STANDARDS OF PRACTICE

Society of Interventional Radiology Position Statement on Endovascular Intervention for Trauma

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INTRODUCTION

Traumatic injury continues to play a major role in mortality. Injury is the leading cause of death for people younger than 45 years of age in the United States and worldwide, accounting for approximately 10% of deaths globally per year (1,2). During the past decade, mortality rates have continued to improve, in part because of improved medical management in the acute setting. Factors contributing to this improvement include better integration of multidisciplinary care, faster access to advanced imaging and interventions, and increasing expertise at level I and secondary-level trauma centers. Use of nonoperative management in specific scenarios has also led to improved outcomes.

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Upon initial presentation, multiple interventions are considered for initial stabilization, including hemodynamic assessment and resuscitation, neurologic assessment, and imaging. Endovascular intervention is considered at certain points in various treatment algorithms and/or when clinically indicated.

For optimal utilization of endovascular interventions, certain resources must be readily available. First, immediate 24-hour access to an interventional angiography suite is necessary. In hospitals in which an angiography suite is not readily available, protocols should be in place to postpone an elective procedure if a trauma intervention becomes necessary. If this is not possible, the protocol should even consider transfer of the patient to another facility where timely intervention can be performed. Second, although many interventions can be performed with patients monitored by nursing personnel, necessity of anesthesia support should always be considered. The system must support the ability to administer blood products, perform rapid infusions, and perform active resuscitation in the interventional suite.

Intervention should be performed with expediency to minimize hemorrhage. In a patient with ongoing blood loss, an earlier intervention can prevent further massive blood loss, which has been widely recognized as a cause of multiple-organ failure and disseminated intravascular coagulation. Recognizing that different angiographic interventions will vary in length of time, the interventional team should be ready to intervene within 60 minutes from the time a joint decision is made to proceed with angiography. This time cutoff was made jointly through discussions with the American College of Surgery Committee on Trauma, and consideration was given to the need for expedient care balanced with appropriate triage of any other diagnostic and/or therapeutic procedures.

In the past 20 years, transcatheter arterial embolization for traumatic injury has played a pivotal role in improving survival, reducing morbidity, and decreasing operative blood loss. Its effectiveness has been demonstrated in multiple regions, including the liver, spleen, kidneys, and pelvis. Additionally, embolization and vascular reconstruction with covered stents have been found to be effective in many vascular beds that are relatively inaccessible to operative interventions, such as subclavian, intercostal, lumbar, and phrenic arteries, and should be considered on a case-by-case basis in those scenarios. Although embolization has been attempted in other organs as well, such as the bowel or pancreas, its limited utility in those settings must be taken into consideration.

The present position statement outlines parameters to consider in endovascular intervention in various organ systems. As new data emerge in the future, this evolving document will continue to be updated.

MATERIALS AND METHODS

Panel Formation

Under the direction of the Society of Interventional Radiology (SIR), a multidisciplinary group of experts composed of personnel from

interventional radiology, trauma surgery, orthopedic surgery, and vascular surgery units was convened to review the current literature on endovascular interventions for trauma.

Literature Review

A comprehensive literature search was conducted on January 1, 2019, in PubMed using the following search terms: kidney and/or renal trauma, kidney and/or renal embolization, aortic transection, blunt traumatic thoracic aortic injury, traumatic aortic repair, minimal aortic injury, pelvic angiography trauma, pelvic embolization trauma, blunt pelvic ring trauma, liver injury embolization, hepatic trauma angiography, trauma liver angiography, blunt splenic trauma, and splenic artery embolization. The search was limited to reviews, clinical trials, and case series, with exclusion of case reports published between 1990 and 2018. After removal of duplicates, a total of 107 studies remained for inclusion in this review. **Figure E1** (available online on the article's Supplemental Material page at *www.jvir.org*) contains all reviewed and graded literature.

Recommendation Development and Consensus Achievement

Recommendations were drafted and graded according to the updated SIR evidence grading system (3). Many of the recommendations made in this document combine conclusions from the peer-reviewed literature and expert opinion. According to the SIR grading system, the majority of the literature on trauma management is of level evidence D, and therefore only a "weak" recommendation can be made. However, in assessing existing guidelines developed by other trauma societies, more weight was placed on assessing strength based on the balance of benefits and risks, as opposed to the quality of the body of evidence. Therefore, in an attempt to standardize grading for the reader, SIR has aligned its rating of a strong versus a weak recommendation with these existing societal guidelines. A strong recommendation was made in instances in which the benefits of an intervention outweighed the risks (or vice versa), and a weak recommendation was made in instances in which the benefits and risks were closely balanced. A modified Delphi technique was used to achieve consensus agreement on the recommendation statements. All recommendations in the position statement achieved a consensus agreement of $>$ 80%.

