Source control in intra-abdominal infections: What you need to know

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ABSTRACT: Providing optimal source control (SC) for intra-abdominal sepsis (IAS) is a critically important surgical principle, yet one that remains nebulous in terms of strict definitions and required conduct. The entire concept of SC has evolved in the last decades. Contemporary SC is not only surgical but also embraces minimally invasive percutaneous and medical therapies. We propose that adequate SC has evolved from the mere anatomical control of enteric leakage, cleansing of obvious contaminants and necrosis, to a more comprehensive anatomo-phyiological-biochemical model. While any breaches in the integrity of the gastrointestinal tract should be addressed urgently, SC should ultimately aim to control the generation and propagation of systemic biomediators, bacterial toxins, and toxic catabolites that perpetuate multisystem organ failure and death. Much urgently needs to be learned to understand and hopefully mitigate the dysbiotic influences of IAS on the human microbiome. Finally, the therapy offered should always be individualized, recognizing patient's unique pathophysiology, clinical condition, comorbidities, and predeclared preferences regarding invasive therapies and life-support. (*J Trauma Acute Care Surg.* 2025;00: 00–00. Copyright © 2025 Wolters Kluwer Health, Inc. All rights reserved.)

KEY WORDS: Source control; emergency; infections; abdominal; surgery; trauma; mortality; antibiotic; stewardship, human microbiome.

Intra-abdominal infections (IAIs) represent an ever-increasing global disease burden. Intra-abdominal infections range in severity from self-limiting infections amenable to nonsurgical management, to severe sepsis or septic shock with high morbidity and mortality requiring urgent surgery.[1] Thus, the appropriate therapy for an IAI may range from noninvasive antibiotic therapy only, to minimally invasive approaches, or ultimately to open surgical techniques involving permanent anatomic changes.[2] It is critical to recognize that typically it is not the actual IAI that kills the patient, but the patient's own metabolic efforts to combat the IAI with the release of inflammatory mediators that drive progressive organ failure, which is ultimately lethal.

Sepsis of intra-abdominal origin is the second most common cause of severe surgical infectious emergencies[3] with millions of related deaths/year worldwide.[4] The Global WISS study noted a 41% mortality rate in patients with IAIs,[5,6] and in developing countries, mortality rates may be 80% when septic shock accompanies IAS.[7] Multiresistant bacteria unfortunately will contribute to increase these numbers. Intra-abdominal infections are clinically linked to classifications of peritonitis, recognizing that peritonitis is a clinical phenomenon typically produced by inflammation of peritoneum due to the occurrence of IAI.[8] Most cases of severe IAS relate to secondary peritonitis, wherein due to gut dysfunction or damage, bacteria and enteric contents may pass outside the gut and cause IAIs that may progress up to severe intra-abdominal sepsis (IAS) and septic shock.

Sepsis is not a specific illness but rather a syndrome defined by the pathophysiological response to infection associated with many inciting conditions, such as bacterial pneumonia, meningitis, severe COVID, necrotizing soft tissue infections, in addition to severe IAS. Pathophysiologically, sepsis related to intra-abdominal infections presents unique challenges not encountered in most other manifestations of sepsis.[9] There will often be secondary inflammation necessitated by the inflammatory response to invasive surgery if surgery is required.[9] Further, the abdominal cavity presents unique and complex problems related to both the human microbiome and compartment physiology. Unlike other forms of sepsis, IAS likely directly impacts the home of most of the human microbiome and often induces both directly and indirectly intra-abdominal hypertension which equates to intra-abdominal ischemia. Thus, there will be potentially profound implications for IAS to further affect distant organs with systemic inflammation which will be mentioned later and further elaborated on in excellent reviews in the "What you need to know series."[10]

WHAT IS SOURCE CONTROL?

