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INFECTION AND TRAUMA (M SARTELLI, SECTION EDITOR)

Intra-abdominal Infections After Abdominal Organ Injuries

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Abstract
Purpose of Review This review is focusing on intra-abdominal infections after abdominal injuries which are a major source of morbidity following abdominal trauma.
Recent Findings Intra-abdominal infections after abdominal injuries pose a diagnostic and therapeutic challenge to the trauma surgeon. Its diagnosis is based on clinical and radiological findings. Once an intra-abdominal infection is diagnosed, the next step is to achieve prompt and efficient source control coupled with early initiation of broad-spectrum antibiotics. Over the past several years, research has found some predictors for intra-abdominal infections after abdominal trauma. However, the role of prophylactic and therapeutic antibiotics remains unclear. The operative strategy for these patients is largely based on the trauma surgeon experience. However, temporary abdominal closure with negative pressure wound therapy seems to be the best approach to managing post-traumatic intra-abdominal infections.
Summary Early administration of broad-spectrum antimicrobials coupled with rapid and efficient source control is of paramount importance for improving outcomes in patients with post-traumatic intra-abdominal infections.

Keywords Intra-abdominal infections · Trauma infections · Abdominal trauma infections · Abdominal trauma

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Introduction

Intra-abdominal infections (IAIs) include a broad spectrum of pathological conditions, ranging from a non-complicated IAI to complicated fecal peritonitis. IAIs are an important cause of morbidity and mortality in critically ill patients, ranking the top three causes of severe sepsis in the intensive care unit [1]. Although IAIs result most commonly from non-traumatic pathologies such as appendicitis, cholecystitis, and diverticulitis [2••], post-traumatic causes remain of paramount importance given its association with poor outcomes and the challenging scenario that those represent to the trauma surgeon.

Patients with post-traumatic IAIs have higher medical and economic expenditures. These patients frequently develop other complications, such as fistulas and thus, require longer intensive care unit and hospital stay, more re-operations, and the need of complex medical care.

Predictors of Intra-abdominal Infections

To date, several studies have highlighted factors that are associated with the development of complications after abdominal trauma (Table 1).

Demetriades et al. [6] performed a prospective multicenter study to evaluate the safety of primary anastomosis or diversion and to identify independent risk factors for the development of colon-related abdominal complications. Colon-related abdominal complications were defined as anastomotic leak, intra-abdominal abscess or peritonitis, fascial dehiscence, and colon obstruction or necrosis. In this study, 19% of patients developed an intra-abdominal abscess, and multivariate regression analysis identified severe peritoneal contamination, more than four units of blood within the first 24 h and single-agent antibiotic prophylaxis as significant independent risk factors for abdominal complications. Bradley et al. [9•] used

Table 1 Different studies highlighting the factors associated with development of complications after an abdominal trauma

Study	Patients (*n*)/injuries (%)	IAIs occurrence (*n*)	Significant risk factors for the development of IAIs
Poret 1991 [3]	*n* = 151/NR	*n* = 34/151	-Increasing ATI -Grade of contamination -Increasing transfusions
Fabian 1991 [4]	*n* = 484/hepatic trauma		-Increasing ATI -Increasing transfusions
Ivatury 1993 [5]	*n* = 252/NR	*n* = 43/252	-Increasing ATI -Presence of colostomy
Demetriades 2001 [6]	*n* = 297/SB 58; liver 26%; stomach 20%; kidney 18%; MAV 9%	*n* = 55/297	-Severe peritoneal contamination - ≥ 4 units of blood within the first 24 h -Single antibiotic prophylaxis
Bulger 2003 [7]	*n* = 181/single colon 88%; multiple sites of colonic injury 12%	*n* = 51/181	-Hypotension on admission -PATI score > 25
Morales 2004 [8]	*n* = 762/NR	*n* = 81/762	-ATI score > 24 -Abdominal contamination -Admission to the ICU
Bradley 2013 [9•]	*n* = 517/NR	*n* = 111/517	-Large bowel resection -Increasing number of re-explorations -Increasing fluids administered at 48 h
Paulus 2015 [10•]	*n* = 1518/SB 33%; stomach 15%; colon 19%; colon + SB 22%; S + SB 3%; S + colon 5%; S + colon + SB 4%	*n* = 148/1518	-Increasing ISS -Increasing transfusions -Combined S + colon injuries -Combined colon + S injuries -Combined S + colon + SB injuries -Concomitant pancreatic or liver injury
Tatebe 2017 [11]	*n* = 267/SB 49%; mesentery 47%; liver 21%; MAV 19%; kidney 15%; stomach 12%; pancreas 11%; bladder 3%	*n* = 51/267	-Amount of colloid fluid in the first 24 h

