Treatment algorithm and management of retrohepatic vena cava injuries

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Despite advances in trauma care, injuries to the inferior vena cava (IVC) continue to have a high mortality rate, ranging from 33% to 75%.[1–3] The retrohepatic IVC (RHIVC) is a particularly lethal region in which to sustain an injury, because the vessel is relatively fixed to the liver, and difficult to access and control. Patients with RHIVC injuries that survive to arrival at a trauma center will typically have a contained retroperitoneal hematoma. If this hematoma ruptures before laparotomy, survival is rare, with mortality rates reported as high as 100%.[3]

Management principles for injuries to the RHIVC consist of a combination of packing, additional exposure to gain vascular control, direct repair, and in some cases, shunting. The management of this severe injury requires rapid decision making and stepwise progression through a defined treatment algorithm (Fig. 1) as described in the following video technique article with supplemental digital online content. All videos are of procedures performed during teaching sessions on fresh non-embalmed cadavers and in accord with the standard operating procedures of the University of Southern California Fresh Tissue Dissection Laboratory.

PREOPERATIVE CONSIDERATIONS

Understanding the anatomy of the IVC is essential to managing these injuries. Briefly, the IVC forms anterior to the L5 vertebral body at the confluence of the common iliac veins,

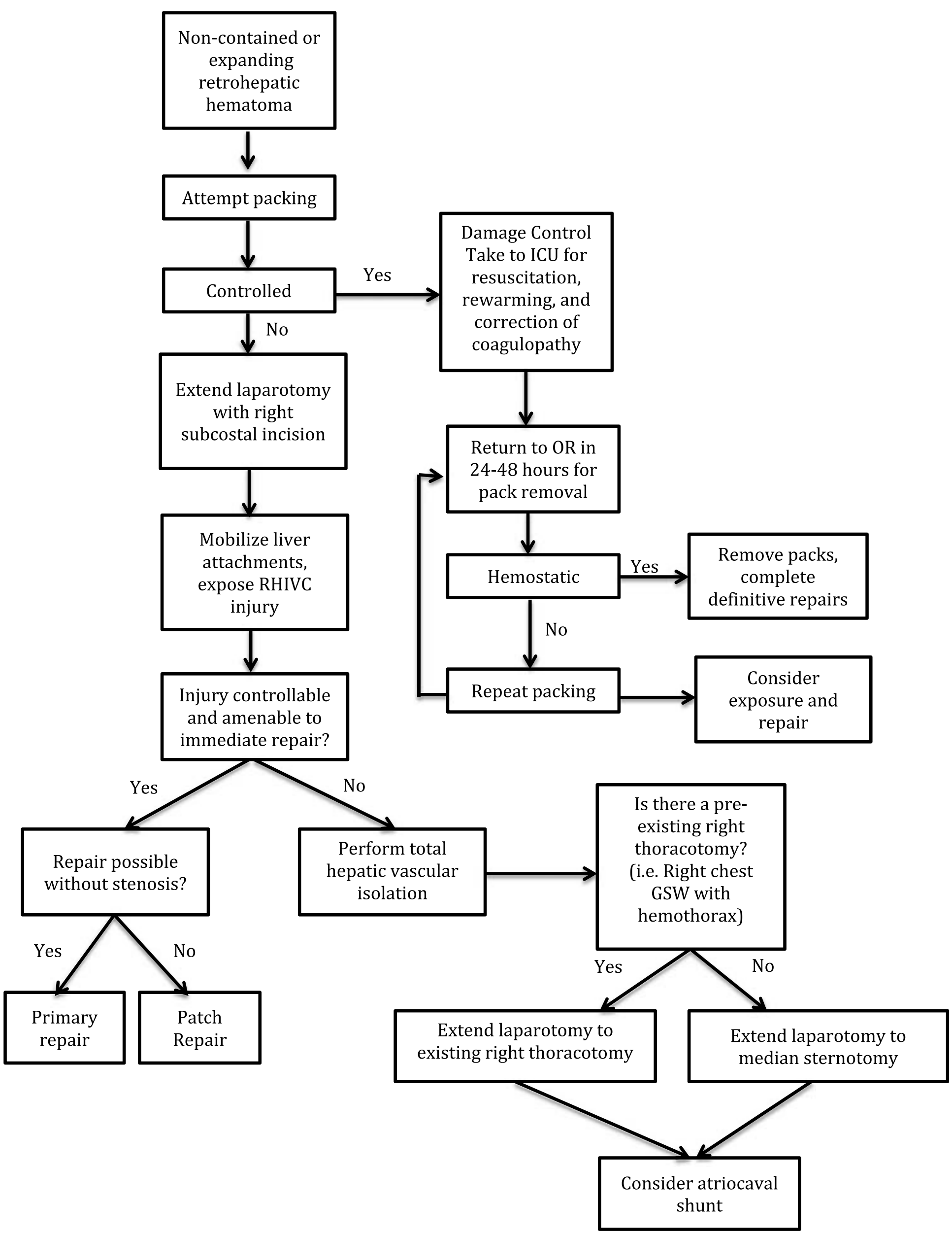

Figure 1. Retrohepatic IVC injury treatment algorithm.

courses cranially passing through the diaphragmatic hiatus at T8, and is situated to the right of the vertebral bodies. Above the diaphragm, the IVC resides within the pericardium and enters the right atrium. Along the course of the IVC, a number of tributaries can bleed during attempted dissection. These include lumbar veins, the inferior phrenic veins, the right gonadal vein, and right suprarenal vein. The RHIVC is 8 cm to 10 cm in length and is particularly difficult to access because the liver is anchored to its entire length. Further complicating injury to the RHIVC are accessory veins from the caudate and right liver lobes draining directly into this segment. The three major hepatic veins draining into the IVC have short extrahepatic portions (0.5–1.5 cm). Above the liver, a short segment of IVC (1 cm) is usually accessible below the diaphragm.