Adding to the complexity of providing comprehensive therapy for IAS, which is more demanding than most other types of infections, is the frequent need for additional more invasive and complex therapies beyond antimicrobial treatment. While extra-abdominal infections may often be successfully treated with antibiotic therapy alone, severe IAS typically requires source control in addition to systemic antibiotics. Source control (SC) is considered an essential element in IAI management

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TABLE 1. Patient Stratification

Patient Stratification	
Class A	Healthy patients with no or well-controlled comorbidities and no immunocompromise, where the infection is the main problem.
Class B	Patient with major comorbidities and/or moderate immunocompromise but currently clinically stable, in whom the infection can rapidly worsen the prognosis.
Class C	Patients with important comorbidities in advanced stages and/or severe immunocompromise, in which the infection worsens an already severe clinical condition.

although, as will be discussed, it can be hard to define and be open to individual interpretation. However, even without a definitive consensus as to what it is, delay in providing it has been associated with adverse outcomes including death in IAS.[11–14] This is illustrated in contemporary reviews of the importance of SC, which do not define or describe what actually constitutes adequate SC despite commenting on its necessity.[11,12] One exception was Reitz and colleagues who considered source control procedures to be identified using Current Procedure Terminology (CPT) codes including up to six source control procedures, but without any quantification or analysis of the quality of such procedures.[13] Another notable forward-thinking review article from Marshall and colleagues defined SC as a term that “encompasses all those physical measures that can be used to control a focus of infection and to modify factors in the infectious milieu that promote microbial growth or impair host antimicrobial defenses.”[14] They further described the components of SC as consisting of the drainage of infected fluids, debridement of infected soft tissues, removal of infected devices or foreign bodies, and finally, definite measures to correct anatomic derangement resulting in ongoing microbial contamination and to restore optimal function.[14] The optimal provision of source control must also consider patients' condition, comorbidities, present and previous therapies combined to the source of infections and the timing of presentation. However, despite accepted by all as necessary, the current definition and practical application of SC are still debatable. Many studies use the term “appropriate or adequate source control” in association with a patient’s clinical improvement or to justify duration of antibiotic therapy. However, without a universally agree upon and unequivocal definition of general and above all of SC adequacy, such guidelines and indications are functionally impossible to apply without bias or confusion. Thus, the timing, involved strategies, the adequacy, and the ultimate results of SC may vary between patients and different clinical scenarios.

Therefore, given the extreme importance of providing timely and appropriate SC in critically ill patients with IAS, the aim of the present article is to comment and propose a contemporary definition of SC, in order to facilitate future studies to assess its adequacy and appropriateness in different surgical abdominal conditions. To justify this, we will outline the conceptual evolution that accompanies a broader understanding of both the pathobiology of sepsis and advances in source control technologies and techniques that are adjunctive to open surgery.

THE EVOLUTION OF THE SOURCE CONTROL CONCEPT

Anatomical and Physiological Source Control

The authors consider *SC as the complete set of all physiological/pharmacological/interventional measures adopted to control a focus of infection, to modify factors in the infectious milieu promoting microbial growth or impair host antimicrobial defenses, and to allow the host to restore homeostasis or achieve a physiological steady state commensurate with healing* (Table 1).[2,15,16] Thus, SC can no longer be simply defined as only being an anatomical procedure (Fig. 1).

We also propose that there be differentiation in the details of SC as to:

-**Anatomical source control** as the ensemble of all the invasive and/or minimally-invasive approaches focused on removing the gross source of infection. This can be considered as adequate whenever no macroscopical residuals of bacterial infection, fecal contamination, or necrosis are present.
-**Physiological source control** as the removal or attempted removal of all resultant products of the infection (i.e., bacteria, toxins, catabolites, inflammatory mediators, pathogen-associated molecular patterns, and damage-associated molecular patterns) propagating physiological and metabolic derangements. The definition of adequate SC is thus complex and requires managing a balance of factors including clinical, physiological, metabolic, and laboratory.

Therefore, the need to consider a comprehensive approach to physiologic SC warrants a multidisciplinary approach that considers all the potential procedures and options, that effectively expands SC from being only the only surgeon’s responsibility, to a concept that tasks all disciplines providing critical care in IAI. Thus, the “source control team” involves the collaboration of not only surgeons, anesthesiologists, intensivists, emergency physicians, infectious disease specialists but also potentially rheumatologists, hematologists, oncologists, and solid organ transplant teams, although it should remain surgeon led.