IAI intra-abdominal infection, *SB* small bowel, *MAV* major abdominal vessel, *S* stomach, *NR* not reported, *ATI* Abdominal Trauma Index, *ICU* intensive care unit

data from the AAST open abdomen registry to identify patients who developed abdominal complications, specifically enterocutenous fistula, enteroatmospheric fistula or intra-abdominal sepsis/abscess, with the aim of determining their independent predictors. They found that large bowel resection, increasing fluid intake at 48 h after surgery, and increasing number of re-explorations were independent predictors of abdominal complications.

Although studies discussed earlier highlighted significant risk factors for complications, these studies classified various conditions (fistulas, anastomotic leak, abscess, fascial dehiscence, colon obstruction) as abdominal complications. In contrast, some studies have tried, specifically, to elucidate risk factors/predictors for intra-abdominal infections after abdominal trauma.

Morales et al. [8] conducted a prospective cohort study where the primary outcome variable was intra-abdominal infection. Multivariate analysis found that ATI score greater than 24, presence of abdominal contamination, and admission to the intensive care unit were independently associated with the development of intra-abdominal infection after abdominal trauma. Bulger et al. [7] performed a retrospective 10-year

review of penetrating colon injuries with the objective of define risk factors associated with morbidity after penetrating colon trauma. They included 181 patients, of which 51 developed an intra-abdominal abscess. After adjusting for confounders, they found hypotension on admission and a Penetrating Abdominal Trauma Index (PATI) score > 25 as independent risk factors for the development of an intra-abdominal abscess. Another study on penetrating injuries to the colon conducted by Ivatury et al. [5] showed that PATI and the presence of colostomy were independent risk factors for abdominal abscess formation.

In general, therefore, it seems that increasing injury scores, hemodynamic instability, and the presence and severity of abdominal contamination should alert the trauma surgeon that there is an increased risk of intra-abdominal infection. However, some other factors such as combined hollow viscus injuries [10•], concomitant hepatic [4] or pancreatic injuries, and the presence of ingested projectiles [3, 12] should be taken into account.

The Role of Missed Injuries

Injuries missed during the initial assessment or surgery lead to increased morbidity and mortality. Previous studies have shown that hollow viscera are the most commonly involved organs in missed injuries [13, 14]. As hollow viscera have a high bacterial load, it is not irrational to think that missed injuries to these organs may increase the risk of intra-abdominal sepsis.

In 1988, Scalea et al. [15] published a paper in which they described 12 patients that required re-operation for missed injuries at the initial surgical approach. They found that patients with undiagnosed small bowel and pancreatic injuries developed clinical signs of sepsis and concluded that patients presenting with clinical sepsis or early multiple organ failure after initial operation should undergo prompt abdominal re-exploration to detect these injuries. Moreover, Sung et al. [14] described the morbidity associated with missed injuries in abdominal trauma and found that sepsis occurred in 42% of the patients with injuries lost during the initial operation.

Surgical Approach of Choice for Penetrating Colon Injuries During Damage Control Laparotomy

As colonic wounds represent one of the most important factors contributing to the development of abdominal sepsis after trauma, it is, therefore, important to discuss best surgical approach in these patients.

Experience learned during World War II led to the axiom of mandatory proximal diversion of all colonic wounds. However, a randomized controlled trial, conducted in 1979 by Stone and Fabian [16], thoughtfully placed in question the dogma that "routine colostomy must be performed for all colonic injuries." In this trial, fewer complications developed in the group of primary repair compared to the colostomy group.

