, and 500cc 20% albumin. The patient's baseline hemoglobin was 13, and after the case was 9.2. She remained intubated overnight in the ICU and was successfully extubated with baseline mental status the following morning. Urine output that night approached 100cc/hr. Baseline creatinine was 1.1, and on postoperative day one was 0.9. She was transferred to the floor, and her diet was advanced to puree without issues. She was discharged home on postoperative day two.

Discussion

ED thoracotomy with resuscitative aortic occlusion (RAO) is a well-described and highly morbid technique to control massive abdominal/pelvic hemorrhage and polytrauma. REBOA was first described in combat in 1954, and a recent series of promising animal studies renewed interest. Since then, REBOA has seen increased utility in military and domestic trauma scenarios worldwide.[1] While the role of REBOA is still being defined, trauma centers have reported good outcomes with early utilization in appropriate patients, such as those with subdiaphragmatic hemorrhage.[2,3] Given the potential to quickly control massive hemorrhage with low morbidity, REBOA is an attractive option in select non-traumatic situations. It has been evaluated for bleeding after abdominal surgery, gastrointestinal and obstetric bleeding, and ruptured visceral or abdominal aortic aneurysms.[4] REBOA has also been examined as a

means to preferentially perfuse the heart and brain during resuscitation after nontraumatic cardiac arrest.[5] Despite some promising results, the consequences of prolonged ischemia below the level of occlusion can be devastating. Guidelines outlining non-traumatic use of REBOA have not been well-defined.[6]

Animal studies have helped demonstrate how REBOA may be used to control hemorrhage while minimizing ischemic damage below the level of occlusion. A bovine model induced hemorrhagic shock and monitored femoral and carotid pressures with incremental inflation of a supradiaphragmatic aortic balloon. Serial CT imaging was used to measure the degree of aortic occlusion. The study demonstrated a linear correlation between both rises in carotid pressures and falls in femoral pressures with percentage of aortic occlusion.[7] Partial REBOA may be ideal in a monitored setting, where the balloon can be incrementally inflated until mean arterial pressure reduces the risk of ischemic brain injury while allowing some ongoing perfusion below the level of occlusion. Another study using a swine model with abdominal aortic injury found significantly improved survival and reduced acidosis with intermittent balloon deflation during resuscitation. They studied different time-based deflation intervals and a protocol based on mean arterial pressure, and found the pressure-defined protocol to be most successful.[8] Intermittent balloon deflation as blood pressure allows during resuscitation may also help prevent ischemic injury.

There was concern for an aortic injury during hiatus approximation in the present case. This complication during an elective hiatal hernia repair or fundoplication may be lethal; case reports describe conversion to open surgery and, in one case, death due to this injury.[9–11] Depending upon the level of the injury and anatomy, exposure could be problematic with laparotomy alone, and sternotomy may be necessary. Rapid hemorrhage can be very difficult to control laparoscopically; suctioning may be inadequate to clear the field, and aggressive suctioning can evacuate pneumoperitoneum. Rapid hemorrhage may also be encountered from the liver, spleen, inferior vena cava, or, as in the present case, the short gastric vessels.

REBOA in the present case decreased the rate of hemorrhage and facilitated laparoscopic re-exploration and hemostasis, thereby avoiding the morbidity of laparotomy and extended postoperative stay. REBOA was used as described in the above animal studies—degree of balloon inflation was titrated to the patient's blood pressure by radial invasive monitoring, sustaining partial perfusion to the viscera. The balloon was deflated in intervals in a stepwise manner throughout the exploration, at times when exposure was stable, and bleeding could be easily suctioned. This approach also helped identify the source of bleeding and facilitated repair.

Successful hemostasis relied upon excellent coordination among the operating surgeon, the acute care surgeon performing REBOA, and anesthesiology. Partial REBOA helped clear the operative field and allowed the infusion rate of resuscitative products to exceed that of hemorrhage. Balloon deflations were timed when a good pausing-point for the operating surgeon coincided with anesthesia, feeling they had caught up with resuscitation. This approach showed no signs of ischemic damage to any organ system postoperatively despite massive blood loss and resuscitation.

Conclusion

REBOA is finding increased utility in both traumatic and non-traumatic resuscitative scenarios. Manipulating central perfusion can precipitate disastrous morbidity, and efforts must be taken to minimize ischemia. The described approach may only be feasible in centers with experienced acute care providers available on call. Waiting for REBOA should not delay conversion to open surgery if intraoperative bleeding cannot be controlled laparoscopically. In the case of postoperative hemorrhage, if REBOA can be performed while the patient is being prepped for surgery, it can facilitate a minimally invasive approach to hemostasis. Ongoing research may establish parameters to guide partial balloon occlusion and intermittent balloon deflation to minimize ischemic injuries.

Lessons Learned

A case is described where REBOA facilitated laparoscopic hemostasis of postoperative hemorrhage after laparoscopic hiatal hernia repair. Partial balloon occlusion and intermittent deflation were utilized to avoid ischemic injury. With a three-team approach, the source of blood loss was quickly identified and repaired laparoscopically, and the patient made a quick recovery.

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