Nonoperative management of abdominal solid-organ injuries following blunt trauma in adults: Results from an International Consensus Conference

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Nonoperative management (NOM) is an initial nonsurgical management strategy of a solid-organ injury which usually consists of observation, but may include use of endovascular, percutaneous, or endoscopic procedures. Nonoperative management for blunt solid organ injuries has become the standard of care for patients who are hemodynamically stable, without other indications for exploratory laparotomy.[1] This is particularly true, since the mid-1990s, for spleen injuries, with a success rate which has increased in some reports as high as 95%.[2–8]

Liver injuries have a reported success rate of 95% for NOM.[9] The data about NOM for pancreatic trauma is less clear,[10–12] but NOM may be safe and effective in selected patients,[13,14] even in grades III to IV injuries.[15] Nonoperative management has become the preferred way of managing blunt kidney injuries,[16–19] even for high-grade injuries, with a reported overall success rate greater than 80%.[20,21]

Computed tomography (CT)[22] allows clinicians to recognize and grade solid-organ injuries[23–25] and to rule out possible contraindications to NOM.

Moreover, the implementation of angioembolization (AE)[26–30] and endoscopic procedures[31,32] has expanded the role of NOM, treating vascular injuries which include active bleeding (extravasation) and nonbleeding vascular injuries (pseudoaneurysm [PSA] and arteriovenous fistula), as well as managing complications in stable patients.[33–36]

The aim of the International Consensus Conference (ICC) on NOM of solid-organ injuries held in Milan in December 2016 was to develop evidence-based guidelines to identify the indications for NOM in adult blunt trauma patients to choose the best and most appropriate modality for follow-up, as well as the best technique to manage complications.

PATIENTS AND METHODS

The organizing committee (O.C., S.C.) was established to plan the ICC on the NOM of solid-organ injuries. The ICC was conducted according to "The Methodological Manual—How to Organize a Consensus Conference," edited by the Higher Health Institute.[37] Eleven Italian and international scientific societies, identified by the organizing committee to be interested in the topic, were asked to appoint one or two representatives each to participate the Milano ICC. The following societies were involved: Trauma Update Network, American Association for the Surgery of Trauma (AAST), the Italian Association of Hospital Surgeons, the European Society of Trauma/Emergency Surgery, the Italian Society of Anesthesia, Analgesia, Resuscitation and Intensive Care, The Italian Society of Emergency Surgery and Trauma, the Italian Society of Emergency Medicine, the Italian Society of Intensive care, the Lombard Society of Surgery, the World Society of Emergency Surgery and its Italian chapter. The organizing committee selected a scientific board (Scientific Board, 10 members) and national (National Panel of Experts, 11 members) and an international (International Panel of Experts, five members) panels of experts. The organizing committee and SB selected the following four main topics:

1. NOM in spleen injuries
2. NOM in liver injuries
3. NOM in pancreatic injuries
4. NOM in kidney injuries

The national and international panelists were divided into four groups, and each was assigned a topic. A systematic review of the literature from 2000 to 2016 was undertaken by a medical reference librarian in May 2016. Two investigators (S.C., F.S.) created a preliminary search strategy by selecting the following key words: abdominal trauma, nonoperative management; liver injury; spleen injury; kidney injury; pancreas injury, angiography, angioembolization. Searches were conducted incorporating novel terms when relevant citations were found using the following database: MEDLINE, PubMed, EMBASE, Scopus, and Cochrane Database of Systematic Reviews. Three investigators (S.C., F.R., F.S.) independently screened titles and abstracts selecting studies according to PRISMA statements.[38] The following types of articles were included: (I) prospective randomized controlled trials; (II) observational studies in which data were collected prospectively; (III) retrospective analyses based on clearly reliable data; (IV) systematic reviews of literature; (V) meta-analyses; and (VI) relevant case series, all articles eligible for evaluation were divided according to the selected topics and sent for further evaluation to members of each of four groups. Panelists were asked to assign levels of evidence (LoE) and grades of recommendations (GoR) based on the Grading of Recommendation Assessment, Development, and Evaluation hierarchy criteria (Table 1).[39]

Each panel was asked to answer the key question and some specific subquestions pertaining to the assigned topic. On December 11, 2016, a meeting was held involving the organizing committee, IPE, SB, and the representatives of the scientific societies to discuss topics and define statements to be presented during the conference. On December 12, 2016,

TABLE 1. Grading of Recommendation From Guyatt et al.[35] (GRADE)

1A. Strong recommendation, high-quality evidence	Benefits clearly outweigh risks and burdens, or vice versa	RCTs without important limitations or overwhelming evidence from observational studies	Strong recommendation, applies to most patients in most circumstances without reservation
1B. Strong recommendation, moderate-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs with important limitations (inconsistent results, methodological flaws, indirect analyses or imprecise conclusions) or exceptionally strong evidence from observational studies	Strong recommendation, applies to most patients in most circumstances without reservation
1C. Strong recommendation, low-quality or very low-quality evidence	Benefits clearly outweigh risk and burdens, and vice versa	Observational studies or case series	Strong recommendation but subject to change when higher-quality evidence becomes available
2A. Weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burdens	RCTs without important limitations or overwhelming evidence from observational studies	Weak recommendation, best action may differ depending on the patient, treatment circumstances, or social values
2B. Weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burdens	RCTs with important limitations (inconsistent results, methodological flaws, indirect analyses or imprecise conclusions) or exceptionally strong evidence from observational studies	Weak recommendation, best action may differ depending on the patient, treatment circumstances, or social values
2C. Weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burdens; benefits, risks, and burdens may be closely balanced	Observational studies or case series	Very weak recommendation, alternative treatments may be equally reasonable and merit consideration

RCT, randomized-controlled trials.

the ICC took place in Milan with 235 delegates. For each topic, a 90-minute session was held with two clinical case presentations, a literature review by a member of the NPE, a lecture by member of IPE, and a discussion with the audience. It was recorded for later analysis and subsequent manuscript preparation.

RESULTS AND DISCUSSION

The database searches identified 1,122 citations (Fig. 1.) By removing duplicates, titles not related to the topic, case reports, articles on nontrauma patients, articles on pediatric trauma, articles on penetrating trauma, and articles where full text was unavailable, 898 citations were excluded. Of the remaining 224 citations, 134 were excluded due to overlapping data or because they were letters to the editor. The resulting 90 articles were divided according to each topic: 37 for topic 1, 19 for topic 2, 16 for topic 3, 18 for topic 4 (Fig. 1). These studies were included and evaluated for GoR and LoE by the

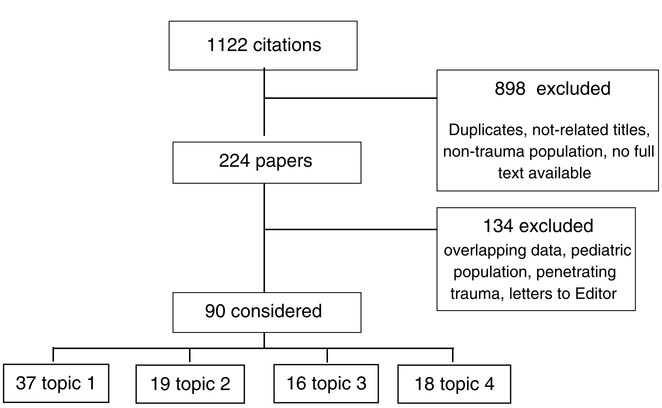

Figure 1. Bibliography search (PRISMA).