In the decades following that first clinical trial, more articles were published supporting primary repair and thus, a favorable attitude toward performing this technique was seen among surgeons. Therefore, the practice of primary repair of non-destructive colonic injuries in physiologically stable civilian patients with minimal fecal contamination was adopted. Furthermore, a meta-analysis [17] of randomized controlled trials comparing the outcomes of primary repair versus fecal diversion in the management of penetrating colon injuries found that the primary repair group experienced a significantly lower rate of total complications, infectious complications, and wound-related complications. The authors concluded that primary repair was superior to fecal diversion in the management of penetrating colon injuries.

Although primary repair became the standard of practice for minor or moderately severe penetrating colon injuries, the optimal management of severe destructive colon injuries requiring resection remained controversial. Therefore, in 2001, Demetriades et al. [6] demonstrated that in patients with destructive colon injuries requiring resection, the method of colon management (primary anastomosis or diversion) did not influenced the occurrence of abdominal complications and thus, recommended to perform primary anastomosis in patients with this kind of injuries. Ordonez et al. [18] showed the feasibility of delayed anastomosis for destructive colon injuries during damage control laparotomy, leaving colostomy only for those presenting with recurrent intra-abdominal abscesses, severe bowel wall edema and inflammation, or persistent metabolic acidosis. Moreover, data from a recent multicenter study [11] showed that damage control laparotomy with delayed anastomosis was not associated with increased rates of intra-abdominal abscess and other abdominal complications and that the odds ratio for surgical complications in patients undergoing damage control laparotomy and delayed repair was also not significant.

In summary, resection with primary anastomosis, or damage control laparotomy with delayed anastomosis, is a feasible option to be performed in patients with penetrating destructive colon injuries. These techniques do not seem to be associated with an increased risk of intra-abdominal infections and other complications compared to fecal diversion. However, evidence synthesized here cannot replace the surgeon's clinical judgment at the moment of choosing the appropriate surgical approach.

Physical Examination Findings

The diagnosis of peritonitis is a clinical diagnosis, based mostly on history and physical examination [19]. Early recognition is of paramount importance to minimize the odds of poor outcomes. Abdominal pain, fever, tachycardia, persistent ileus, and/or leukocytosis suggest the presence of an intra-abdominal infection in patients with predisposing conditions, such as primary intra-abdominal disease or abdominal surgery.

Sartelli et al. [2••] analyzed the data from 1898 patients with complicated intra-abdominal infections and found that the most common clinical findings on admission were as follows: (1) abdominal pain, abdominal rigidity, and WBC > 12,000 or <4000 in 19.8% of patients; (2) abdominal pain, abdominal rigidity, $T > 38$ or <36 °C, and WBC > 12,000 or <4000 in 16.5% of patients; (3) only abdominal pain in 15% of patients; and (4) abdominal pain, and WBC >12,000 or <4000 in 14% of patients.

Although the main symptom in all cases is abdominal pain, the presence of a deep abscess may hide this symptom and thus, other symptoms such as tachycardia, persistent fever, progressive multi-organ dysfunction, and ileus should guide the diagnosis.

Diagnosis

The diagnosis of intra-abdominal infections is primarily clinical. However, it should always be guided by imaging studies.

Bedside Ultrasound

Patients with severe trauma who develop intra-abdominal infections are commonly in a critical condition. As some of these patients are unable to be taken out of the intensive care unit to the tomography room, it is desirable to make diagnostic interventions as safe and efficient as possible. Bedside ultrasound is a rational approach to be performed in post-trauma critically ill patients as it is readily available, portable, and inexpensive. In experienced hands, it could achieve an exceptional diagnostic performance with an accuracy rate greater than 90% for diagnosing intra-abdominal abscesses [20, 21]. Furthermore, data from one study performed in patients with peritonitis secondary to non-traumatic causes showed that the sensitivity of ultrasound was superior to that of surgeon's clinical judgment alone for the diagnosis of peritonitis causes [22].