The Definition of Adequate SC

The adequacy of SC encompasses fundamental aspects, such as the elimination of gross contamination, resolution of the source of infection, administering adequate and effective but not excessive or overly prolonged antibiotic therapy, and

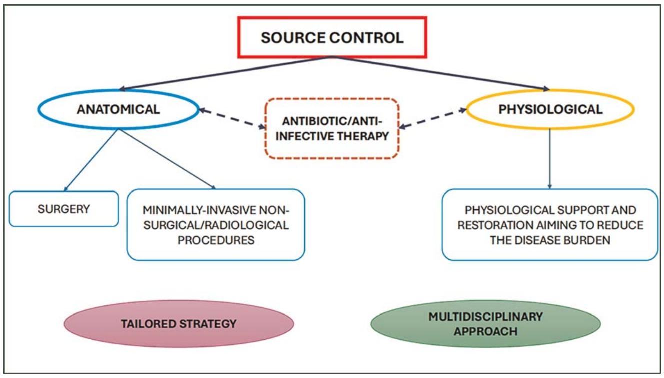

Figure 1. Source control key components.

TABLE 2. Clinical Classification of Patients With Immune Deficiency or High Risk

Mild–moderate immune deficiency
Elderly (according to the age and general status of the patient)
Malnourished
Diabetic
Burns
Trauma
Uremic
Active malignancy, not on chemotherapy
HIV with CD4+ count >200/mm^3
Splenectomized
Severe immune deficiency
AIDS
HIV with CD4+ count <200/mm^3
Transplant (solid organ, bone marrow)
High-dose steroids (more than 20 mg/day prednisone)
Malignancy on chemotherapy
Neutrophil count <1,000/mm^3
High-risk population (medical or surgical causes)
Low serum albumin concentration
Older age
Obesity
Smoking
Diabetes mellitus
Ischemia secondary to vascular disease or irradiation
Prolonged or delayed/late procedures

restoring the patient's physiology, by supporting vital functions and eliminating the circulating mediators and toxins.[2,17] The availability of technical expertise and infrastructure at the local institution may deeply influence the adequacy definition, raising questions regarding centers of excellence in IAI management that are beyond the scope of this article. It needs to be stressed, however, how a hub and spoke system of referral and excellence should be considered for severely sick patients affected by IAIs who require extensive resources.

Personalized Source Control: Patient Stratification

Adequate and appropriate SC may offer an opportunity to practice personalized medicine, wherein each patient receives SC that is tailored to them specifically and thus individualized.[9,18] Therefore, personalized SC should be planned according to a multitude of consideration including but not limited to; disease severity, the source of infection, the general physiological condition of the patient appreciating comorbidities and risk factors, and especially any predeclared wishes of the patient.[2] Thus, the surgeon-led multi-disciplinary team should always evaluate and balance the disease burden, the SC induced physiological derangements and the potential risk/benefits for the patient.[19] As previously described, as comprehensive SC is a broader topic that just a surgical operation, every patient should be approached considering a multidisciplinary approach even if after consideration, a less complex treatment plan is considered appropriate. In most cases the surgeon is the team leader and ultimate decision maker, having the most experience, especially if they are co-credentialed as surgeons and intensivists (surgical intensivists). The hope is that with improved care, the final team member will be a rehabilitation medicine specialist to finally complement the team after successful rescue of patients who would have previously succumbed to such illness but thus are greatly deconditioned in the course of their now survivable illness.

Given the complexity of the wide range of individual patient physiology and disease severity, patients should be stratified to appropriately guide the diagnostic measures required and thereafter the appropriate therapeutic pathways and relevant timing of such.

Functionally, patients can thus be categorized into three classes each class which can be sub-stratified as to whether the patient is hemodynamically stable with septic shock or not (Table 1)[2]: Critically ill patients with septic shock represent the sickest subset of septic patients in whom the underlying

TABLE 3. Acute Cholecystitis Management

Acute Cholecystitis				
Patients	Cholecystitis	Surgery	Operative Source control	Antibiotic therapy
Class A	Uncomplicated Complicated	Urgent	Cholecystectomy	No Short course
Class B	Uncomplicated Complicated	Urgent	Cholecystectomy	No Short course
Class C	Uncomplicated Complicated	Emergent/Urgent	Cholecystectomy ± Physiological function restoring therapies - Cholecystostomy*	Yes
Critically ill	-	Emergent/Urgent	Damage control ± Physiological function restoring therapies	Yes

(* Patients With Major Comorbidities Unfit for Surgery and With Stable Hemodynamic Condition May Be Managed With Percutaneous Image-Guided Drainage) (With Permission From: Source Control in Emergency General Surgery: WSES, GAIS, SIS-E, SIS-A Guidelines. Coccolini F, et al. World J Emerg Surg. 2023 Jul 21;18(1):41)[2]