NPE and the IPE. Statements for each topic were suggested by the SB, approved by the IPE and the scientific societies, and discussed with the audience during the Milan conference. Everything was recorded during the ICC to allow us to write a report with definitive conclusions.

1. NOM in spleen injuries

Questions

A. What are the criteria for NOM in spleen injuries?
B. Is proximal or distal splenic artery embolization more effective?
C. Which is the best strategy for follow-up?

Statements

A. Patients with blunt spleen injuries of any AAST grade who are hemodynamically stable and without peritonitis or associated abdominal injuries requiring surgery can be managed nonoperatively [GoR B, LoE I];

- In adult patients, a CT scan with IV should be performed to identify and assess the severity of splenic injury and evaluate associated injuries, to determine if NOM is wise [GoR C; LoE II];
- NOM of AAST III-V grade blunt splenic injuries should be considered only when continuous monitoring is possible and an operating room always available. Institutions without these capabilities should either operate or transfer these patients [GoR C; LoE II].

B. AE is an effective adjunctive tool to NOM in stable patients [GoR B; LoE II];

- In stable patients with blunt splenic injury, AE should be performed early, regardless of grading, if active bleeding

or nonbleeding vascular injury is seen on CT scan [GoR B; LoE I];
- Angiographic embolization should be performed in grade IV/V BSI, regardless of the presence or absence on CT of bleeding or nonbleeding vascular injury to increase success of NOM [GoR B; LoE I];
- Proximal AE is preferable to distal embolization [GoR B; LoE II];
- Close monitoring is necessary to timely detect possible complications of AE [GoR C; LoE II].

C. There is no clear recommendation for repeated imaging in blunt splenic injury, but high risk patients for late vascular injuries (grade III–V), regardless of whether they have AE, should be considered for repeat imaging in 48 hours to 72 hours [GoR C; LoE II].

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The management of blunt splenic injuries has changed drastically during the past 30 years, due to the recognition of the spleen's immunological importance and the lifelong risk of overwhelming post-splenectomy infections (OPSI). First popularized by pediatric surgeons, NOM has become the standard of care for hemodynamically stable adult patients since the mid-1990s,[2] with laparotomy used for those patients who are hemodynamically unstable or who have associated injuries that mandate exploration (hollow viscus, diaphragmatic, or high-grade pancreatic trauma).[40]

The advantages of NOM are the avoidance of overwhelming post-splenectomy infection, as well as reduction of negative or nontherapeutic laparotomies and postoperative complications.[41] Factors, such as neurologic impairment, severe extra-abdominal associated injuries, or an age older than 55 years, that in the past prompted mandatory surgical management, today are no longer considered as contraindications for NOM.[3,42–44] There is a substantial failure rate to NOM of splenic injuries (19.6% for grade III; 33.3% for grade IV and 75% for grade V, respectively),[45] but this is not an absolute contraindication to a trial for NOM[46] in stable patients.

The cornerstones for the success of NOM are accurate patient selection, the correct AAST grading of splenic injuries, and the identification of the associated intra-abdominal injuries which preclude NOM. Multislice contrast-enhanced CT scan is the modality of choice to diagnose and characterize splenic injury, (hematoma, laceration). Computed tomography also allows visualization of vascular structures in different phases after intravenous contrast injection, increasing sensitivity of detecting contrast extravasation and characterizing it (extrasplenic active hemorrhage or focal intraparenchymal contrast accumulation, suggesting PSA), which may prompt adjunctive AE to improve the success rate of NOM.

The risk of delayed splenic rupture is 20% for AAST III, 50% when blush is found, and 70% when signified hemoperitoneum exists.[45] Thus, NOM must be considered only in an environment with the capabilities for monitoring, serial clinical evaluation, and 24/7 operating room availability.[46,47]

Angioembolization has proven to be an effective adjunct in NOM of splenic injuries reducing the need for surgery.[48–52] Gaarder at al[26] observed an increased splenic salvage rate from 57% to 75% after implementing AE into their clinical protocol. It may be used, in stable patients, in the initial phase of management when contrast extravasation is evident on CT scan, or to treat delayed PSA diagnosed on repeated imaging.[33] Angioembolization may reduce the failure of NOM (fNOM) by decreasing the arterial pressure at the level of the splenic parenchyma and/or vascular injury, allowing injuries to heal, but preserving splenic viability.[23] The presence of contrast extravasation at CT scan is widely accepted as a high risk factor for fNOM, mandating AE.[23,42,47] The incidence of blush has been reported as 15% to 19% among stable NOM patients, with a fNOM rate of 67% to 93% if observed without intervention.[23] For this reason, AE should be performed in case of contrast extravasation, regardless of the grade of injury.[23,46]

The absence of blush on CT in low-grade injuries seems to reliably exclude bleeding. However, in high-grade injuries, it is not accurate in excluding vascular injury. Haan et al.[26,47] described that 23% of patient with grade III to V injuries who were embolized after a positive diagnostic angiography had no signs of vascular injury on admission CT scan. Furthermore, the same author demonstrated that after negative angiography, the patient was still at risk of delayed bleeding, with a failure rate higher than 10%[27,47] in grades III-V.

For this reason, it seems reasonable to perform AE in grade IV to V injuries, regardless of the presence or absence of contrast extravasation at CT scan.[46,53] Moreover, AE seems to cause only minor a impact on splenic function.[54]

In a prospective study, the antibody response to pneumococcal vaccine of AE patients was not different from that of healthy controls.[55]

The panel did not reach consensus about mandatory AE in grade III, considering that further studies are needed to match the risks of AE with the rate of delayed bleeding in this AAST grade of spleen injury.

In a recent clinical trial, mandatory AE of high-grade (IV-V) injuries and selective AE of lower grades provided optimum NOM results of IV to V grade injuries (only 3% of failure rate) and limited unnecessary angiograms.[56]

There is also debate as to whether the spleen should be embolized proximally (proximal splenic artery embolization [PSAE]) or distally (distal splenic artery embolization [DSAE]),[27,52–57] because of the concern of preserving immunologic function after embolization and possible complications. Proximal AE is performed by occluding the splenic artery after the origin of dorsal pancreatic artery. This decreases blood flow and intrasplenic arterial pressure, allowing blood clot formation and subsequent healing of the splenic injury. Proximal splenic artery embolization allows the spleen to remain perfused by collateral arteries, limiting the risk of infarction. Distal splenic artery embolization addresses only the segmental branches of disrupted vessel, creating a limited portion of devascularized tissue: it does not produce ischemia in nonembolized areas, without prevention of other vascular injuries.