Despite the proved benefits of ultrasound, it has several disadvantages. Firstly, its performance is operator-dependent. Secondly, it could be a futile procedure in the diagnosis of deep abdominal infections. Thirdly, intervening open abdomen and surgical dressings (both common in trauma patients) can create problems with image definition and thus, errors in diagnosis [21].

Computed Tomography

Previous research has established that in adult patients not undergoing immediate laparotomy, computed tomography scan is the imaging modality of choice to determine the presence of an intra-abdominal infection and its source [23••, 24]. Go et al. [25] showed that abdominal computed tomography was superior to ultrasound in the diagnosis of intra-abdominal non-trauma infections and concluded that ultrasound should not be performed as the initial diagnostic test. Velmahos et al. [26] conducted a prospective study to evaluate the value of computed tomography in the evaluation of sepsis of unknown origin after trauma. In this study, abdominal computed tomography was 97% sensitive and 61% specific for the diagnosis of IAIs after major trauma. Moreover, predictors of an abnormal computed tomography result were the presence of penetrating injury and emergent laparotomy.

In our experience, computed tomography must be carried out whenever possible and without any delay. An abnormal abdominal computed tomography allows the surgeon to perform a "CT-guided laparotomy," a fact that may improve source control. Ultrasound should be reserved for those critically ill patients unable to go out of the ICU for further studies. However, a negative ultrasound result should not rule out the diagnosis of an IAI, and thus, in patients unable to go out of the ICU but with highly clinical suspicion, an exploratory laparotomy should be considered.

Treatment

Importance of Source Control

Early diagnosis coupled with prompt source control is of paramount importance for improving outcomes among patients with post-traumatic IAIs. A recent position paper on abdominal sepsis [27] published by the World Society of Emergency Surgery (WSES) explicitly recommends: "*The timing and adequacy of source control are of outmost importance in the management of intra-abdominal sepsis, as late and/or incomplete procedures may have severely adverse consequences on outcome*".

Source control involves all the interventions aimed to eradicate the source of infection. It can be achieved by open laparotomy, percutaneous drainage, and non-operative techniques. However, as a large proportion of patients with post-traumatic intra-abdominal sepsis have concomitant progressive multi-organ failure, are physiologically exhausted and thus, are in a critically ill state, it is possible that in the setting

of post-traumatic abdominal sepsis, percutaneous drainage and non-operative techniques have a limited scope as source control methods. Therefore, in patients with a diagnosed post-traumatic intra-abdominal infection, using CT scan or ultrasound or in those with highly clinical suspicion, an exploratory laparotomy is mandatory. During the procedure, three objectives must be achieved: (1) determining the cause of peritonitis, (2) draining fluid collections, and (3) controlling the origin of the abdominal wound [27].

Our Approach to Source Control in Patients with Post-traumatic Intra-abdominal Infections

Deciding to complete a definitive bowel repair at an index laparotomy or to perform a damage control laparotomy in a critically ill patient with post-traumatic IAI is by all means complex. Traditionally, surgeons have performed procedures involving anastomosis or diversion at index laparotomy. However, we consider that the most rational surgical approach in these patients is to perform damage control surgery with a deferred reconstruction strategy.

For the procedure, we proceed with source control with drainage/lavage of the peritoneal cavity, debridement or resection of infected/necrotic tissue, segmental bowel resection leaving the ends in discontinuity, and temporary closure of the abdomen. When hemodynamic stability and bowel viability are achieved, a deferred anastomosis (DA) or delayed ostomy (DO) is carried out during a subsequent re-laparotomy. Using this "deferred reconstruction strategy," we have seen a decrease in the rate of ostomies performed in these patients.

Re-laparotomy, Open Abdomen?

