



HAL
open science

Intra-abdominal infections survival guide: a position statement by the Global Alliance For Infections In Surgery

Massimo Sartelli, Philip Barie, Vanni Agnoletti, & Majdi N. Al-Hasan, Luca Ansaloni, Walter Biffi, Luis Buonomo, Stijn Blot, William G. Cheadle, Raul Coimbra, et al.

► To cite this version:

Massimo Sartelli, Philip Barie, Vanni Agnoletti, & Majdi N. Al-Hasan, Luca Ansaloni, et al.. Intra-abdominal infections survival guide: a position statement by the Global Alliance For Infections In Surgery. World Journal of Emergency Surgery, 2024, 19 (1), pp.22. 10.1186/s13017-024-00552-9 . hal-04615845

HAL Id: hal-04615845

<https://hal.science/hal-04615845>

Submitted on 18 Jun 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

REVIEW

Open Access



Intra-abdominal infections survival guide: a position statement by the Global Alliance For Infections In Surgery

Massimo Sartelli^{1*}, Philip Barie², Vanni Agnoletti³, Majdi N. Al-Hasan⁴, Luca Ansaloni⁵, Walter Biffi⁶, Luis Buonomo⁷, Stijn Blot⁸, William G. Cheadle⁹, Raul Coimbra^{10,11}, Belinda De Simone¹², Therese M. Duane¹³, Paola Fugazzola⁵, Helen Giamarellou¹⁴, Timothy C. Hardcastle¹⁵, Andreas Hecker¹⁶, Kenji Inaba¹⁷, Andrew W. Kirkpatrick¹⁸, Francesco M. Labricciosa¹⁹, Marc Leone²⁰, Ignacio Martin-Loeches^{21,22,23,24}, Ronald V. Maier²⁵, Sanjay Marwah²⁶, Ryan C. Maves²⁷, Andrea Mingoli²⁸, Philippe Montravers²⁹, Carlos A. Ordóñez³⁰, Miriam Palmieri¹, Mauro Podda³¹, Jordi Rello^{32,33}, Robert G. Sawyer³⁴, Gabriele Sganga³⁵, Pierre Tattevin³⁶, Dipendra Thapaliya³⁷, Jeffrey Tessier³⁸, Matti Tolonen³⁹, Jan Ulrich⁴⁰, Carlo Vallicelli⁴¹, Richard R. Watkins⁴², Fausto Catena⁴¹ and Federico Coccolini⁴³

Abstract

Intra-abdominal infections (IAIs) are an important cause of morbidity and mortality in hospital settings worldwide. The cornerstones of IAI management include rapid, accurate diagnostics; timely, adequate source control; appropriate, short-duration antimicrobial therapy administered according to the principles of pharmacokinetics/pharmacodynamics and antimicrobial stewardship; and hemodynamic and organ functional support with intravenous fluid and adjunctive vasopressor agents for critical illness (sepsis/organ dysfunction or septic shock after correction of hypovolemia). In patients with IAIs, a personalized approach is crucial to optimize outcomes and should be based on multiple aspects that require careful clinical assessment. The anatomic extent of infection, the presumed pathogens involved and risk factors for antimicrobial resistance, the origin and extent of the infection, the patient's clinical condition, and the host's immune status should be assessed continuously to optimize the management of patients with complicated IAIs.

Keywords Antimicrobial resistance, Antimicrobial therapy, Intra-abdominal infections, Source control

Introduction

Intra-abdominal infections (IAIs) are a major cause of morbidity and mortality in hospital settings worldwide. However, data from most published clinical trials underestimate the true mortality risk for several reasons. First, patients with complicated acute appendicitis are often

over-represented in clinical trials. Second, because clinical trials of investigational antibiotics for complicated IAIs (cIAIs) must demonstrate safety as well as efficacy, enrolled patients with IAIs have a low likelihood of mortality, due to specific trial eligibility criteria that exclude patients with shock or critical illness and sometimes, specific comorbidities. For example, registrational trials usually report a mortality rate of $\leq 2\%$ [1], whereas mortality may exceed 20% from IAIs in critically ill patients [2], usually due to multiple organ dysfunction syndrome. The prospective observational Complicated Intra-Abdominal

*Correspondence:
Massimo Sartelli
massimosartelli@gmail.com

Full list of author information is available at the end of the article



© The Author(s) 2024. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

Infections Score Study (WISS), which included 4,553 patients with cIAIs from 132 medical institutions worldwide, showed in 2015 an overall mortality rate of 9.2% [3], which is likely a more accurate assessment of the overall mortality risk from IAIs.