RESULTS

Algorithmic Care of the Trauma Patient

The immediate care of the trauma patient mandates a multidisciplinary effort among physicians from emergency medicine, critical care, and trauma surgery units. In the appropriate setting, physicians from orthopedic surgery, vascular surgery, neurosurgery, and interventional radiology units play pivotal roles (4). Because of the involvement of numerous clinical services, the formation of and adherence to treatment algorithms individualized for each institution are necessary for streamlined, consistent, and ultimately optimized care. Ideally, treatment algorithms should be delineated for each trauma scenario. Creation of such institutional algorithms must be based on evidence-based guidelines and available resources at that facility. An example of the blunt pelvic trauma treatment algorithm at Harborview Medical Center (Seattle, Washington), the level I trauma center for the 4-state region of Washington, Alaska, Montana, and Idaho, is shown in the **Figure**.

Recommendation: The development and adherence to evidence-based treatment algorithms for each trauma scenario is necessary to ensure streamlined and consistent care to optimize patient outcomes. (Level of evidence, E; strength of recommendation, strong.)

Operator Training and Experience

Interventions in the trauma patient can be much more challenging than comparable elective situations. Rapid embolization or revascularization is necessary to minimize blood loss and decrease ischemic times. Small-vessel catheterization is much more challenging in this setting because the arterial vasculature is often vasoconstricted as a result of significant blood loss or surrounding hematoma.

To perform transcatheter embolization in the setting of trauma, the interventionalist should have significant experience as primary operator with small-vessel embolization, particularly in the elective setting. Having operative experience, experience with nonvascular intervention, or experience with large-vessel intervention (eg, aortic repair) is inadequate to perform small-vessel catheterization and embolization in the setting of trauma, specifically in the liver, kidney, or pelvis. The concepts, equipment, and technique for small-vessel angiography and embolization are not translatable from work within other vascular territories. Similarly, endovascular repair of the aorta should be done by an operator who has significant experience with endovascular aortic reconstruction in the elective setting. Small-vessel and large-vessel interventions require expertise specific to each.

Recommendation: Operator expertise with performing endovascular interventions is essential for the trauma patient. Small- and large-vessel endovascular interventions each require distinct skill sets and training. (Level of evidence, E; strength of recommendation, strong.)

Pediatric Trauma

Management of trauma in pediatric patients can oftentimes be more complex than in adults. Because of the nature of care that pediatric patients require, institutions that are not pediatric trauma centers should develop and adhere to evidence-based algorithms and care pathways, as have been used in the adult trauma population. Only 1 evidence-based guideline on pediatric trauma currently exists, specifically focused on the management of blunt renal trauma (**Appendix A** [available online on the article's Supplemental Material page at *www.jvir.org*]) (5). Although there is literature available on the management and care of the pediatric trauma patient, there is a gap in the availability of evidence-based clinical practice guidelines in this area. Pediatric trauma services would benefit from the development of this evidence-based guidance.

Recommendation: The development and adherence to evidence-based treatment algorithms for each trauma scenario in pediatric patients is necessary to ensure streamlined and consistent care to optimize patient outcomes. (Level of evidence: E; strength of recommendation: strong.)

SPECIFIC ORGAN SYSTEM MANAGEMENT

Aorta

Similar to the current management of atherosclerotic disease in large vessels, the traditional approach of operative treatment for aortic and iliac injury has shifted toward endovascular intervention at many centers, with improved outcomes including decreased complications and length of stay (6). However, similar to solid organ injury, it is important to recognize limitations of endovascular intervention, as failed attempts may result in catastrophic complications or poor outcomes and delay of appropriate operative repair.