TABLE 4. Acute Appendicitis Management

Acute Appendicitis				
Patients	Appendicitis	Surgery	Source control	
			Operative	Antibiotic therapy
Class A	Uncomplicated	Urgent	Appendicectomy	No
	Complicated			Short course
Class B	Uncomplicated	Urgent	Appendicectomy	No
	Complicated			Short course
Class C	Uncomplicated	Emergent/Urgent	Appendicectomy	Yes
	Complicated	Emergent/Urgent	Appendicectomy ± Physiology restoring therapies (Drainage*)	
Critically ill	-	Emergent/Urgent	Damage control ± Physiology restoring therapies	Yes

(* Patients With Major Comorbidities Unfit for Surgery and Peri-Appendiceal Abscess and With Stable Hemodynamic Condition May Be Managed With Percutaneous Image-Guided Drainage) (With Permission From: Source Control in Emergency General Surgery: WSES, GAIS, SIS-E, SIS-A Guidelines. Coccolini F, et al. World J Emerg Surg. 2023 Jul 21;18(1):41).[2]

circulatory and cellular/metabolic abnormalities are profound enough to substantially increase mortality.[20] Septic shock is defined as a subset of sepsis in which particularly profound circulatory, cellular, and metabolic abnormalities are associated with a greater risk of mortality than with sepsis alone.[20]

- **Class A** Healthy patients have no or else well-controlled comorbidities, and no immunocompromise, so that the IAI is the main problem.
- **Class B** Patients with moderate comorbidities and/or moderate immunocompromise[21] are at risk of adverse outcomes due to their predisposing conditions, but are currently clinically stable. However, the IAI could rapidly worsen the prognosis.
- **Class C** Patients with severe comorbidities with advanced stages and/or severe immunocompromise,[21] in which the infection worsens an already severe clinical condition.

Some patients may be defined as at high risk due to intrinsic patient conditions (low serum albumin concentration, older age, obesity, smoking, diabetes mellitus, and ischemia secondary to vascular disease or radiation therapy) or based on surgical risk factors (prolonged or delayed/late procedures).[21,22] In all patients, it is critical to incorporate patient wishes into decision making.[23–25] This is especially true for those with severe comorbidities and frailty for whom futility even with optimum care is likely. Thus, consideration, appraisal, and discussion regarding of patient quality of life, advanced directives, and mutual willingness to undertake invasive procedures and support should guide difficult decision making.

Timing and Priorities of Source Control

The timing of optimal SC remains a highly debated topic. The general stated principle of "as soon as possible" is inappropriately vague for such a critical concept. Hence, the literature reflects variable interpretations ranging from "immediately" to "as soon as possible" in patients with severe IAI's and suggests appropriate timelines for source control provision ranging from

TABLE 5. Acute Left colon Diverticulitis Management

Acute Left Colonic Diverticulitis				
Patients	Diverticulitis	Surgery	Source control	
			Operative	Antibiotic therapy
Class A	Uncomplicated	No	No	No
	Complicated (Stage 1 or 2a)	No	Abscess drainage*	Short course
	Complicated (Stage 2b or higher)	Urgent	Colonic resection ± primary anastomosis/stoma	Yes
Class B	Uncomplicated	No	No	No
	Complicated (Stage 1 or 2a)	No*	Abscess drainage*	Short course
	Complicated (Stage 2b or higher)	Urgent	Colonic resection ± primary anastomosis/stoma	Yes
Class C	Uncomplicated	No	No	Short course
	Complicated	Emergent/Urgent	Hartmann procedure ± Physiology restoring therapies	Yes
Critically ill	-	Emergent/Urgent	Damage control ± Physiology restoring therapies	Yes

(*Percutaneous Drainage for Abscess Larger Than 5 cm) (With Permission From: Source Control in Emergency General Surgery: WSES, GAIS, SIS-E, SIS-A Guidelines. Coccolini F, et al. World J Emerg Surg. 2023 Jul 21;18(1):41).[2]