A series of CT scans of embolized spleen has shown that PSAE was associated with less frequent and smaller infarcts than DSAE,[53] and recent reports showed that PSAE was associated with long-term preserved immunological function.[57] Moreover, PSAE is faster, technically easier, less expensive and associated with an increased rate of splenic salvage.[47] There are no sufficient

TABLE 2. Reviewed Articles for Topic 1

Reference	Year	Design	Comments	GoR-LoE
Bala et al.[2]	2007	Prospective cohort	Indications for NOM: SBP > 90 mm Hg; GCS >8; OIS ≤ 3; less than 3 extra-abdominal injuries	1B
Banghu et al.[5]	2011	Systematic review	Risk factor for fNOM: AAST grade 4–5; moderate-large hemoperitoneum, increasing ISS, increasing age	2B
Barrio et al.[40]	2010	Retrospective	AE is an effective tool to manage splenic vascular injuries in stable patients, improving NOM	2A
Bessoud et al.[57]	2007	Retrospective	PSAE is effective and safe in grade OIS 3–5, improving NOM	2B
Bessoud et al.[53]	2006	Prospective	PSAE is a well-tolerated technique without major long-term impact on splenic anatomy and immune function	2A
Bhullar et al.[23]	2013	Retrospective	AE is indicated in all high-grade BST regardless of CB to improve NOM	2B
Bhullar et al.[42]	2012	Retrospective	AE is a valuable adjunct to NOM in high-grade injuries and age > 55	2B
Bhullar et al.[56]	2017	Retrospective	A protocol using mandatory AE of all high-grade (IV-V) injuries without CB and selective AE of grade (I-V) with CB may provide for optimum salvage with safe NOM of the high-grade injuries (IV-V) and limited unnecessary angiograms.	2C
Brault-Noble et al.[44]	2012	Retrospective	Prophylactic SAE should be considered in elderly patients with high OFR	2B
Capecci et al.[48]	2015	Multi-institutional cohort study	Angiography must be a part of BSI protocol; in low-grade injuries angio benefits must be weighed against risk	2B
Chastang et al.[45]	2015	Regional multicenter prospective	SAE is an alternative to surgery if signs of bleeding are present; otherwise it increases morbidity	1B
Chen et al.[41]	2011	Retrospective	The early use of SAE if CT signs of bleeding are present significantly improves NOM	2B
Dasgupta et al.[49]	2011	Retrospective	Embolization of splenic injuries is, with a good technique, successful -even in higher-grade lacerations	2B
Duchesne et al.[52]	2008	Retrospective	PSAE is effective and safe in low-grade injuries with signs of bleeding; in high-grade caution should be used. Increased rate of infectious complication is possible	2A
Ekeh et al.[58]	2013	Retrospective	Distal embolization is associated with major complications	2B
Gardeer et al.[26]	2006	Prospective	AE increases the NOM success rate and splenic salvage rate	1B
Haan et al.[47]	2007	Prospective	Persistent PSA after main coil embolization may do not require any further treatment	2A
Hui et al.[60]	2009	Systematic review	Though CT scans are an invaluable resource and are becoming more easily accessible, they should not replace careful clinical examination and should be used only in appropriate patients	1C
Jeremitsky et al.[50]	2011	Retrospective	Routine follow-up CT is not necessary to detect delayed PSA after splenic embolization	2B
Kornpratt et al.[3]	2006	Prospective multicentric	NOM is a safe and effective strategy in a stable patient with splenic trauma	1B
Leeper et al.[33]	2014	Retrospective	SAE is both safe and effective	2B
Lin et al.[51]	2008	Retrospective	PSAE is a time–saving procedure, improving recovery from shock and avoiding incomplete hemorrhage control in PSA or AVF. Selective embolization should be used to control artery branches supplying the zone of parenchyma with contrast extravasation	2B
McCray et al.[4]	2008	Retrospective	Inpatient observation for patients with splenic injuries is not justified beyond the point where their hemoglobin stabilizes	2B
Miele et al.[61]	2016	Review	Contrast-enhanced ultrasound is timesaving, and it has several advantages, such as its portability, the safety of contrast agent, the lack to ionizing radiation exposure and therefore its repeatability, which allows follow-up of those traumas managed conservatively, especially in cases of fertile females and pediatric patients.	2C
Miller et al.[27]	2014	Prospective	AE is an adjunct to NOM recommended in all grade 3–5 splenic injuries. Angiographic evaluation is recommended if signs of vascular injuries are present	1B
Miller et al.[27]	2014	Prospective	Use of a protocol requiring angiography and embolization for all high-grade spleen injuries slated for NOM leads to a significantly decreased failure rate. Angiography and embolization as an adjunct to NOM for all grade III to V splenic injuries is advised	2A
Muroya et al.[34]	2013	Retrospective	Follow-up enhanced CT performed approximately 1 week after splenic injury may be useful to detect delayed PSA formation	2A
Olthof et al.[55]	2014	Clinical prospective	The splenic immune function of embolized patients was preserved, and therefore routine vaccination appears not to be indicated	2A

Continued next page

TABLE 2. *(Continued)*

Reference	Year	Design	Comments	GoR-LoE
Olthof et al.[6]	2017	Systematic review	Nowadays, NOM is the standard of care in hemodynamically stable patients with blunt splenic injury. The available evidence (although with a relatively small number of patients) shows that splenic function is preserved after NOM, a major advantage compared to splenectomy	1C
Ong et al.[43]	2005	Retrospective multicentric	Older age is associated with fNOM, mostly in high-grade injuries	2A
Robinson et al.[22]	2016	Systematic review	Diagnostic imaging occupies a crucial role in detecting and characterizing injuries to the solid organs. Injuries to the liver, spleen, kidneys, pancreas, and adrenals share many common features,	2A
Smith et al.[7]	2017	Retrospective cross-sectional	Higher grade injuries (III–V) and intraparenchymal or subcapsular hematomas are associated with a higher failure rate of NOM ± AE and should be managed more aggressively.	2A
Skattum et al.[6]	2012	Retrospective	SAE has only minor impact on splenic function and that immunization probably is unnecessary.	2C
Stassen et al.[46]	2012	Guidelines	NOM is the treatment of choice in stable blunt splenic trauma patient, irrespective of grade of injury, age, associated injuries	1A
Tien et al.[59]	2007	Prospective cohort study	Trauma patients are exposed to significant radiation doses from diagnostic imaging, resulting in a small but measurable excess cancer risk. This small individual risk may become a greater public health issue as more CT examinations are performed. Unnecessary CT scans should be avoided.	1C
Tugnoli et al.[8]	2015	Retrospective	NOM of splenic injuries is feasible and safe in hemodynamic stable patients. AE should be preferred in high-grade injuries	2B

SBP, systolic blood pressure; GCS, Glasgow Coma Scale; OIS, Organ Injury Scale; AAST, American Association for the Surgery of Trauma; ISS, Injury Severity Score; SAE, splenic artery embolization; BST, blunt splenic trauma; CB, contrast blush; OFR, observation failure risk; BSI, blunt splenic injury; AVF, arteriovenous fistula.

data to investigate whether a difference exists between proximal and distal embolization in terms of splenic function.[6]

During the days and weeks after AE, complications occurred in 20% of cases and include abscesses, infarction, missed injuries, and failure to control bleeding (10–15%).[46] Ekeh et al.[58] observed that irrespective to the location of AE, major complications (splenic bleeding, splenic infarction, splenic abscess, and contrast-induced renal insufficiency) occurred in 27% of patients, and minor complications (fever, pleural effusions, and coil migration) occurred in 53% of patients. For these reasons, patients must be closely monitored by serial clinical examinations and serial hematocrit measurements, to timely detect a possible unfavorable evolution. What remains unclear in the literature is the duration and the frequency of these interventions.[4]

Another topic of debate is the need for repeated imaging in blunt splenic trauma. McCray et al.[4] and Jeremitsky and coworkers[50] reported that they do not routinely obtain repeated imaging on patients treated by NOM. However, the risk of delayed formation of PSA has been reported in 30.4% of grade II and 18.4% of grade III injuries,[33,34] and the persistence of PSA after AE has been documented in 20.8% of patients.[47] Even if the vast majority of these PSA resolve spontaneously and do not affect clinical decision making,[47,50] a CT scan at 48 hours to 72 hours has been suggested in all grades higher than I, to reliably identify the late PSA formation, and to allow prompt endovascular intervention when appropriate, to reduce the risk of fNOM. The panel agreed that follow-up imaging in grades III to V was wise, but did not reach consensus about follow-up CT in grade II, commenting that further studies are needed to assess the risks of late vascular injuries in these patients. Awareness should be given to the cumulative radiation exposure with repeated imaging in trauma patients and unnecessary CT scans should be avoided.[59,60]

An useful alternative might be contrast-enhanced ultrasound (CEUS), but evidences are lacking and appropriateness should be individualized and based on local expertise.[61]

Table 2 summarizes referral articles for topic 1.