Historical estimates are that fewer than 20% of patients with traumatic aortic injuries survive to reach a hospital, and, among those who do survive, 23%–50% will die within 24 hours of hospitalization (7–9). Fifty to seventy percent of aortic injuries involve the proximal descending aorta, and therefore a majority of the evidence and experience relates to management of injuries in this region. Early open operative repair, frequently involving cardiopulmonary bypass and a high posterolateral thoracotomy, was considered the standard of care (6) since the landmark 1958 article by Parmley et al (10). However, open repair is associated with a very high mortality rate of 28% and a paraplegia rate of 16% (11,12). In addition, the high frequency of concomitant major organ injuries with an aortic injury has diminished this treatment approach, and strategies such as medical management, delayed repair, and endovascular aortic repair have gained wider acceptance (6,8,13). In particular, thoracic endovascular aortic repair (TEVAR) for suitably selected patients has developed from initial single-center experience with handmade devices 20 years ago to the currently available US Food and Drug Administration–approved devices (14).

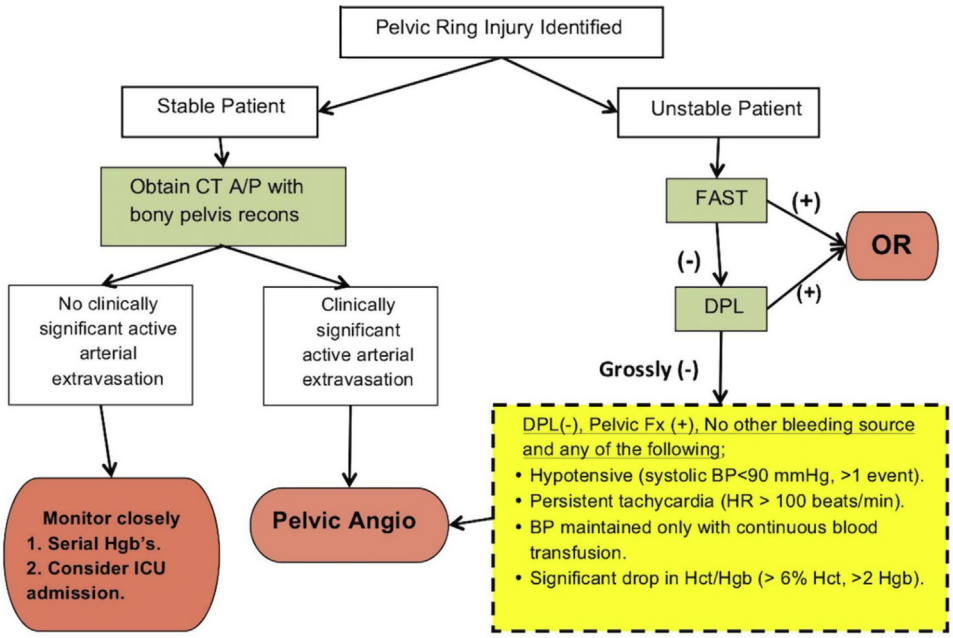

Figure. Graphic algorithm for pelvic trauma management created by Harborview Medical Center, University of Washington, Seattle, Washington (courtesy of Lisa McIntyre, MD). DPL = diagnostic peritoneal lavage; FAST = focused assessment with sonography for trauma; OR = operating room.

There is no prospective randomized trial directly comparing open versus endovascular repair of aortic injury, and this is unlikely to occur because clinical equipoise would be difficult to ensure given the 2-decade experience and widespread availability of TEVAR. Hence, other societal guidelines (**Appendix B** [available online on the article's Supplemental Material page at *www.jvir.org*]), while recommending endovascular over open repair, do so based on relatively limited evidence (6,15). This recommendation is based on the reported improvement in survival with decreased major complications of spinal cord injury, graft and systemic infections, and renal dysfunction.

Not all aortic injuries require repair. The most commonly used classification scheme (16) uses 4 grades: grade 1, intimal tear; grade 2, intramural hematoma; grade 3, pseudoaneurysm; and grade 4, rupture. TEVAR should be used in anatomically favorable grade 3 and grade 4 aortic injuries, with nonoperative management (antihypertensive and antiimpulse medication with close symptomatic and/or radiographic follow-up) favored for grade 1 and grade 2 injuries (also known as minimal aortic injury) (17–19). Correlation of aortic injury grade on computed tomography (CT) with the pre- and posttraumatic comorbidities of the patient is vital to appropriate patient selection.

Recommendation: Emergent TEVAR should be used in anatomically favorable grade 3 and grade 4 aortic injuries, with nonoperative management (antihypertensive and antiimpulse medication with close symptomatic and/or radiographic follow-up) favored for grade 1 and grade 2 injuries (also known as minimal aortic injury). (Level of evidence, D; strength of recommendation, strong.)