For many years, there has been much controversy on the most appropriate re-laparotomy strategy in critically ill patients with intra-abdominal infections. Thus far, previous studies have indicated that on-demand re-laparotomy is associated with improved outcomes among patients with severe peritonitis, compared with planned re-laparotomy [28, 29]. Furthermore, the WSES guidelines on the management of intra-abdominal infections [23••] recommend on-demand re-laparotomy for patients with severe peritonitis. On the other hand, the same guideline [23••] highlights the benefits of temporary abdominal closure techniques which include ease of subsequent exploration, control of abdominal contents, reduced risk of intra-abdominal hypertension and abdominal compartment syndrome, and fascial preservation to ensure proper closure of the abdominal wall.

Although on-demand re-laparotomy or open abdomen seems to be better alternatives to critically ill patients with intra-abdominal infections, the decision to choose one strategy (open abdomen or re-laparotomy on demand) relies heavily on the surgeon experience. The key outcomes that should be taken into account at the moment of choosing one strategy over others are exudate reduction, early fascial closure, length of hospital stay, lower mortality, improvement in patient quality of life, and lower rate of secondary procedures to reconstruct the abdominal wall.

In our experience, patients with post-traumatic intra-abdominal infections and experiencing physiological exhaustion and/or progressive multi-organ dysfunction should be managed following negative pressure wound therapy (NPWT) principles.

Several reports have shown the benefits of NPWT in the management of open abdomen [30, 31]. For example, Cirocchi et al. [30] conducted a meta-analysis with the objective of compare NPWT and non-NPWT techniques in the management of open abdomen. They found that NPWT resulted in lower 30-day mortality rate, lower rates of fistula and abscess formation, and lower length of ICU stay. In a prospective comparative study, Cheatham et al. [32] compared the vacuum packing technique and the ABThera system for the management of open abdomen in surgical or trauma patients. They found that the ABThera system was associated with a better 30-day primary fascial closure and that patients treated with the ABThera system were significantly more likely to survive than those treated with the vacuum packing technique. More recently, Kirkpatrick et al. [33] conducted a randomized controlled trial to determine the efficacy of the ABThera system in reducing systemic inflammation compared to the Barkers vacuum pack. In this trial, there was no difference in the plasma concentration of pro-inflammatory cytokines between the groups. However, the ABThera group had a significantly lower 90-day mortality rate.

Surgical Management of Retroperitoneal Abscess After Damage Control Laparotomy or Surgical Repair of Traumatic Duodenal Injuries

The surgical options for the management of traumatic duodenal injuries are out of the scope of this review. However, it is worth mentioning the techniques available to the trauma surgeon for the management of postoperative duodenal complications, such as a retroperitoneal abscess. Case reports and small case series have shown the utility of retroperitoneal laparostomy in patients with a retroperitoneal abscess. Fang et al. [34] performed a retrospective case series of 52 patients with blunt duodenal injuries, of which 11 developed retroperitoneal abscesses. Six of these patients were managed using a retroperitoneal laparostomy. Good outcomes were achieved with the approach used, and only two patients developed an incisional hernia. Ordonez et al. [35] also showed the utility of retroperitoneal laparostomy in patients with postoperative complications after complex, penetrating duodenal injuries. They concluded that retroperitoneal laparostomy is an

effective means of treating a duodenal leak and associated extensive retroperitoneal abscess.

The rationality behind retroperitoneal laparostomy is that it allows for re-exploration and drainage of necrotic tissue from the duodenum without the risk of intraperitoneal cross-contamination. Added to that, it offers the advantage of the inherent natural tendency of a duodenal fistula to drain toward the back following the gravitational pull instead of requiring an antigravity-directed flow via a temporary abdominal closure device [35].

Antibiotic Therapy

The Role of Prophylactic Antibiotics

Patients with penetrating abdominal trauma, especially those physiologically exhausted and with hollow viscus injuries, carry a higher risk for intra-abdominal infections. However, questions related to whether prophylactic antibiotics add any advantage in the management of patients with penetrating abdominal trauma remain unanswered.

A 2013 Cochrane Review [36] conducted with the objective of assessing the benefits and harms of prophylactic antibiotics after penetrating abdominal trauma was unable to give any recommendation on the subject. The authors concluded that no evidence existed at that time upon which to base the use of prophylactic antibiotics in patients with penetrating abdominal injury. On the other hand, the Eastern Association for the Surgery of Trauma published a guideline on the use of prophylactic antibiotics after penetrating abdominal trauma [37]. They concluded that in patients presenting with associated hollow viscus injuries, a course of prophylactic antimicrobials of no more than 24 h could be given to prevent septic abdominal complications.