1. NOM in liver injury

Questions

A. What are the criteria for NOM in liver injuries?
B. What are the indications for angioembolization?
C. When is follow-up imaging indicated?
D. Which is the best treatment of biliary complications?

Statements

A. Patients with blunt liver injuries of any AAST grade who are hemodynamically stable and do not have peritonitis or associated abdominal injuries requiring surgery may be managed nonoperatively [GoR C; LoE I];
   - NOM of medium/high-grade blunt hepatic injuries should be considered only in institutions that can provide intensive monitoring and have an operating room always available. Institutions without these capabilities should transfer these patients [GoR C; LoE II];
   - In adult patients, CT scan with iv contrast should be performed to identify and assess the severity of liver injury and evaluate associated injuries, to plan NOM [GoR C; LoE II];

B. Patients with ongoing instability warrant operative management and are not candidates for AE, unless performed in hybrid environment [GoR C; LoE I];

Patients, hemodynamically stable, with blunt liver injury of any AAST grade, with contrast extravasation or

PSA on CT scan should be considered for AE [GoR C; LoE II];

C. A routine repeated imaging is not necessary unless there are clinical or laboratory signs of complications [GoR B; LoE I].

Biliary complications after NOM increase with severity of liver injury [GoR B; LoE I]

Endoscopic retrograde cholangio-pancreatography (ERCP) with sphincterotomy and/or biliary stenting, percutaneous drainage and surgical intervention (open or laparoscopic) are all effective ways to manage biliary complications [GoR B; LoE I]

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Nonoperative management of liver injuries has become standard in stable or stabilized patients without signs of peritonitis or other indications for abdominal surgery,[9,62] with a reported success rate > 90%.[63] Nonoperative management is associated with a decrease in overall mortality, abdominal complications, and transfusion requirements when compared to surgical management.[64] Factors previously thought to preclude NOM of hepatic injuries, such as high hepatic injury grade, associated brain injury, high injury severity score, large hemoperitoneum, age greater than 55 years, number of transfusions, periportal tracking of blood or pooling of contrast/a blush on CT scan, are no longer considered absolute contraindications to a trial of NOM in hemodynamic stable patients. Although a success rate of up to 90% has been reported, fNOM is associated with poor overall outcome and higher mortality.[62] Approximately 25% to 27% of liver trauma managed nonoperatively will require intervention as a result of complications, such bleeding.[65] The risk of bleeding is particularly significant in grades IV and V liver injuries initially treated by NOM.[66–68]

The choice of NOM is appropriate if there is the ability to predict the need for surgery before the patient becomes unstable. For this reason, NOM of hepatic trauma should be performed only in centers able to correctly diagnose and grade liver injury, to rapidly respond to change in patient status and to intervene if complications arise. Availability of clinical monitoring and 24/7 availability of an operating room is mandatory to support this approach. Although no study explores the role of blood components administration on success rate of NOM in liver and other sold organs injuries, it is likely that adherence to hemostatic resuscitation strategies, using massive transfusion protocols, can improve the number of severe liver injuries treated nonoperatively.[69]

The successful use of NOM, regardless of the grade of hepatic injury has been improved by the development of more sensitive high speed CT scanners. A CT scan with iv contrast has a reported sensitivity of 92% to 97% and a specificity of 98.7% in liver trauma,[64] allows precise diagnosis and detects associated intra-abdominal or retroperitoneal injuries which may make NOM a poor choice. Moreover, new-generation CT scans allow for better visualization of the vascular tree in different phases after contrast injection, revealing contrast extravasation, which indicates active bleeding, or signs of confined bleeding such as PSA, or indirect signs of vascular damage as vessel truncation, which may increase the risk of delayed bleeding, mandating AE. Misselbeck et al.[63] showed that patients with contrast extravasation at CT scan are 20 times more likely to require AE than those who did not.

AE can be a valuable adjunctive tool to control intrahepatic bleeding.[62,66,70] However, even in experienced hands, it can be a time-consuming procedure. In a patient who is a transient responder, primary AE before surgical exploration should be attempted only if a hybrid room is available to allow for immediate laparotomy if embolization is unsuccessful.[62] Operative exploration still represents a safer approach for those patients who are persistently unstable despite resuscitative efforts. Operative treatment options depend on available resources and expertise. Many patients who need surgery for a liver injury will most likely get the liver packed. At the end of damage control laparotomy, if the patient is still hemodynamically abnormal, postoperative AE can control arterial bleeding in inaccessible areas deep in the liver parenchyma.[62,63] This is achieved faster in a hybrid environment. The reported efficacy of AE to control hepatic bleeding is as high as 83%. Repeated angiography is sometimes necessary to achieve definitive bleeding control, accounting for an AE failure rate of 13% to 20%.[71]

Different clinical protocols for AE are available in the literature.[28,29,63,66,72] In a series of 138 consecutive patients with liver trauma, Gaarder et al.[66] performed AE in acute settings in all stable or stabilized patients with active contrast extravasation on CT scan, and angiography the next day in all grade III-V liver injuries without initial CT scan evidence of bleeding. None of the patients without signs of bleeding at the admission CT needed embolization. Misselbeck et al.[63] performed AE on all stable patients who demonstrated active contrast extravasation at admission CT. Of these, 60% required embolization, conversely only 7% who did not exhibit contrast extravasation on CT scan required embolization. Letoublon et al.[29] demonstrated that AE was never indicated in the absence of obvious extravasation on CT scan, even in high-grade injuries. These results support AE in the presence of contrast extravasation on initial CT scan, irrespective of injury grade. In the same way, AE should be considered if PSAs are detected on the initial CT, because of the risk of delayed hemorrhage.[72]

The necessity of routine follow-up CT scan is controversial. Bertens et al.[28] suggested routine CT scan 24 hours to 48 hours after injury to assess delayed PSA formation, mostly in high-grade injuries, to avoid fNOM due to delayed hemorrhage. Other authors reported that only 0.5% of cases needed intervention based on the findings of the follow-up CT scan, and in these cases, all patients demonstrated clinical signs, such as tachycardia, abdominal pain, fever, and enzyme elevation.[72] Routine follow-up CT scan seems unnecessary for patients with blunt hepatic injury managed by NOM, as long as clinical or laboratory signs (unexplained drop in hemoglobin level, abnormal liver function tests) and symptoms are absent.[62]

Most patients with blunt liver injuries treated with NOM, heal without complications. However, the risk of complications increases with the grade of injury, from 1% in grade III to 63% in grade V.[9,29,63] Hepatic related complications are necrosis, abscess, bilioma, biliary leaks, hemobilia, and delayed hemorrhage.[63] Biliary complications, affecting 3.2% of all hepatic trauma, usually present in a delayed fashion with signs of systemic inflammation, jaundice, abdominal pain, and/or sepsis. The combination of liver trauma with ischemia