Pelvis

In the setting of blunt trauma, as many as 9% of patients sustain a major injury to the pelvis (20). Mortality rates in the setting of major pelvic injury are reported to be as high as 56%, particularly in patients with a pelvic fracture and hemodynamic instability (20–22). Most bleeding that occurs in the setting of pelvic fracture is of venous or bony origin, but as many as 10% of all patients with a pelvic injury will experience bleeding from an arterial source (20,21,23–25). Although less common, arterial injury is more frequently associated with hemodynamic instability than venous injury (25). In the setting of an unstable pelvic ring injury, arterial injuries can occur in as many as 60% of patients (20,21,26). Additionally, an arterial source of hemorrhage in pelvic injury is identified in more than 70% of patients with no response to fluid resuscitation or transfusion (20).

When the clinical condition of the patient permits, contrast-enhanced CT should be pursued and is the most sensitive and specific test to identify the source of arterial bleeding in the pelvis. When active contrast agent extravasation is demonstrated on contrast-enhanced CT of the pelvis, there is a high likelihood of active arterial hemorrhage demonstrated at the time of angiography, with sensitivity ranging from 80% to 90% and specificity ranging from 85% to 98% (20,27–29).

The control of pelvic hemorrhage from an endovascular approach is expedient and effective with appropriate patient selection and when proper techniques are employed. Angiography quickly became adopted as the gold standard for the treatment of arterial injury caused by pelvic injury after multiple series were published demonstrating the success of this technique in achieving hemostasis quickly and efficiently (25,30). Currently, most high-volume trauma centers consider embolization for pelvic trauma to be first-line therapy and the standard of care over surgery (20,24,27,30). Surgical control of bleeding after pelvic injury often fails, given the difficulty of achieving expeditious hemostasis as a result of the involved vessels (25).

Indications for angiography with possible embolization currently include:

1. A pelvic ring fracture visualized on plain radiography in a patient in hemodynamically unstable condition in whom intrathoracic and/or intraabdominal sources of bleeding have been excluded by imaging evaluation, ultrasound, or diagnostic peritoneal lavage (20,24,25,31).
2. The presence of a vascular injury or contrast agent extravasation on contrast-enhanced CT in association with other findings of vascular injury on imaging, such as a large-volume pelvic hematoma, pseudoaneurysm, vasospasm, or arterial stretch injury or a vascular "cutoff" sign (eg, implying thrombosis, transection, or vasospasm of the involved artery) (20,29,32–34).

There is currently no consensus whether to proceed directly to angiography in the patient in hemodynamically stable condition with active contrast agent extravasation on CT. Given significant improvements in the quality of CT imaging during recent decades, many small vascular injuries

are now identified that may have been previously missed. Multiple studies (20,29,34–36) have demonstrated that angiography findings can be negative despite contrast agent extravasation on CT, and, on the contrary, angiography findings can be positive when CT has demonstrated no contrast agent extravasation. Despite these published discrepancies, clinical suspicion for bleeding and hemodynamic stability remain the driving factors in the decision to proceed to angiography.

The pattern of pelvic injury can also be helpful in predicting the site of arterial injury. Published fracture patterns that tend to predict a high likelihood for arterial injury are vertical shear-type fracture pattern, combined mechanisms, and high-grade anterior/posterior and lateral compression fractures (26,28,37). Anterior/posterior–type pelvic injuries have a high association with posterior-division internal iliac artery injuries, and lateral compression-type pelvic injuries are often associated with anterior-division internal iliac artery injuries (38). However, it is worth noting that a series of 39 patients (39) found no significant correlation between the presence of a major pelvic fracture and positive angiographic findings.

Active extravasation is seen in 28%–100% of patients with pelvic fractures who are sent to undergo angiography (24,40). The wide range of positive findings is likely a result of each institution's patient selection algorithm. Rates of clinical success, when defined as an immediate improvement in vital signs and decreased transfusion requirements, have been reported in 84%–100% of patients (28,31,41).

A return to the angiography suite may be required in some patients with suspected ongoing or recurrent bleeding, with reported rates of repeat angiography of 0%–23% (20,24,25,42,43). Findings at angiography frequently demonstrate a new site of hemorrhage that was not treated or visualized on the initial study (30). The following findings are highly predictive of recurrent arterial hemorrhage: hypotension, disruption of the pubic symphysis, transfusion requirement of $>$ 2 U/h of packed red blood cells, and more than 2 arterial injuries visualized on the initial pelvic angiogram (30).