We recommend that in the context of penetrating abdominal trauma, prophylactic antibiotics be used at surgeon discretion. Some variables such as the severity of trauma, the presence of hollow viscus injury, and the degree of contamination and physiologic exhaustion should encourage the utilization of a short course of prophylactic antibiotic therapy after index laparotomy, especially when abdominal damage control techniques are performed. However, further study is required prior to widely adopting this approach.

Anti-infective Therapy for Post-traumatic Intra-abdominal Infections

The correct antimicrobial therapy for the treatment of post-traumatic intra-abdominal infections remains controversial. Early administration of broad-spectrum antibiotics in combination with rapid and practical source control is of paramount importance in the successful management of the post-traumatic septic patient. Surviving sepsis campaign guidelines [38] recommend administration of broad-spectrum antimicrobials for all possible pathogens within 1 h after sepsis recognition, obtaining of early anatomic source control, and daily evaluation of patients for antimicrobials de-escalation.

It is important to know exactly when the infection started to initiate the adequate antimicrobial therapy. Peritonitis that debuts after 48 h is highly likely to be nosocomial and thus, an inadequate antimicrobial therapy selection may be associated with worse outcomes [39]. (Please refer to the "*2013 WSES guidelines for management of intra-abdominal infections Appendixes 1*, *2*, *3*, *4*, *5*, *6*, *7*, *8*, *9*, *and 10*" for a better understanding of the most rational antimicrobial therapy in different scenarios [23••]).

Conclusions

The literature has revealed some predictors of intra-abdominal infections after abdominal trauma. Most of these predictors can be recognized early in the clinical evaluation and during the surgical procedure and may aid the trauma surgeon in his/her decision to initiate a short course of prophylactic antibiotics. If predictors are present, then the surgeon must be aware of the increased risk of intra-abdominal infection. The diagnosis of these infections is mainly clinical. However, it always must be guided by radiological aids such as bedside ultrasound and computed tomography. Computed tomography is superior to ultrasound in the diagnosis of intra-abdominal infections; it should be performed whenever possible and without any delay. Bedside ultrasound is reserved for critically ill patients who are unable to go out of the ICU for further studies. Once an intra-abdominal infection is diagnosed, prompt and efficient source control and antibiotic therapy are of paramount importance to improve patient outcomes. If the abdomen is left open, then it is recommendable to apply negative pressure wound therapy as the temporary abdominal closure technique of choice.

Being limited to a literature review, we were unable to find studies on the correct antimicrobial therapy specifically for post-traumatic intra-abdominal infections. Therefore, further studies should focus on determining the appropriate anti-infective therapy in these patients. Moreover, more research is needed to better understand the correct indications and effects of prophylactic antibiotics after abdominal trauma.