TABLE 3. Review Articles for Topic 2

Reference	Year	Design	Comments	GoR-LoE
Bala et al.[74]	2012	Retrospective	In patients with clinical evidence of biliary complications, CT scan is a useful diagnostic and therapeutic tool. AE, ERCP and temporary internal stenting, together with percutaneous drainage of intra-abdominal or intrahepatic bile collections, represents a safe and effective strategy for the management of complications following both blunt and penetrating hepatic trauma	2B
Bertens et al.[28]	2015	Retrospective cohort	NOM is an effective and successful option in the majority of blunt hepatic trauma patients	2B
Boese et al.[9]	2015	Systematic review	Risk factors for fNOM: clinical signs of shock; associated intra-abdominal injuries; peritoneal signs	2C
Bonariol et al.[65]	2015	Retrospective	Requirements for successful NOM: hemodynamic stability; correct injury grading by CT scan; early use of AE if contrast extravasation present at CT scan	2C
Cannon et al.[69]	2017	Guideline	DCR can significantly improve outcomes in severely injured bleeding patients	1A
Clemente et al.[70]	2011	Retrospective	NOM eventually associated with AE is safe and effective in any grade of hepatic injury provided hemodynamic stability	2C
Dabbs et al.[73]	2009	Retrospective	Major hepatic necrosis tended to occur in high-grade injures, was associated with higher complication rates, longer hospital length of stay, and higher transfusion requirements.	2A
Gaarder et al.[66]	2007	Prospective	The availability of a formal protocol of NOM for hepatic trauma seemed to improve patient outcome. AE must be a part of the NOM protocol	1C
Hommes et al.[67]	2015	Prospective single-center	NOM of BLI has a high success rate (95%). Nonoperative management of BLI should be considered in patients who respond to resuscitation, irrespective of the grade of liver trauma. Associated intraabdominal solid organ injuries do not exclude NOM.	2A
Kapoor et al.[76]	2012	Systematic review	Most bile leaks from the intrahepatic biliary tree are transient and managed conservatively by drainage alone or endoscopic biliary decompression. Selected cases may require reoperation and enteric drainage or liver resection for management	1C
Kittaka et al.[72]	2015	Prospective	Spontaneous resolution of PSA < 10 mm is possible. There is no significant relationship between early occurrence of PSA and patient mobilization	1C
Lee et al.[71]	2014	Retrospective	Risk factor for early AE failure: high-grade (IV-V) hepatic injury; incomplete embolization, HR > 110 bpm in ER	1C
Letoublon et al.[29]	2011	Retrospective	AE is an effective tool for hepatic trauma management; awareness of the ischemic complications is important	1C
Li et al.[64]	2014	Retrospective	NOM is the first option of treatment in a stable patient; AE associated with correction of lethal triad is an effective tool	1C
Misselbeck et al.[63]	2009	Retrospective	HA/AE has become an important interventional adjunct in the NOM of hepatic injuries	2C
Polanco et al.[68]	2013	Retrospective Multi-center	Failed NOM was associated with higher mortality. Several predictors of failed NOM were identified including age, sex, ISS, GCS, and hypotension. These factors may allow for better patient selection and improved outcomes.	2C
Stassen et al.[62]	2012	Guidelines	NOM is treatment modality of choice in hemodynamically stable patients, irrespective of the grade of injury, or patient age, if the environment provides capabilities for monitoring, serial clinical evaluation and urgent laparotomy	1A
Yuan et al.[75]	2014	Retrospective	High injury grade; centrally-located liver trauma; and use of TAE are risk factors for major bile leak after blunt liver trauma. ERC should be arranged early if the patient has risk factors and their plasma bilirubin level is greater than 43.6 μmol/L during admission.	2A

ER, emergency room; HA, hepatic angiography; HR, heart rate.

caused by AE could predispose to necrosis and biliary complications.[73]

Most peripheral bile leaks will seal without intervention and only continuous high output biliary drainage should be managed by ERCP[74] .

In a large retrospective study,[75] bile leak occurred in 4.9% of blunt liver trauma. Risk factors were central location of injuries, high ASST grade, emergency embolization. Follow-up imaging was performed on clinical indication, such as fever, abdominal pain, central location of injury, increased alanine transaminase, or bilirubin. Intraperitoneal or intrahepatic fluid collection was the most common finding. If clinical recovery was unsatisfactory, percutaneous drainage was the next step followed by ERCP and stenting if persistent leak. In this study, only 27.5% (10 of 40) patients with abdominal fluid collections after blunt liver trauma required ERCP for major bile leak. ERCP allows for conservative treatment of bile leak, with the possibility of stenting, nasobiliary drain, or sphincterotomy which produce bile diversion, being stenting as the most used technique because of less morbidity.[76] Hepatic abscesses occur in up to 4% of liver trauma, leading to a mortality of 10%.[6] Their treatment has been improved by interventional radiology techniques of percutaneous drainage, but a surgical approach (open or laparoscopic) still remains an option.[52] Moreover, laparoscopy, in absence of contraindications, represents a viable tool to perform peritoneal cavity washout in case of biliary peritonitis, helping to resolve the systemic inflammatory response related to bile extravasation.[52]

Table 3 summarizes the reference articles for topic 2.

1. NOM for pancreatic injuries

Questions

A. Which is the most effective method for diagnosis and grading of pancreatic injuries?
B. Which are the criteria for NOM in pancreatic injuries?
C. Which is the role of endoscopic management?

Statements

A. Grading and diagnosis of main ductal injury are key factors in the decision making [GoR C; LoE II];

- Diagnostic delay increases the risk of mortality and morbidity [GoR C; LoEII];
- Contrast-enhanced CT scan performed during the portal venous phase is the diagnostic modality of choice in hemodynamically stable blunt abdominal trauma patients to diagnose pancreatic injury. CT scan is not sensitive for detecting main ductal injury [GoR C; LoE II];
- Repeated CT scan may increase the accuracy of detecting a pancreatic injury [GoR C; LoE II];
- Magnetic resonance cholangiopancreatography (MRCP) represents the first choice for evaluation of duct injury if appropriate [GoR C; LoE II];
- ERCP is the most sensitive technique to detect a main ductal injury and allows simultaneous treatment [GoR C; LoE II].

B. NOM requires that patients be stable and without associated organ injuries requiring laparotomy [GoR C; LoE II];

- In grade I/II pancreatic injuries NOM has low morbidity [GoR C; LoE II];
- For grade III/IV pancreatic injuries, operative management is recommended, as fNOM contributes to treatment delays and increases complications. In selected centers with advanced skills, endoscopic management may be an option [GoR C; LoE II].

C. The treatment of complications, pseudocyst, persistent pancreatic fistula or peripancreatic fluid collections may be possible with endoscopic or percutaneous drainage [GoR C; LoE II].

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Blunt injury to the pancreas is uncommon, with an incidence of 0.2% to 12% of all abdominal trauma.[9] Radiologic and laboratory abnormalities may be subtle. A delay in diagnosis increases morbidity and mortality. Accurate identification of signs of pancreatic trauma and its grading is mandatory to plan the best treatment strategy.