Recommendation: Embolization for pelvic trauma should be first-line therapy and the standard of care over surgery. (Level of evidence, D; strength of recommendation, strong.)

Liver

Appropriate management of blunt hepatic injury is critical because uncontrolled bleeding in the liver carries a mortality rate of 54% (44). Frontal-impact injuries typically result in injury within the left lobe of the liver along the falciform ligament (45). Conversely, injuries to the right lobe of the liver are more frequently seen in complex injuries from a side impact (eg. horse kick, crush injuries) and are more frequently associated with concomitant injuries at sites other than the liver (44).

Surgical management of trauma-related liver injury was previously the standard treatment from the early 20th century through the beginning of the 1990s, as it was believed best able to provide hemostasis and manage biliary injuries (46,47). However, there has been a paradigm shift, with nonoperative management becoming the treatment of choice in the majority of patients with blunt hepatic injury who are in hemodynamically stable condition. This has resulted in decreased abdominal infections, decreased transfusions, and decreased lengths of hospital stay (47).

Small retrospective case series constitute the bulk of the available literature investigating the use of nonoperative management including the use of embolization in the treatment of blunt hepatic injury (48). Some studies even question the overall clinical impact of embolization when combined with additional operative measures given the contribution of venous injury as a major source of hemorrhage (44,49,50). However, a recent meta-analysis (48) reported technical success in 93% of cases with delayed hemorrhage. Complication rates related to embolization are generally low, with hepatic necrosis remaining the most concerning. Studies suggest that this occurs in fewer than 16% of patients and is decreased through selective embolization and appropriate choice of embolic material (48,51–60).

Based on the current published data, some general parameters may be considered when determining whether to intervene with embolization (48,61,62). Observation and medical optimization may be considered in patients with grade I–III injuries on CT provided that they remain in hemodynamically stable condition. Exploratory laparotomy should be considered in patients in hemodynamically compromised condition regardless of the grade of injury. Embolization should be considered in patients in hemodynamically stable condition with evidence of ongoing bleeding (eg, decreasing serial hematocrit measurements), in whom an arterial source of bleeding is identified on CT angiography, or in whom hemodynamic instability continues despite operative intervention and there is a high clinical suspicion for a liver source of arterial bleeding. High-grade injuries tend to be associated with portal and/or biliary injuries, and most of these are best evaluated and treated by operative evaluation. Close follow-up and management are critical to evaluate the need for repeat intervention.

Recommendation: Nonoperative management should be the treatment of choice in patients with blunt hepatic injury who are in hemodynamically stable condition, with embolization to be considered in cases of ongoing bleeding, identification of an arterial source of bleeding on imaging, or suspicion of a persistent source of arterial bleeding despite operative intervention. (Level of evidence, D; strength of recommendation, weak.)

Spleen

Splenic artery embolization plays a critical role in the treatment of blunt splenic trauma, specifically to improve the success of nonoperative management. Splenic embolization has shown high rates of success in preventing splenectomy; however, this may result from selection bias because low-grade injuries were included in some of the early reported series (63,64). Historically, the challenge has been to define the patient populations who would benefit most from splenic artery embolization versus observation or splenectomy.

The precise role of splenic artery embolization in blunt splenic trauma remains controversial, and variability exists among institutions. Patients in unstable condition are managed operatively because of the need to rapidly control bleeding, which may not be from major arterial sources. The American Association for the Surgery of Trauma (AAST) organ system grading to define the severity of splenic injury was revised in 2018 to reflect data demonstrating that vascular injuries reduce the success rate of nonoperative management (65). Identification of pseudoaneurysms and active extravasation are now important parts of determining the injury grade, with the 2018 update classifying these as grade IV or V (66–69).