When preparing patients with presumed abdominal vascular injury for surgery, the surgical and anesthesia teams must address several issues before incision. Large bore intravenous access above the diaphragm is preferred as femoral catheters, placed below the injury, will be of little benefit if the IVC requires clamping. Before induction of general anesthesia these patients should be prepped and draped with a member of the surgical team scrubbed at the bedside. Due to the severity of the hemorrhage these patients are at high risk for hemodynamic collapse and might require immediate intervention. Additionally, the operating room (OR) staff should have sternotomy and thoracotomy equipment available to access the supradiaphragmatic IVC.

TECHNIQUE

Attempt Packing First

Encountering a retrohepatic hematoma or bleeding is indicative of injury to the RHIVC or hepatic veins. If there is no evidence of active bleeding or expanding retrohepatic hematoma, the liver ligaments should *not* be divided, and the hematoma should be left undisturbed. If there is hemorrhage or an expanding hematoma, the surgeon should attempt packing first. Effective packing requires compressing the liver posteriorly against the IVC to tamponade the injury. Packs are placed between the liver and the anterior abdominal wall, and along the inferior surface of the liver. Packs placed between the liver and IVC may help trigger the clotting cascade and act as a framework for clot construction. Excessive packing between the liver and IVC, however, can worsen bleeding. Care should be taken because the compression required to control bleeding may decrease preload sufficiently to result in a cardiac arrest. If packing is sufficient to control the bleeding, consideration should be made for angiographic embolization of associated or contributing arterial injury. These patients should then be taken to the intensive care unit for resuscitation, with a planned return to the OR in 24 hours to 48 hours for removal of packs. At the initial return to the OR, if bleeding persists, an additional attempt at control with packing is still warranted. Diligent packing alone may be successful in up to 60% of patients.[4]

Additional Exposure

If bleeding cannot be controlled with packing, exposure of the RHIVC becomes necessary to repair the injury. Identification of the RHIVC as the source of injury is critical, and a Pringle maneuver should be performed first to identify the source of bleeding (see section Hepatic Vascular Control for technique). If the hemorrhage slows, then the liver itself is likely the primary source. However, if bleeding does not improve after a Pringle maneuver is performed, then the RHIVC is the likely source of bleeding and will need to be explored. Early use of the Pringle maneuver should be considered for severe hemorrhage.