Integrity of the pancreatic duct is the most important factor for appropriate decision making, because it determines the morbidity and mortality from pancreatic injury.[14] If not promptly recognized, major ductal disruption (AAST grades III-V) produces pancreatic enzyme leakage which triggers an inflammatory cascade resulting in pancreatic necrosis, enzymatic digestion of neighboring vascular and visceral structures, and infection. The local and systemic consequences may be lethal. In case of fNOM, delayed diagnosis and treatment of pancreatic duct injury of 24 hours is associated with higher morbidity and mortality rates, ranging from 66% to 100% and 11.1% to 14%, respectively.[13,14,35]

Several diagnostic options are available to detect pancreatic trauma and identify ductal injury early.[1,10,31,32,35] Computed tomography scan is the modality of choice, with a reported variable sensitivity (65–80%) and specificity for detecting pancreatic trauma.[10,11] Detection of pancreatic duct injury using CT also varies, with sensitivity ranging from 52% to 54% and specificity between 90% and 94%.[11] Improved ductal visualization is possible with newer multidetector CT (MDCT) scanners which enable multiplanar reconstructions and minimum intensity projections.[10]

The accuracy of multiplanar CT in detecting ductal injuries has been tested in different acquisition phases, resulting in an accuracy of 97.9% (parenchymal phase), 100.0% (portal venous phase), and 96.8% (equilibrium phase), respectively.[10] Thus, the portal venous phase is the most accurate scan to detect pancreatic duct injury. Moreover, in the face of normal initial CT scan, if pancreatic injury is suspected on the basis of clinical evaluation or evolution of lipase/amylase levels,[13] CT should be repeated[12] or MRCP, when available, may be performed.

Magnetic resonance cholangiopancreatography is the gold standard for noninvasive delineation of the pancreatic duct, enabling accurate detection of the site of pancreatic duct disruption and the integrity of the duct located distal to the site of injury, which may not be detected by ERCP.[10,13,32] The concurrent use of secretin improves the diagnostic yield of MRCP in the evaluation of pancreatic duct.[77]

The fracture line, which still contains some static fluid, is hypodense in T1 and hyperdense in T2 images.[10] However, the presence of fluid and blood around the injured pancreas limits the effectiveness of MRCP in the immediate post-trauma period, when the disrupted pancreatic duct is not dilated. The sensitivity is optimal after a few days, allowing time to arrange the examination, which is not always readily available or wise because of associated conditions in an emergency setting.[10] Magnetic resonance cholangiopancreatography can also provide additional information that ERCP cannot provide, such as the presence of peripancreatic or peritoneal fluid collection, with or without communication of the pancreatic duct, as well as damage to other organs.[10]

Endoscopic retrograde cholangio-pancreatography is the most sensitive tool to detect ductal injury, even if the distal pancreatic duct cannot be visualized.[10,31,35] Ductal disruption produces contrast extravasation which may remain within the gland or leak outside the pancreas. The major disadvantages include its invasive nature, high rate of complications (5–15%) and the lack of availability of the technique or trained personnel to do this procedure during an emergency.[10,31] Endoscopic retrograde cholangio-pancreatography provides therapeutic options, such as ductal stenting, sphincterotomy, transpapillary drainage that improves successful NOM even in case of high-grade pancreatic trauma.[10,15,35,72,78]

Selection of patients for NOM is the key. It is widely accepted that if the patient is stable with a low-grade injury, in the absence of any associated injury mandating explorative laparotomy, NOM can be attempted.[11,12] NOM of low grade I to II pancreatic injuries is accepted with a reported 20% complication rate,[11] if major ductal involvement is excluded. If the pancreatic duct is not definitively intact, further evaluation of the duct with additional imaging studies (MRCP or ERCP) is indicated,

TABLE 4. Reviewed Articles for Topic 3

Reference	Year	Design	Comments	GoR-LoE
Bhasin et al.[32]	2009	Systematic review	ERCP is the most accurate diagnostic tool to detect the site and the extent of pancreatic duct injury. Complications are possible	2B
Biffl et al.[12]	2013	Systematic review	NOM is indicated for low-grade pancreatic injuries, without pancreatic duct involvement. ERCP is an effective therapeutic tool if a pancreatic fistula develops	2C
Bjornsson et al.[79]	2013	Systematic review	ERCP was first reported as a diagnostic tool in the settings of pancreatic injury but has in recent years been used increasingly as a treatment option with promising results.	1C
Girard et al.[14]	2016	Retrospective	NOM is feasible and safe in PT in absence of pancreatic duct injuries. ERCP is the most sensitive tool to detect ductal injury and allows its treatments; MRCP is sensitive enough to detect ductal injuries only few days after trauma	2C
Girard et al.[13]	2016	Systematic review	NOM could be attempted in PT in presence of ductal injury if ERCP is available for ductal stenting	2C
Holden et al.[1]	2008	Systematic review	NOM is feasible in low-grade PT, CT surveillance is necessary to detect PT related complications (abscesses; pseudocysts; necrosis); nonoperative techniques are reserved to treat these complications	2C
Ho et al.[11]	2016	Guidelines	NOM or nonresectional management is conditionally recommended in grade I/II PT, due to low complication rate	1A
Jeroukhimov et al.[31]	2015	Retrospective	ERCP is effective and a relatively safe tool to detect ductal injury; its use might avoid unnecessary interventions in selected cases	2B
Kim et al.[80]	2017	Retrospective	ERCP helps clinicians choose a treatment modality for major pancreatic duct injury since it provides information about the precise condition of the major pancreatic duct injury. ERCPwith transpapillary pancreatic stenting also shows promise as a substitute for laparotomy or pancreatic resection in selected patients	2A
Koganti et a[15]	2016	Retrospective	NOM should be attempted in selected cases of grade III/IV PT, if patient is hemodynamically stable, isolated PT, no pancreatic necrosis and when a confined leak of a pseudocyst	2C
Krige et al.[72]	2015	Retrospective	ERCP may be effective to treat ductal injuries and to manage late complications of PT	2C
Kumar et al.[10]	2016	Systematic review	MRCP has superseded ERCP in evaluation of acute pancreatic duct injury	2C
Lin et al.[35]	2007	Retrospective	Unresolved pseudocyst must be treated to avoid complications. Percutaneous drainage is indicated if distal ductal injury is present. If proximal, ERCP is the method of choice	2C
Tirkes et al.[77]	2013	Systematic review	MRCP performed with secretin and with new 3D fast SE techniques has markedly improved, In selected cases, secretin-enhanced MRCP has proved itself to be a valuable noninvasive complementary procedure to endoscopic US and ERCP, accurately characterizing pancreatic duct abnormalities while sparing patients the need for an invasive procedure.	1C
Walter et al.[78]	2014	Prospective	EUS-guided stenting is an effective tool to treat peripancreatic collections	2C

ERCP, endoscopic retrograde cholangio-pancreatography; EUS, endoscopic ultrasound; PT, pancreatic trauma.

because this may change the grade of the injury and therefore modify the recommended treatment plan. NOM of grade III-IV, is still debated.[12,15,72]

The Eastern Association for the Surgery of Trauma and Western Trauma Association both recommend operative management for grade III to IV pancreatic injury,[11,12] to avoid pancreatic duct-related complications, which may make failure of NOM. Failure of NOM is reported in 10% to 50% of grade III to IV pancreatic injury,[11] with a complication rate of 30%, mostly related to the presence of major fistula. Fistula development is seen in 60% of grade III to IV pancreatic trauma patients managed nonoperatively, significantly higher when compared patients treated operatively.[11] Moreover, high-grade pancreatic trauma is often associated with surrounding visceral involvement with a high risk of hollow viscus injuries which can be missed with NOM.