Splenic artery embolization should be considered in patients in hemodynamically stable condition with AAST grade IV/V injuries because nonoperative management has been shown to fail most frequently in these patients. A 16-year experience of treating blunt splenic trauma (70) compared 3 groups of patients: those treated before the availability of embolization, those treated during a period of discretionary use of embolization, and those treated with a uniform protocol established based on imaging findings. Use of embolization increased over time, as did the splenic salvage rate, and mortality was reduced (70). In a retrospective study of 539 patients in hemodynamically stable condition with blunt splenic trauma (71), 104 patients with grade IV/V injuries, contrast blush, or decreasing hemoglobin levels underwent embolization. The remaining 435 with lower-grade injuries were observed without intervention. The failure rate of nonoperative management (ie, progression to splenectomy) was the same (4%) in both groups. This study (71) suggested that embolization improved splenic salvage because the higher-grade injuries were salvaged at an equivalent rate to low-grade injuries. A meta-analysis of nonoperative management of blunt splenic trauma (72) found that the use of embolization significantly reduced the failure of nonoperative management in grade IV/V injuries compared with observation alone, emphasizing the role for embolization in these high-risk groups.

Failure rates after splenic artery embolization are 4%–12%, with higher-grade injuries associated with failure rates as high as 25% (63,66,70–72). However, these publications used the previous AAST grading scale in which vascular injuries were not automatically included as grade IV/V.

Studies assessing immune function after splenic artery embolization have established that immune function indeed remains intact (73–75). Malhotra et al (76) showed similar levels of CD4+ T cells in patient cohorts

undergoing embolization and no intervention, but significantly lower levels among those undergoing splenectomy.

Recommendation: Splenic artery embolization should be considered for patients in hemodynamically stable condition with grade IV/V blunt splenic trauma. (Level of evidence, D; strength of recommendation: moderate.)

Recommendation: Embolization should be considered in patients in hemodynamically stable condition with any grade injury who have imaging or clinical evidence of ongoing splenic hemorrhage. (Level of evidence, D; strength of recommendation, strong.)

Kidney

The overall incidence of renal injury in patients with abdominal trauma is 1%–3% (77,78). The vast majority of renal injuries (75%–80%) are minor and represent contusions or superficial lacerations that can be managed conservatively (77). Major renal injuries (ie, grade V) are rare and usually require emergent operative interventions. The remainder are serious injuries, and it is here where endovascular-based intervention has played the most significant role.

Minimizing hemorrhage with the intent of preserving renal function is the goal in the treatment of renal trauma. Additionally, patients may already undergo exploratory laparotomy for a concurrent solid organ injury, which has been reported to be present in 61% of renal stab wounds (79). The increasing use of nonoperative management is largely the result of increased use of CT for diagnostic workup, improved care in the intensive care unit, and increasing use of arterial embolization.

Because grade I/II renal lacerations are often self-limited, observation alone is recommended. In a prospective observational series of 200 patients presenting with renal stab wounds (79), 96% of grade I lesions and 73% of grade II lesions were successfully managed nonoperatively. The remainder required immediate or delayed surgical intervention. Grade III/IV lesions are most likely to benefit from angiographic evaluation with embolization, as this may allow the avoidance of surgical intervention and decrease the incidence of delayed recurrence of bleeding. Within these categories, the presence of large perirenal hematomas or active contrast agent extravasation have been associated with the need for angiographic embolization (80,81). In cases of severe hemodynamic instability, severe injury to other abdominal organs, or the presence of urine leaks, or when there is greater than 50% involvement of the kidney, surgical intervention is preferred.

Similar to the published literature for hepatic trauma, recommendations for the endovascular management of renal trauma largely result from retrospective series with relatively low numbers of patients. In the only prospective study evaluating angiography with embolization for isolated renal injuries (82), a protocol was instituted whereby all patients in hemodynamically stable condition with grade III–V lesions underwent angiography within 3 hours of CT imaging. Embolization was performed if contrast agent extravasation or an arterial–venous fistula was identified on CT. In the 21 patients undergoing angiography in this series (82), 8 exhibited significant arterial injuries, which were successfully embolized. One of the 21 patients required laparotomy with nephrectomy after angiography as a result of avulsion of the renal vein. Two of the 21 patients died as a result of multiple trauma or multiple-organ failure. Overall, greater than 90% of the patients avoided an exploratory laparotomy.

Recommendation: Angiography and embolization should be considered in patients with grade III/IV renal injuries when surgical exploration is not warranted as a result of other indications. (Level of evidence, D; strength of recommendation, strong.)

Extremities

Vascular trauma of the extremities can be treated by an operative or endovascular approach. The goal of angiographic intervention in extremity trauma is to restore arterial patency or to prevent ongoing hemorrhage from an arterial source. Endovascular intervention has a limited role in high-velocity insults in which there is a concern for wound contamination or the possibility of compartment syndrome. In addition, because osseous fixation often needs to be done concurrently, primary surgical repair of arterial damage is appropriate in most cases.