The operation will typically have begun with a midline laparotomy. Once the decision has been made to explore this hematoma, adequate exposure is paramount. To facilitate exposure of the RHIVC, the standard midline laparotomy is insufficient. The authors prefer the addition of a right subcostal incision, which affords excellent visualization of the posterior surface of the liver and the retroperitoneum. This provides better visualization of the RHIVC and may be sufficient to perform repair (see Video, Supplemental Digital Content 1, which demonstrates subcostal extension of the laparotomy incision for mobilization of the liver and exposure of the RHIVC, http://links.lww.com/TA/A961).

Once the right upper quadrant is fully exposed, the liver should be mobilized. The falciform ligament should be divided between clamps. Its areolar tissue then divided with cautery until it begins to separate, signaling proximity to the hepatic veins. The right coronary and triangular ligaments can then be taken down with electrocautery. This mobilization allows medial rotation of the liver and excellent visualization of the RHIVC.

Repair

After the injuries are identified and hemorrhage is controlled, repair can be performed. For small injuries, Allis clamps may be used to grasp and oppose the edges. Many of these repairs can be performed with a 3-0 or 4-0 nonabsorbable monofilament suture. Repairs can be simple sutures for small injuries, or may require running repairs for longer lacerations. Avoid causing significant stenosis of the IVC when performing this repair to decrease the chance of postoperative thromboembolism. If a repair will cause a significant stenosis of the IVC, a patch repair (autologous vein, biologic or synthetic patch) may be performed. Choice of repair technique should be guided by the primary goal of rapid repair and arrest of hemorrhage.

If hemorrhage is ongoing due to incomplete occlusion and repair is being compromised, sponge sticks may be useful for compression of the IVC. Additionally, vascular clamps may be placed across the lacerated vessel. This is a critical moment when air embolism can occur. Anesthesia should be made aware of this possibility. Early direct compression of the injury with rapid proximal and distal control is the best method to prevent this complication. In cases of penetrating injury, always explore for a posterior injury when an anterior injury is identified. This may require extending the anterior laceration to improve visualization of the posterior wall.

Hepatic Vascular Control

Total hepatic vascular isolation may be required for large injuries or those that cannot be controlled with packing. This approach requires the following key steps: infradiaphragmatic clamping of the aorta, Pringle maneuver, infrahepatic and suprahepatic IVC control. Once complete vascular control is achieved, a short window of time is available to control the injury.

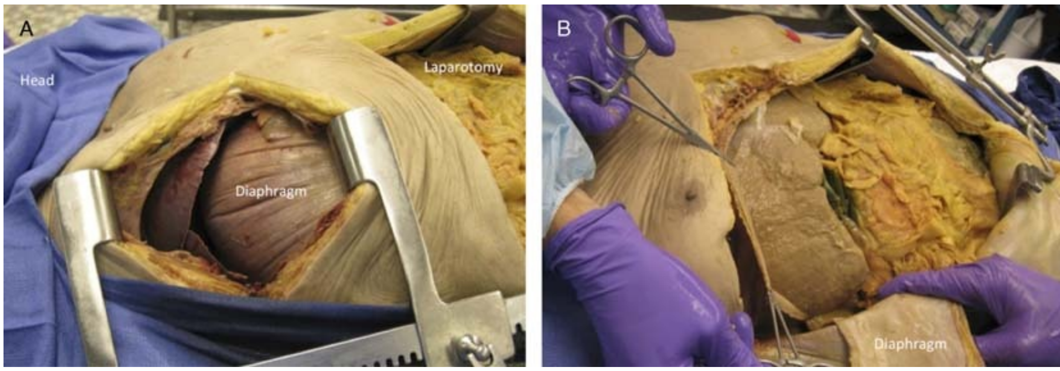

Figure 2. (*A*) Right thoracotomy and separate laparotomy incisions. (*B*) Improved exposure after the right thoracotomy incision was extended to the laparotomy incision and the diaphragm taken down.