TABLE 6. Acute Right colon Diverticulitis Management

Acute Right Colonic Diverticulitis				
Patients	Diverticulitis	Surgery	Source control	
			Operative	Antibiotic therapy
Class A	Uncomplicated	No	No	Short course
	Complicated	Urgent	Right hemicolectomy	Yes
Class B	Uncomplicated	No	No	Short course
	Complicated	Urgent	Right hemicolectomy	Yes
Class C	Uncomplicated	No	No	Yes
	Complicated	Emergent/urgent	Right hemicolectomy ± intestinal anastomosis ± physiology restoring therapies	
Critically ill	-	Emergent/Urgent	Damage-control ± physiology restoring therapies	Yes

(With Permission From: Source Control in Emergency General Surgery: WSES, GAIS, SIS-E, SIS-A Guidelines. Coccolini F, et al. World J Emerg Surg. 2023 Jul 21;18(1):41).[2]

7 hours to 24 hours from diagnosis for IAI presenting without signs of systemic inflammation.[26–30] The Surviving Sepsis Campaign guidelines suggested that a "target of 6 hours to 12 hours after diagnosis should be sufficient for "most cases".[31] It is further debated as to whether patients with septic shock from a presumed intra-abdominal source with physiological instability may benefit from a period of resuscitation and "optimization" prior to operative SC.[32] Some data suggested a potential increase in mortality linked to a delay in operative SC without, however, stratifying the patients.[33–35]

Therefore, the authors recommend that the timing of the SC must be evaluated case by case based on the patient's physiological conditions, the source of infection and observed clinical course. The time from symptom-onset or from admission are important but must be integrated into a more complete and articulated evaluation.[36–38]

Thus, three thresholds for SC timing can be considered[2]:

-***Emergent source control***—describes patients with severe physiological derangement source control must be undertaken without delay after the diagnosis is strongly suspected or established.
-***Urgent source control***—describes patients whenever delaying an intervention between 1 and 24 hours to improve the clinical condition by providing an adequate fluid resuscitation and a broad-spectrum antibiotic therapy may be helpful. However, if the patient continues to deteriorate during this period of attempted resuscitation, it should be stopped, and SC procedures should be implemented emergently.
-***Delayed source control***—describes patients where it may be appropriate to wait until the demarcation of infectious process, to reduce the risks of collateral surgical morbidity.

SOURCE CONTROL COMPONENTS

To obtain effective SC with the least morbidity, the relative attributes and capabilities of combined therapeutic options should be considered.

-*Antibiotic/Anti-infective therapy*, with specific attention in covering multi-resistant bacteria, while at all times respecting principles of antibiotic husbandry.[39–48] There are many cases now of mild IAS that may be managed just with antibiotics such as diverticulitis.
-*Minimally invasive non-surgical/radiological procedures*, involving interventional radiological or endoscopic approaches to drain collections or divert biological fluids.[49,50]
-*Surgery*, formal surgical procedures conducted to drain, debride (dead tissues and/or devices removal), decompress, or restore anatomy and function, ranging from limited surgical interventions up to complex multistage damage-control procedures.[51,52]
-*Physiological Support* encompasses all the critical care therapies that are currently used to support the circulatory systems,

TABLE 7. Small Bowel Perforation Management

Small Bowel Perforation			
Patients	Surgery	Source control	
		Operative	Antibiotic therapy
Class A	Urgent	Bowel resection	Short course
Class B	Emergent/Urgent	Bowel resection	Short course
Class C	Emergent/Urgent	Bowel resection ± intestinal anastomosis	Yes
Critically ill	Emergent/Urgent	Damage control ± Physiology restoring therapies	Yes

(With Permission From: Source Control in Emergency General Surgery: WSES, GAIS, SIS-E, SIS-A Guidelines. Coccolini F, et al. World J Emerg Surg. 2023 Jul 21;18(1):41).[2]

TABLE 8. Gastroduodenal Perforation Management

Gastroduodenal Perforation			
Patients	Surgery	Source control	
		Operative	Antibiotic therapy
Class A	Urgent	Surgical repair/resection	Short course
Class B	Emergent/Urgent	Surgical repair/resection	Short course
Class C	Emergent/Urgent	Surgical repair/resection	Yes
Critically ill	Emergent/Urgent	Damage control ± Physiology restoring therapies	Yes