Endovascular intervention may be appropriate in patients who have sustained a low-velocity injury in which prolonged open exposure increases the risk of injury to adjacent vital structures or bleeding from operative dissection. However, combined operative and endovascular procedures might be beneficial in emergent situations to limit blood loss (83,84). Treatment for an arterial occlusion includes stent placement or aspiration thrombectomy, with embolization in cases of active extravasation. The advantages of endovascular treatment include the minimization of trauma to the surrounding tissues and a decrease in blood loss and operative time (85,86). Disadvantages include the need for a second procedure in patients who may already be going to the operating room for osseous fixation and the unknown long-term durability of stents in young patients.

In cases of hemorrhage from an arterial source, treatment options include embolization or placement of a covered stent. If a pseudoaneurysm is present, placement of a covered stent may be appropriate in certain situations. Anatomic locations with relative flexibility such as common femoral, popliteal, or axillary arteries may limit the long-term effectiveness of endovascular repair. Unfortunately, there are no large series reporting treatment outcomes and strategies given the unique nature of these injuries. In each of these situations, consultation with the trauma, orthopedic, and vascular surgery teams is essential to individualize the treatment for each patient (87).

Two anatomic areas have emerged as the most frequent sites for endovascular repair: the iliac and the axillary–subclavian arteries. Endovascular intervention with stent placement in the external or common iliac artery has been shown to reduce morbidity and mortality compared with open surgical repair (84). Similarly, repair of the axillary–subclavian artery requires a sternotomy for proximal control and surgical dissection, which presents the possibility of injury to the surrounding nerves, making endovascular repair in this region more straightforward and associated with less morbidity. If definitive repair is not possible from an endovascular approach, or if hemodynamic instability develops, an occlusion balloon can be placed in conjunction with an open approach to minimize blood loss (88).

Embolization of active hemorrhage in the extremities should be considered in the appropriate context. Although distal perforating branches of the main vessels can usually be embolized safely, caution is warranted in the decision to embolize the main arteries supplying the extremity, and knowledge of which arteries are expendable is of paramount importance (89).

Recommendation: Embolization for active hemorrhage in the extremities should be considered in the appropriate context of expendability of the embolized artery. (Level of evidence, D; strength of recommendation, weak.)

CONCLUSIONS

It is the position of SIR that endovascular intervention plays a critical role in the care of the trauma patient. In-depth knowledge of intervention parameters, expedient care, and the ability to work in a multidisciplinary fashion are paramount to achieving optimum outcomes.

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Appendix A. Current Society Clinical Practice Guidelines

Society	Recommendation
	Aorta
Eastern Association for the Surgery of Trauma, 2015 (1)	In patients diagnosed with blunt thoracic aortic injury, we strongly recommend the use of endovascular repair in patients who do not have contraindications to endovascular repair. (Strong recommendation, low-quality evidence.)
Society for Vascular Surgery, 2011 (2)	We suggest that endovascular repair be performed preferentially over open surgical repair or nonoperative management (grade IIC).
	Pelvis
World Society of Emergency Surgery, 2017 (3)	Angioembolization is an effective measure of hemorrhage control in patients with arterial sources of retroperitoneal pelvic bleeding (grade IA).
	Liver
World Society of Emergency Surgery, 2016 (4)	Blunt trauma patients with hemodynamic stability and absence of other internal injuries requiring surgery should undergo an initial attempt of non-operative management irrespective of injury grade (grade 2A); non-operative management is contraindicated in the setting of hemodynamic instability or peritonitis grade 2A).
	Spleen
Eastern Association for the Surgery of Trauma, 2012 (5)	Angiography should be considered for patients with AAST grade > III injuries, presence of contrast blush, moderate hemoperitoneum, or evidence of ongoing splenic bleeding (level II).
	Kidney
American Urological Association, 2017 (6)	Clinicians should use noninvasive management strategies in hemodynamically stable patients with renal injury. (Standard; evidence strength, grade B.) The surgical team must perform immediate intervention (surgery or angioembolization in selected situations) in hemodynamically unstable patients with no or transient response to resuscitation. (Standard; evidence strength, grade B.)
Eastern Association for the Surgery of Trauma and Pediatric Trauma Society (7)	In pediatric patients with blunt renal trauma of all grades, we strongly recommend nonoperative management vs operative management in hemodynamically stable patients. (Strong recommendation, very low-quality evidence.) In hemodynamically stable pediatric patients with high-grade (AAST grade III–V) renal injuries from blunt trauma, we strongly recommend angioembolization vs surgical intervention for ongoing or delayed bleeding. (Strong recommendation, very low-quality evidence.)