Compliance with Ethical Standards

Conflict of Interest Drs. Ordoñez and Manzano declare no conflicts of interest relevant to this manuscript.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. Vincent J, Rello J, Marshall J, et al. International study of the prevalence and outcomes of infection in intensive care units. JAMA. 2009;302:2323–9.
2.•• Sartelli M, Catena F, Ansaloni L, et al. Complicated intra-abdominal infections worldwide: the definitive data of the CIAOW study. World J Emerg Surg. 2014;9:37. **A multicenter observational study in 68 medical institutions worldwide during a 6-month study period (October 2012–March 2013) describing the clinical, microbiological, and treatment profiles of both community- and healthcare-acquired complicated IAIs in a global context**.
3. Poret HA III, Fabian TC, Croce MA, Kudsk KA. Analysis of septic morbidity following gunshot wounds to the colon: the missile is an adjuvant for abscess. J Trauma Acute Care Surg. 1991; 31.
4. Fabian TC, Croce MA, Stanford GG, Payne LW, Mangiante EC, Voeller GR, Kudsk KA. Factors affecting morbidity following hepatic trauma. A prospective analysis of 482 injuries. Ann Surg. 1991;213:540–8.
5. Ivatury RR, Gaudino J, Nallathambi MN, Simon RJ, Kazigo ZJ, Stahl WM. Definitive treatment of colon injuries: a prospective study. Am Surg. 1993;59:43–9.
6. Demetriades D, Murray JA, Chan L, et al. Penetrating colon injuries requiring resection: diversion or primary anastomosis? An AAST prospective multicenter study. J Trauma. 2001;50:765–75.
7. Bulger EM, McMahon K, Jurkovich GJ. The morbidity of penetrating colon injury. Injury. 2003;34:41–6.
8. Morales CH, Villegas MI, Villavicencio R, et al. Intra-abdominal infection in patients with abdominal trauma. Arch Surg. 2004;139:1278–85.
9.• Bradley MJ, Dubose JJ, Scalea TM, et al. Independent predictors of enteric fistula and abdominal sepsis after damage control laparotomy: results from the prospective AAST open abdomen registry. JAMA Surg. 2013;148:947–55. **This study provides an overview of predictors of complications (including intra-abdominal sepsis) after damage control laparotomy for trauma**.
10.• Paulus EM, Croce MA, Shanan CP, Zarzaur BL, Sharpe JP, Dileepan A, Boyd BS, Fabian TC. Synergistic effect of combined hollow viscus injuries on intra-abdominal abscess formation. Am Surg. 2015;81:674–8. **This study highlights the effect of combined hollow viscus injuries in the development of intra-abdominal infections**.
11. Tatebe LC, Jennings A, Tatebe K, et al. Traumatic colon injury in damage control laparotomy—a multicenter trial: is it safe to do a delayed anastomosis? J Trauma Acute Care Surg. 2017; 82.
12. Sarmiento JM, Yugueros P, Garcia AF, Wolff BG. Bullets and their role in sepsis after colon wounds. World J Surg. 21:648–52.
13. Ugur M, Akkucuk S, Koca YS, Oruc C, Aydogan A. Missed injuries in patients with abdominal gunshot trauma: risk factors and mortality rates. Eur Surg. 2016;48:347–51.
14. Sung CK, Kim KH. Missed injuries in abdominal trauma. J Trauma. 1996;41:276–82.
15. Scalea TM, Phillips TF, Goldstein AS, Sclafani SJ, Duncan AO, Atweh NA, Shaftan GW. Injuries missed at operation: nemesis of the trauma surgeon. J Trauma. 1988;28:962–7.
16. Stone HH, Fabian TC. Management of perforating colon trauma: randomization between primary closure and exteriorization. Ann Surg. 1979;190:430–6.
17. Nelson RL, Singer M. Primary repair for penetrating colon injuries. In: Nelson RL, editor. Cochrane Database Syst. Chichester: Rev. John Wiley & Sons Ltd; 2003. p. CD002247.
18. Ordonez CA, Pino LF, Badiel M, Sanchez AI, Loaiza J, Ballestas L, Puyana JC. Safety of performing a delayed anastomosis during damage control laparotomy in patients with destructive colon injuries. J Trauma. 2011;71:1512–8.
19. Ordoñez CA, Puyana JC. Management of peritonitis in the critically ill patient. Surg Clin North Am. 2006;86:1323–49.