(With Permission From: Source Control in Emergency General Surgery: WSES, GAIS, SIS-E, SIS-A Guidelines. Coccolini F, et al. World J Emerg Surg. 2023 Jul 21;18(1):41).[2]

maintain oxygenation, enhance perfusion, and optimize acid-base and temperature balance that form the core discipline of critical care management.[53]
-*Physiological Source Control* is not yet a standard of care but which we suggest be considered for the future. As circulating bacteria, toxins, and mediators are the active "end-effector" result of the infectious state, comprehensive care should move beyond just addressing the anatomical/physical aspects of contamination and source control to actively contribute to the management of the "physiological source of infection."[2,31]

TABLE 9. Summary: When to Do What When Dealing With Intra-Abdominal Infections (IASs) Requiring Source Control

When	What to Do
First assessing patient	Assess hemodynamic stability
	Diagnose intra-abdominal infection
	- Typically CT scan or clinical for most severe
	Stratify patient into risk category and urgency
After Diagnosing Patient	Assess need for Resuscitation
	Obtain vascular access
	- Resuscitation as appropriate to hemodynamics
	Typically start broad spectrum antibiotics appropriate for patient and hospital (consider Candidiasis risks)
	Make initial plan to source control
	- Medical management for mild IASs
	- Percutaneous management for established abscesses
	- Laparoscopic surgery for selected moderate IAS
	- Open surgery typically for the most cases
Medical management selected	narrow coverage as soon as possible according to microbiology
	Be vigilant for failures of medical management requiring more invasive therapies
Percutaneous management selected	obtain microbiology from percutaneous method
	Tailor antibiotics as per microbiology and narrow when able
	Be vigilant for failures of percutaneous management requiring more invasive therapies
Laparoscopic management selected	obtain microbiology from percutaneous method
	Repair, resect, or drain as appropriate
	Tailor antibiotics as per microbiology and narrow when able
	Be vigilant for failures of laparoscopic management requiring more invasive therapies
Open surgery selected	obtain microbiology from open method
	Repair, resect, or drain as appropriate
	Tailor antibiotics as per microbiology and narrow when able
	Consider damage control as appropriate to hemodynamic stability
	Consider temporary open abdomen technique for source control
	- Ideally within the paradigm of an appropriate randomized trial
	Be vigilant for failures of open management requiring reoperation

Disclaimer: As discussed in the article there is marked limitations in the supporting scientific literature to guide clinical decision making with certainty. The following recommendations are the best opinions of the authors subject to refinement with future data.

ANTIBIOTIC STEWARDSHIP

All complex and/or severe IAS should be managed using a multi-disciplinary approach including representatives of the Hospital's Antibiotic Stewardship Committee. The appropriate antibiotic must be administered early, but broad-spectrum antibiotics must not be inappropriately continued after they are no longer required. This is important to not cause antibiotic resistance and to reduce possible microbiome impairment.[54,55] In complicated IAIs, the surgical strategy, the duration of antibiotic therapy, and the strategies to support physiology must be evaluated continuously taking into account intra-abdominal findings, the patient's initial physiologic status and physiological evolution, the potential involved bacteria, and the treating institutions antibiogram data.[56–58]

DAMAGE CONTROL AND OPEN ABDOMINAL THERAPY FOLLOWING SOURCE CONTROL

The open abdomen technique used in the management of IAI includes temporarily leaving the fascia unapproximated after a source-control laparotomy[59] and managing the peritoneal cavity with the use of a "temporary abdominal closure (TAC)" dressing utilizing negative peritoneal pressure.[60–63] The use of this strategy is frequently described in the treatment of the most severe cases of IAS even though there is no definitive evidence supporting its efficacy,[52,64,65] and low-level evidence criticizing its utilization.[62,66–68] However, a biological rationale and theoretical benefits exist, including the potential of mitigating the bio-mediators of the inflammatory cascade, mediating IAH, and expediting surgical procedures.[69–71] These benefits, however, are counteracted by potential increased costs and the potential increased risks of entero-atmospheric fistulae; although modern TAC techniques may potentially mitigate this complication.[72] While the Closed or Open after Laparotomy for Severe Complicated Intra-Abdominal Sepsis (COOL Trial) is ongoing to address the question about its efficacy in abdominal sepsis,[73–76] surgeons should remain conservative in the discretionary use of the OA in IAI if they are not participating in an ethically approved study to answer this question.[66]

Overview of Intra-Abdominal Infection Management

Intra-abdominal infections (IAI) include many different conditions that may be initially divided into biliary and extra-biliary infections to guide the preliminary approach during the initial contact with the patient. Subsequent stratification may be done according to the specific anatomical organ involved after further clinical, imaging, or surgical results become available. The cornerstones of management remain the same for all the extra-biliary infections and for acute cholecystitis. Source control, hemodynamic support and adequate antibiotic therapy are the most important. Detailed management of IAIs depend on the type of baseline intra-abdominal disease, its severity and the patient physiology and comorbidities. Detailed management of the most frequent IAIs are summarized in (Tables 2–8), with an overview review presented in Table 9.