Ductal disruption at or distal to superior mesenteric vein is managed definitively by distal pancreatectomy. For proximal ductal injuries (grade IV), recommendations have ranged from simple external drainage (possibly with endoscopic stenting of the duct of Wirsung) to complex procedures such as pancreaticoduodenectomy, or closure of the proximal stump with drainage of the distal pancreas into a Roux-en-loop. The former option seems to be preferred.[12,15]

Few reports of successful NOM of grade III-IV pancreatic injury in the adult population are available and results are controversial.[14,15,32] Koganti et al.[15] described the largest group of high-grade pancreatic trauma managed nonoperatively. In this series of stable patients with grade III to IV pancreatic injury, a controlled leak from duct disruption developed. The pancreatic juice loss was managed without any operation: the controlled leak produced a well-defined walled off pancreatic necrosis and pseudocyst formation, amenable to endoscopic or percutaneous procedures, without the need for an additional surgical intervention.

If the patient is hemodynamically stable, pancreatic enzymatic leak is contained, and local resources and expertise are available, endoscopic therapy of pancreatic duct injuries seems to be a reasonable alternative to surgery, mostly for right-sided injuries.[14,32] The principal factor of success is the correct positioning of the endoprosthesis which should bridge the ductal disruption whenever possible.[14] If this is not possible, insertion of a transpapillary stent, after sphincterotomy, should allow reduction of the fistula rate by decreasing intraductal pressure.

In any case, ERCP should be performed early, so that surgical therapy can be rapidly completed in case of failure.[14,79,80]

In contrast to the former encouraging results, Lin et al.[35] reported a high rate of ductal strictures observed after removal of earlier placed stents. Therefore, while endoscopic management of ductal injury in acute setting is an attractive minimally-invasive option in selected cases, the development of ductal strictures remains a concern. The contribution of stenting to stricture development is not clear. Potentially stent-induced ductal changes may be avoided by using softer and smaller diameter 3-Fr or 4-Fr stents, with an unflanged inner end.[32]

The role of endoscopy and interventional radiology is well established in the management of late complications arising from NOM of traumatic pancreatic leak.[10,14,35] Among them, pancreatic fistula is the most common, with a rate of 20% in isolated pancreatic trauma and 35% in combined pancreaticoduodenal injuries. Conservative management with CT-guided drainage is the initial treatment of choice.[10] After percutaneous drainage, a high-volume and persistent fistula output may be treated with ERCP and stenting.

Pseudocysts develop after about 30% of pancreatic injuries, most commonly due to missed injuries of distal duct.[10] Endoscopic transpapillary drainage has proven to be an effective tool to manage partial pancreatic duct transection. Otherwise, if a complete cutoff of the pancreatic duct precludes transpapillary drainage, endoscopic transgastric or transduodenal drainage of the collection can be successful.[32]

Peripancreatic abscess usually occur following contamination from hollow viscus or from skin flora through an external drain. These complications increase morbidity and mortality from sepsis. Endoscopic ultrasonography-guided transmural drainage with placement of plastic stents is the recommended modality of drainage, with reported success rate of 82% to 100% for pseudocysts and of 53% to 100% for walled off pancreatic necrosis, respectively.[78]

Pancreatic duct strictures causing chronic obstruction and increased intraductal pressure may lead to chronic obstructive pancreatitis, presenting months or years after trauma.[10] In these cases, ERCP with ductal stenting is therapeutic.

Table 4 summarizes referral article for topic 3.

4. NOM for kidney injuries

Questions

A. Which is the best method to diagnose and grade kidney injuries?
B. When is NOM and/or AE effective in kidney injuries?
C. Which is the best treatment of urinary leakage?

Statements

A. Contrast-enhanced CT scan, including an excretory phase, is the imaging modality of choice in diagnosing and grading renal injury in hemodynamically stable patient, with blunt abdominal trauma and suspicion of kidney/urinary tract injury [GoR B; LoE I];
B. Hemodynamically stable patients with renal injury regardless the grading can be initially treated with NOM [GoR B; LoE II];
  - Angiography and selective embolization (SAE) may be used and repeated if necessary to manage renal parenchymal injury [GoR B; LoE I];

C. Hemodynamically stable grade IV kidney injuries can be managed by NOM in most cases. Most urinary leaks heal spontaneously [GoR C; LoE I];
  - A persistent urinary leak is an indication for intervention [GoR C; LoE I];
  - Treatment options for urinary leak include open surgery, nephrostomy or ureteral stenting. Less invasive treatment locally available is the preferred [GoR C; LoE I].
  - Traumatic renal artery thrombosis or dissection might be treated when warm ischemia time is less than 4 hours, but it is associated with high rate of kidney loss [GoR C; LoE II].

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Injury to the genitourinary tract occurs in 10% of abdominal trauma, 70% to 80% occur after blunt trauma.[36,81] Nonoperative management has become increasingly attractive for renal injuries, especially for low grades (I-III) in hemodynamically stable patients in the absence of other indications for surgery. The shift toward NOM has been supported by observed reductions in nephrectomy rates, and decreased complications, and hospital stay.[19]

In hemodynamically stable or stabilized patients, advanced imaging allows for identification of those injuries that may preclude NOM and for better identification and grading of renal trauma. A four-phase CT scan of the abdomen and pelvis with noncontrast, arterial-, nephrographic-, and pyelographic phased images is generally considered the "gold standard" in initial imaging if renal trauma is suspected.[16,19,24,36] This diagnostic tool allows clinicians to (1) accurately stage the injury; (2) identify any preexisting renal pathology; (3) document function/presence of the uninjured kidney; (4) identify injuries to other abdominal organs. The pyelographic phase, obtained 10 minutes to 20 minutes after intravenous contrast injection allows for identification of collections or extravasation of contrast medium consistent with injury to the collecting system, which are relative indications for interventions, such as ureteral stenting or percutaneous drainage.[19,24] In a review of 162 renal injuries, 22 (12%) had collecting system injury, but 50% of these had no evidence on admission CT of urinary leak and it was diagnosed only at a second CT scan. Therefore, a follow-up imaging within 48 hours should be recommended in all patients with deep parenchymal injuries and perirenal hematoma which may mask a collecting system leak.[82]

There is a 64% rate of nephrectomy when renal injuries are explored surgically, regardless of indication for exploration.[16] Thus, avoiding exploration of an injured kidney, unless necessary, is a strategy that is more likely to preserve the kidney and its function. In fact, the overwhelming majority of contemporary literature supports selective trials of conservative management with good results, including high-grade renal injury, if the patient is stable.[17,19–21,25,83–86] In a series of 206 grade IV to V renal trauma patients, Van der Wilden et al.[17] reported NOM in 74.8% of patients. It was successful in 92.2% of cases. McGuire et al.[20] reported an overall 82.9% success rate of NOM in a series of high-grade renal trauma, including 51.8% with grade V injury. In a prospective series of grade IV-V renal injuries, Lanchon and coworkers[21] successfully used NOM in 89% of grade IV kidney injuries, with a 40% median relative function of injured kidneys at follow-up DMSA scintigraphy, and in 52% of grade V injuries.