20. Chen S-C, Wang H-P, Chen W-J, Lin F-Y, Hsu C-Y, Chang K-J, Chen W-J. Selective use of ultrasonography for the detection of pneumoperitoneum. Acad Emerg Med. 2002;9:643–5.
21. Saber AA, LaRaja RD. Abdominal Abscess Workup. In: MEDSCAPE. 2016. http://emedicine.medscape.com/article/1979032-workup#c11.
22. Chen S, Lin F, Hsieh Y, Chen W. Accuracy of ultrasonography in the diagnosis of peritonitis compared with the clinical impression of the surgeon. Arch Surg. 2000;135:170–4.
23.•• Sartelli M, Viale P, Catena F, et al. 2013 WSES guidelines for management of intra-abdominal infections. World J Emerg Surg. 2013;8:3. **These are current guidelines on the management of intra-abdominal infections**.
24. Solomkin JS, Mazuski JE, Bradley JS, et al. Diagnosis and management of complicated intra-abdominal infection in adults and children: guidelines by the Surgical Infection Society and the Infectious Diseases Society of America. Clin Infect Dis. 2010;50:133–64.
25. Go HLS, Baarslag HJ, Vermeulen H, Laméris JS, Legemate DA. A comparative study to validate the use of ultrasonography and computed tomography in patients with post-operative intra-abdominal sepsis. Eur J Radiol. 2017;54:383–7.
26. Velmahos GC, Kamel E, Berne TV, et al. Abdominal computed tomography for the diagnosis of intra-abdominal sepsis in critically injured patients: fishing in murky waters. Arch Surg. 1999;134:831–8.
27. Sartelli M, Catena F, Di Saverio S, et al. Current concept of abdominal sepsis: WSES position paper. World J Emerg Surg. 2014;9:22.
28. Hau T, Ohmann C, Wolmershäuser A, Wacha H, Yang Q. Planned relaparotomy vs relaparotomy on demand in the treatment of intra-abdominal infections. Arch Surg. 1995;130:1193–7.
29. van Ruler O, Mahler CW, Boer KR, et al. Comparison of on-demand vs planned relaparotomy strategy in patients with severe peritonitis: a randomized trial. JAMA. 2007;298:865–72.
30. Cirocchi R, Birindelli A, Biffl WL, Mutafchiyski V, Popivanov G, Chiara O, et al. What is the effectiveness of the negative pressure wound therapy (NPWT) in patients treated with open abdomen technique? A systematic review and meta-analysis. J Trauma Acute Care Surg. 2016;81.
31. Roberts DJ, Zygun DA, Grendar J, Ball CG, Robertson HL, Ouellet J-F, et al. Negative-pressure wound therapy for critically ill adults with open abdominal wounds: a systematic review. J Trauma Acute Care Surg. 2012;73.
32. Cheatham ML, Demetriades D, Fabian TC, Kaplan MJ, Miles WS, Schreiber MA, Holcomb JB, Bochicchio G, Sarani B, Rotondo MF. Prospective study examining clinical outcomes associated with a negative pressure wound therapy system and Barker's vacuum packing technique. World J Surg. 2013;37:2018–30.
33. Kirkpatrick AW, Roberts DJ, Faris PD, et al. Active negative pressure peritoneal therapy after abbreviated laparotomy: the intraperitoneal vacuum randomized controlled trial. Ann Surg. 2015;262:38–46.
34. Fang J-F, Chen R-J, Lin B-C, Hsu Y-B, Kao J-L, Kao Y-C, et al. Retroperitoneal laparostomy: an effective treatment of extensive intractable retroperitoneal abscess after blunt duodenal trauma. J Trauma Acute Care Surg. 1999;46.

35. Ordoñez C, García A, Parra MW, et al. Complex penetrating duodenal injuries: less is better. J Trauma Acute Care Surg. 2014;76.
36. Brand M, Grieve A. Prophylactic antibiotics for penetrating abdominal trauma. Cochrane Database Syst Rev. 2013; doi:10.1002/14651858.CD007370.pub3.
37. Goldberg SR, Anand RJ, Como JJ, Dechert T, Dente C, Luchette FA, et al.. Prophylactic antibiotic use in penetrating abdominal trauma: an Eastern Association for the Surgery of Trauma practice management guideline. J Trauma Acute Care Surg. 2012;73.
38. Howell MD, Davis AM. Management of sepsis and septic shock. JAMA. 2017;317:847–8.
39. Montravers P, Gauzit R, Muller C, Marmuse JP, Fichelle A, Desmonts JM. Emergence of antibiotic-resistant bacteria in cases of peritonitis after intraabdominal surgery affects the efficacy of empirical antimicrobial therapy. Clin Infect Dis. 1996;23:486–94.