FUTURE TRENDS IN SOURCE CONTROL

We think, in the future, physiological source control may likely include measures focused on preserving a healthy human microbiome[77–79] and preventing dysbiosis, although much still needs to be learned and studied in this evolving science. Thus we propose that physiological restoration aiming to reduce the bioburden of IAI may become an integral part of comprehensive source control. This can be conceptualized as moving beyond the anatomical/physical aspects of contamination and source control, to actively contribute to the management of the "physiological source of infection."[2,31] Measures to protect, support, and resuscitate the human microbiome should thus be urgently studied. In this regard the evidence is still circumstantial. Numerous therapies have been suggested to modulate the gut microbiota to improve outcomes of sepsis. These have included selective digestive decontamination, probiotics, prebiotics, synbiotics, and even fecal microbiota transplantation. While all have shown some potential, none are ready to be accepted into clinical practice.[80,81] However, given the currently poor overall outcomes in patients with severe IAS, the authors believe we need to continue our efforts to understand the often-forgotten organ of the human microbiome, in terms of how it both helps and exacerbates severe IAS and how, if possible, it might be protected so as to protect its human host. Loss of intestinal microbiota diversity during critical illness is a rapid development and its precise mechanism remains largely unknown.[82] Antibiotics can definitely alter the microbiome, but animal experiments have also shown that intra-abdominal hypertension can induce an IAH-related dysbiosis.[83,84] We suspect but cannot prove that ischemia and malperfusion and ischemia of the gut also associate with dysbiosis. It is well described that even with adequate resuscitation, gut dysfunction promotes distant organ injury.[85] This dysfunction is manifested in a few related but distinct pathologies including mucosal ischemia, altered intestinal transit, luminal nutrient transportation and disuse-associated villus atrophy, resulting in overall reduction in mucosal surface area, loss of barrier function and increased permeability. Multiple Organ Dysfunction Syndrome also likely involves the rapid transformation of a healthy microbiome into a dysbiome or pathobiome.[82] Thus, while not proven, we think it is intuitive that visceral ischemia likely plays a role in dysbiosis, and that all the adverse pathophysiology associated with severe IAS that associates with gut malperfusion, such as hypovolemia, shock, intra-abdominal hypertension, and systemic vasoconstriction should be considered.

CONCLUSION

The authors propose that the overall SC concept needs to be broadened and updated to reflect the complexity of severe intra-abdominal sepsis and the pathobiology of sepsis (Table 1). Thus, the traditional familiar concept of anatomical source control should be expanded to encompass the concept of physiological source control, the appropriate antibiotic/anti-infective therapy, and antibiotic stewardship. These three components should be individualized for every patient, depending on the causative event, the time to diagnosis and treatment, the source of infection bacteria, local bacterial flora, patient condition and their concurrent comorbidities, and finally any predeclared wishes of the patient for complex and potentially invasive medical/surgical care. In conclusion, source control no longer remains a mere surgical issue but should be considered in a multidisciplinary fashion by all disciplines but led by surgeons well versed in operative management.

AUTHORSHIP

F.C., A.W.K and M.S. participated in the conception and study design. F.C., M.S., C.C., and A.W.K. participated in the literature review. F.C., M.S., C.C., A.W.K. participated in the data acquisition. F.C., M.S., C.C., A.W.K. participated in the data analysis and interpretation. F.C., M.S., C.C., A.W.K. participated in the drafting of the article. F.C., M.S., C.C., A.W.K. participated in the critical revision. F.C. and A.W.K participated in the article conception and draft. All authors critically revised the article and contributed with important scientific knowledge giving the final approval.

DISCLOSURE

Conflict of interest: All authors COI forms have been provided as Supplemental Digital Content (http://links.lww.com/TA/E590). AW Kirkpatrick has consulted for the Zoll, Acelity (3 M/KCI), and Innovative Trauma Care Companies.
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