AAST = American Association for the Surgery of Trauma.

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APPENDIX B. EXECUTIVE SUMMARY

Clinical Question

What is the current role for endovascular intervention to address trauma?

Target Population

Patients with trauma of the aorta, pelvis, liver, spleen, kidney, and extremities.

Target Audience

Interventional radiologists and other clinicians who provide care for patients defined by the target population.

Methods

A multidisciplinary expert panel was assembled to develop recommendations for endovascular intervention in trauma. A comprehensive review of the literature was performed, and relevant evidence was evaluated for inclusion into this document. Evidence was rated according to the updated Society of Interventional Radiology (SIR) evidence grading system. The recommendations represent consensus among the expert writing panel.

Recommendations

The development and adherence to evidence-based treatment algorithms for each trauma scenario is necessary to ensure streamlined and consistent care to optimize patient outcomes. (Level of evidence, E; strength of recommendation, strong.)

Operator expertise in the performance of endovascular interventions is essential for the trauma patient. Small- and large-vessel endovascular interventions each require distinct skill sets and training. (Level of evidence, E; strength of recommendation, strong.)

The development and adherence to evidence-based treatment algorithms for each trauma scenario in pediatric patients is necessary to ensure streamlined and consistent care to optimize patient outcomes. (Level of evidence, E; strength of recommendation, strong.)

Emergent thoracic endovascular aortic repair should be used in anatomically favorable grade 3 and grade 4 aortic injuries, with nonoperative management (antihypertensive and antiimpulse medication with close symptomatic and/or radiographic follow-up) favored for the management of grade 1 and grade 2 injuries (also known as minimal aortic injury). (Level of evidence, D; strength of recommendation, strong.)

Recommendation: Embolization for pelvic trauma should be first-line therapy and the standard of care over surgery. (Level of evidence: D; strength of recommendation, strong.)

Nonoperative management should be the treatment of choice in patients with blunt hepatic injury who are in hemodynamically stable condition, with embolization to be considered in cases of ongoing bleeding, identification of an arterial source of bleeding on imaging, or suspicion of persistent source of arterial bleeding despite operative intervention. (Level of evidence, D; strength of recommendation, weak.)

Splenic artery embolization should be considered for patients in hemodynamically stable condition with grade IV/V blunt splenic trauma. (Level of evidence, D; strength of recommendation, moderate.)

Embolization should be considered in patients in hemodynamically stable condition with any grade injury who have imaging or clinical evidence of ongoing splenic hemorrhage. (Level of evidence, D; strength of recommendation, weak.)

Angiography and embolization should be considered in patients with grade III/IV renal injuries when surgical exploration is not warranted as a result of other indications. (Level of evidence, D; strength of recommendation, strong.)

Embolization for active hemorrhage in the extremities should be considered in the appropriate context of expendability of the embolized artery. (Level of evidence, D; strength of recommendation, weak.)

Qualifying Statement

SIR develops Clinical Practice Guidelines (CPGs) to provide educational resources to practicing clinicians to promote high-quality outcomes and patient safety in in vascular and interventional radiology. CPGs are not fixed rules, nor are they the sole determinant of treatment choice, and are not intended to establish a legal standard of care. Use of the CPGs is voluntary, and a deviation from the recommendations should not automatically be interpreted as the delivery of care that is substandard. CPGs are not intended to supplant professional judgment, and a physician may deviate from these guidelines as necessitated by the individual patient, practice setting, or available resources. Other sources of information may be used in conjunction with these principles to produce a process leading to high-quality medical care. The ultimate judgment regarding the conduct of any specific procedure or course of management must be made by the physician, who should consider all circumstances relevant to the individual clinical situation. These guidelines are provided “as is,” and SIR does not warrant the accuracy, reliability, completeness, or timeliness of the guidelines. SIR is not responsible for any actions taken in reliance on these guidelines, including, but not limited to, any treatment decisions made by any health care provider reading these guidelines, and SIR assumes no responsibility for any injury or damage to persons or property arising out of or related to any use of these guidelines or for any errors or omissions.