Control of the proximal abdominal aorta can be achieved via direct compression or cross-clamping immediately below the diaphragm. This will decrease arterial inflow to the liver and will reduce the risk of hypovolemic cardiac arrest. The easiest location to achieve aortic control is the distal thoracic aorta where it is free of dense connective, nervous, and lymphatic tissue.

Infrahepatic vascular control requires both the Pringle maneuver and infrahepatic IVC clamping. The Pringle maneuver consists of dissection of the loose tissue around the hepatoduodenal ligament and gently placing a vascular clamp or tape tourniquet through the Foramen of Winslow and around the portal triad. This decreases and can even eliminate hepatic artery and portal venous inflow into the liver. Infrahepatic IVC control is achieved by placing a vascular clamp on, or a vessel loop immediately above the suprarenal IVC. Although medial rotation of the liver exposes the RHIVC, the addition of a Kocher maneuver or right medial visceral rotation, will aid in the exposure of the infrahepatic IVC. Care should be taken to avoid injury to the short right suprarenal vein at this time (see Video, Supplemental Digital Content 2, which demonstrates infrahepatic vascular control, http://links.lww.com/TA/A962).

Suprahepatic IVC control is obtained by placing a clamp on or tape tourniquet around the supradiaphragmatic IVC through either a median sternotomy or right thoracotomy incision. The choice of incision is guided by the presence of a preexisting right thoracotomy. The classic presentation is a patient with a right thoracic gunshot wound and a massive hemothorax due to the RHIVC injury decompressing through the diaphragm. In this situation, the right thoracotomy incision is extended to the laparotomy incision and the diaphragm taken down anterior to the IVC hiatus, affording exposure of the RHIVC and suprahepatic IVC. Care should be taken to leave a suitable rim of diaphragm for reconstruction (Fig. 2). In patients without a right thoracotomy, the midline laparotomy may be extended cranially and a median sternotomy performed to allow access to the supradiaphragmatic IVC through the pericardium. A large right angle clamp can be used to pass a tape tourniquet around the IVC within the pericardium (see Video, Supplemental Digital Content 3, which demonstrates median sternotomy with supradiaphragmatic IVC control, http://links.lww.com/TA/A963). Suprahepatic, subdiaphragmatic control of the IVC in patients with a RHIVC injury is extremely difficult due to the presence of hematoma and a very short length of IVC. Attempts to obtain control at this site can cause further damage to the venous structures, and in general is not recommended.

Shunt

When a patient is in extremis, exsanguinating from a RHIVC injury, placement of an atriocaval (Schrock) shunt to exclude the injury and possibly repair it has been described.[5] The overall success rate, however, has been difficult to accurately quantify. In multiple small series mortality ranges from 70 to 100%.[2,4] Having two experienced teams working simultaneously, one for each the chest and abdomen, will increase the likelihood of completing this procedure. (See video, Supplemental Digital Content 4, which demonstrates placement of atriocaval shunt, http://links.lww.com/TA/A964).

The laparotomy incision is extended into a median sternotomy and control of the intrapericardial IVC is obtained as described above in Hepatic Vascular Control. The right atrial appendage is grasped with a vascular clamp. A purse string suture is placed with a 2-0 nonabsorbable monofilament suture on the appendage. A 36Fr chest tube or a size 8 endotracheal tube with additional side holes made approximately 17 cm