In all these series, angiography and embolization were used as adjunctive tools to improve the success of NOM. A

TABLE 5. Articles Reviewed for Topic 4

Reference	Year	Design	Comments	GoR-LoE
Aragona et al.[18]	2012	Retrospective	NOM for grade 3–5 blunt renal injury in hemodynamically stable patients allows high kidney salvage rate	1C
Baghdanian et al.[82]	2017	Retrospective	Active hemorrhage in renal trauma is a significant predictor of surgical/endovascular therapy. In collecting system injuries with large perirenal hematoma repeated evaluation is advised	2C
Brick et al.[36]	2016	Guidelines	In high-grade renal trauma conservative management is possible, with the help of AE if contrast extravasation present, if patient is hemodynamically stable	1A
Charbit et al.[25]	2011	Retrospective	In HGRT the absence of contrast extravasation at CT and a perirenal hematoma < 25 mm excludes the need for AE	1C
Fisher et al.[24]	2015	Retrospective	Admission excretory phase at CT is necessary to detect a urinary leak	2C
Gor et al.[86]	2016	Retrospective	NOM is the treatment of choice for low-grade renal injuries. DA and AE improve success of NOM even in higher grade injuries	2B
Holevar et al.[81]	2004	Guidelines	NOM is improved by the use of AE. If urinary leak is present it can be usually managed by endoscopic or percutaneous strategies; NOM of renal lacerations with a devascularized fragment have high morbidity rate	1A
Hope et al.[83]	2012	Retrospective	NOM for a penetrating renal injury is safe in selected patients	2C
Hotaling et al.[85]	2010	Retrospective	DA and AE improves NOM of HGRT	2C
Kautza et al.[16]	2015	Systematic review	NOM allows high renal salvage rate and avoids long-term complications. AE is an effective adjunctive tool	1C
Lanchon et al.[21]	2015	Prospective	NOM can be safely performed in grade IV renal injury. It should also be attempted in grade V	2C
McCombie et al.[19]	2014	Guidelines	NOM should be attempted also in HGRT providing there is hemodynamic stability. CT is the method of choice for early re-imaging	1B
McGuire et al.[20]	2010	Retrospective	NOM should be attempted in HGRT. Grade V and platelet requirements are an independent risk factor for fNOM; older age and hypotension predict complications	1C
Morey et al.[84]	2014	Guidelines	NOM is the treatment of choice for the vast majority of renal trauma. AE allows vascular injury control improving NOM	1A
Pereira et al.[88]	2012	Retrospective	Late results of renal function after conservative treatment of high-grade renal injuries are favorable, except for patients with grades IV with vascular injuries and grade V renal injuries. Moreover, arterial hypertension does not correlate with the grade of renal injury or reduction of renal function.	2A
Saour et al.[30]	2014	Retrospective	In HGRT managed by NOM, AE is safe and does not increase the risk of ARF	2B
Stanislaw et al.[87]	2017	Systematic review	Selective angiographic embolization and/or stenting has been useful in cases of isolated renal vascular trauma. Another way to optimize success rates of the nonoperative approach involves endourologic stenting.	1C
Van der Wilden et al.[17]	2013	Prospective multicentric	Hemodynamically stable patients with grade IV-V renal trauma can be safely managed nonoperatively	2C

ARF, acute renal failure; DA, diagnostic angiography; HGRT, high-grade renal trauma.

recent study carried out by Gor et al.[86] on 1,628 cases of patients with renal trauma identified in the Pennsylvania Trauma Outcome Study database, demonstrated wide use of diagnostic angiography and renal AE (RAE), even for low-grade renal injuries. In high-grade renal trauma patients, the need for RAE is reported in 10% to 40%[25] of cases. Indications for angiography are based on the patient's clinical status with an ongoing renal hemorrhage. If the patient is stable, the presence of bleeding vessels on CT scan should prompt angiography, with a positive predictive value of 78% for the need for RAE. Other reported CT scan criteria used to select the patients with high-grade renal trauma who are likely to benefit from embolization are the discontinuity of Gerota fascia which predicts the need for RAE with a positive predictive value of 92% and a negative predictive value of 78% and the presence of perirenal hematoma rim distance greater than 25 mm.[16,20,25] A study of the US National Trauma Data Bank showed that the use of diagnostic angiography and RAE eliminated the need for nephrectomy in 78% and 83% of grades IV and V, respectively. However, most required a second intervention (most commonly repeated angiography).[16]

The management of patients with grade IV injuries can be particularly challenging due to the number of possible urinary complications. Urinary leaks have been observed in up to 27% of grade IV injuries.[1,65,84] Findings suggestive of ureteral injury include urinary contrast extravasation, ipsilateral delayed pyelogram, ipsilateral hydronephrosis, and lack of contrast in the ureter distal to the suspected injury. Parenchymal collecting system injuries often heal spontaneously, so that a period of observation (48–72 hours) is advocated if minimal contrast extravasation during the CT scan excretory phase is documented. On the other hand, if renal pelvis or proximal ureteral avulsion is suspected because of the presence of large medial urinoma or huge extravasation without distal ureteral contrast, operative intervention is warranted, to prevent further complications, such as sepsis, ileus, and fistula.[84]

Open repair should be attempted if urinary extravasation is detected within 1 week, particularly if the patient needs to be explored for other reasons. Otherwise, urinary drainage should be initially achieved via internalized ureteral stent, a minimally invasive technique. A Foley catheter should be left in place to minimize pressure in the collecting system, thereby facilitating ureteral injury healing. The ureteral stent is removed during follow-up once a complete resolution of urinary leak is documented, usually after at least 3 weeks. If follow-up images document a persistent urinary leakage, an increasing urinoma or superimposed septic complications, urinary drainage should be supplemented with percutaneous urinoma drainage, percutaneous nephrostomy or both.[61] Percutaneous nephrostomy is the technique of choice to ensure collecting system drainage if retrograde stenting is unsuccessful or not possible.[19,84]

Traumatic renal artery injury, as thrombosis, and dissection with intramural hematoma, can be treated with endovascular procedure of stenting or surgery when warm ischemia time is less than 4 hours. However, a totally nonperfused kidney at CT scan is associated with high rate of kidney loss because a timely repair with recovery of normal blood flow is unusual.[87] In a retrospective review, the extent of renovascular injury and the degree of nonperfusion of the kidney at admission CT in grades IV and V appeared to determine the functional volume loss at the follow-up assessment, with a 29% rate of late onset of renovascular hypertension.[88]

Reasoning about the functional outcome of renal trauma based on the initial radiologic evaluation helps to avoid multiple and time-consuming procedures to salvage a nonfunctional kidney.

The prophylactic administration of antibiotics after renal trauma is still debated.[19] Since the reported incidence of urinary tract infection and perinephric abscess formation is 5% to 11% and 0% to 5%, respectively, it seems reasonably advisable to use them only in presence of risk factors, such as devitalized tissues, associated bowel or pancreatic injuries, co-morbidities, or immunosuppression.

Table 5 summarizes referral articles for topic 5.

CONCLUSION

Nonoperative management has become the treatment modality of choice for intra-abdominal parenchymal injuries in hemodynamically stable patients, who do not have other indications for surgery.[45,62,84,89] The availability of new-generation CT scans, angiography, and endoscopy dramatically increases the success rate of NOM. The proven advantages of NOM are decreased surgery-related morbidity and increased salvage rate of organs such as the spleen and kidney, enabling the preservation of their functions and the reduced number of challenging liver procedures. However, because of the need for close monitoring in patients treated with NOM, especially if it is attempted in high-grade injuries, this approach should be applied only in those centers where logistical resources, such as CT scanners, operating rooms, interventional radiology, endoscopy services are available 24/7. These capabilities and services allow a multidisciplinary approach to potential complications of NOM and/or allow a change in strategy to operative repair as needed.

AUTHORSHIP

O.C., S.C., T.S., S.H., A.L., W.B., K.S., organized and designed the consensus, decided the final statements, and wrote and edited the study. G.T., L.A., S.Ri., M.C., A.C., L.F., F.C., E.D, G.Go., G.N., S.M., proposed the statements for various topics. M.Ma., D.P., F.C., A.R., S.Rau., M.Mu., S.D.S., A.G., F.B., F.R., F.S, revised the literature.

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