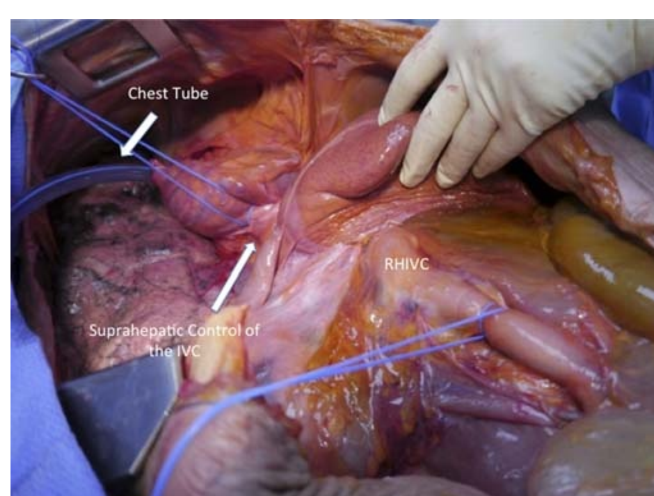

Figure 3. Atriocaval shunt in place, a 36Fr chest tube was used as a conduit. Note the suprahepatic and infrahepatic control of the IVC with blue vessel loops.

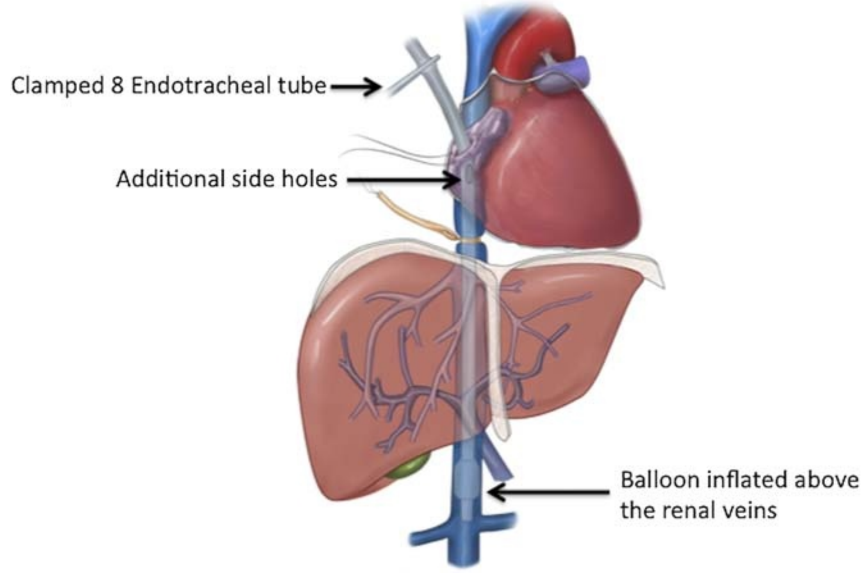

Figure 4. Diagram of an atriocaval shunt in place with an endotracheal tube as a conduit. Note the balloon is inflated above the renal veins. (Adapted from Lam L and Tadlock MD: Inferior vena cava. In: Demetriades D, Inaba K, Velmahos G, eds. *Atlas of Surgical Techniques In Trauma*).[6]

from the proximal end of the tube can be used for bypass. The conduit is then placed into the right atrial appendage, through the previously placed purse string, and into the IVC. The shunt (with additional side holes residing in the atrium) must be guided past the hepatic veins, and the site of injury, ideally into the suprarenal IVC. Tape tourniquets or vessel loops are used to secure the shunt at the intrapericardial and suprarenal IVC. If using an endotracheal tube the balloon may be inflated above the renal veins. Once the shunt is secured above the renal veins, the purse string can be tightened. The proximal end of the shunt that exits the right atrium needs to be clamped or have an infusion port attached for volume resuscitation (Figs. 3 and 4).[6]

CONCLUSION

Retrohepatic IVC injuries are often lethal. The ideal initial management for the bleeding retrohepatic hematoma is packing. If bleeding cannot be controlled with packing, expedient exposure of the RHIVC is facilitated by the use of a subcostal extension, with the addition of a median sternotomy to gain suprahepatic IVC control, and perform vascular exclusion if necessary.

AUTHORSHIP

J.B., D.G., K.I. participated in article writing and literature review. M.T., K.I., L.L., J.B., and D.G. provided figure and video support. All authors participated in critical revisions.

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DISCLOSURE

The authors declare no conflicts of interest.

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