Peritonitis refers to inflammation of the peritoneum. Infectious peritonitis can be categorized into primary, secondary, or tertiary peritonitis based on causation and anatomy. Primary (formerly “spontaneous”) bacterial peritonitis is a diffuse infection caused by a single bacterial species. There is no disruption of the gastrointestinal (GI) tract. Primary peritonitis typically occurs in patients with cirrhosis and ascites or patients with rheumatologic or chronic kidney disease (e.g., systemic lupus erythematosus). Patients with peritonitis associated with a peritoneal dialysis catheter, ventriculo-peritoneal shunt, or other device have primary peritonitis strictly speaking, but such cases are best considered as their own subcategory, device-associated peritonitis (DAP). Primary peritonitis is infrequent on surgical wards, but must be recognized because the treatment is medical and surgical intervention is not indicated. By contrast, DAP is usually treated by removing the device, especially for fungal or pseudomonal DAP (by surgery if necessary), and antibiotics [4]. Primary peritonitis and DAP caused by anaerobes are exceedingly unusual, so isolation of an anaerobe from presumed primary peritonitis or DAP requires evaluation for perforated viscus, which can be caused by erosion of the device.

Secondary peritonitis is the most frequent form of peritonitis presenting to surgical units. It results from the loss of integrity of the GI tract (e.g., GI necrosis, perforated viscus). It is invariably polymicrobial, but varies widely in severity and outcomes. The treatment involves surgical intervention, whether percutaneous or via laparoscopy or open procedure. Percutaneous drainage can obviate the need for surgery, or temporize until treatment confers better surgical risk, whereas an incision provides opportunity to achieve “source control”, which is the principal determinant of outcome. A short course of antibiotics is usually necessary, but adjunctive.

Tertiary peritonitis is a recurrent or persistent infection of the peritoneal cavity after more than one unsuccessful source control procedure for secondary peritonitis. Tertiary peritonitis is a distinct entity, representing an e complication of failed source control for secondary peritonitis [4]. The terms “ongoing peritonitis” or “persistent peritonitis” have been proposed as alternatives because they may describe better the evolution of secondary peritonitis. Patients with tertiary peritonitis are usually critically ill and require substantial hospital resources for nutritional and organ functional support, as well as re-laparotomy (sometimes multiple operations). The microbiology differs from secondary peritonitis in that

is associated with commensal organisms (e.g., enterococci, yeast, *Staphylococcus epidermidis*, or *Pseudomonas aeruginosa*).

The term “acute peritonitis” is vague and is often used generically. cIAI nomenclature, as opposed to the term “uncomplicated intra-abdominal infections” (uIAIs) defines an infection proceeding beyond the organ of origin into the peritoneal cavity. cIAIs are complex conditions, in which numerous aspects of the disease process and management options must be assessed to provide optimal management [4]. The cornerstones of cIAI management include adequate source control achieved by the index procedure; appropriate antimicrobial therapy considering the host, the disease, the likely pathogen(s), and the agents available; and hemodynamic support by intravenous fluid, with judicious vasopressor use for refractory septic shock not responsive to fluid alone [4].

Methods

This evidence-based position statement has been signed by a representative multidisciplinary working group of experts, with its main objective being to describe best practices for cIAI management. The group, representing the Global Alliance for Infections in Surgery, included general and emergency surgeons, intensive care specialists, and specialists in infectious diseases. The statement has been drafted by all contributors, following a comprehensive literature review of pertinent current scientific evidence. The supporting documentation was identified by a search conducted through PubMed (National Institutes of Health, Bethesda, MD, <https://pubmed.ncbi.nlm.nih.gov>) and Google Scholar (Alphabet, Inc., Mountain View, CA, <https://scholar.google.com>). The search identified articles published in English between January 2010 and December 2023, which were supplemented selectively by earlier articles for historical context or to emphasize timeless points. An expert reviewed the selected articles, and drafted the initial manuscript, which was shared with the experts’ group to construct a position statement about the management of cIAIs. The statements have been formulated and graded according to the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) hierarchy of evidence. Evidence quality has been graded high, moderate, low, or very low according to the GRADE methodology. The strength of the recommendations has been classified as weak or strong.

For each statement, consensus among the experts was reached using a Delphi approach. Statements were endorsed as a strong recommendation with agreement by $\geq 80\%$ of participating experts. The final document was approved by each working group member to ensure consensus. Concepts and approaches described are recommended plans of care, based on best available evidence

and the consensus of experts, but they do not exclude other approaches as being within the standard of care.

Recommendations for the management of complicated intra-abdominal infections

Determining the origin of the infection is crucial to defining the operative plan for source control. Factors of importance in the management of cIAIs are the following: (1) origin of the infection; (2) anatomic extent of infection; (3) presumed pathogens involved and risk factors for AMR; (4) clinical conditions; and (5) host immune status.

Statement 1

In patients with cIAIs, a personalized approach is crucial to optimize outcomes and should be based on multiple aspects requiring careful clinical assessment: (1) The anatomic extent of infection; (2) the presumed pathogens and risk factors for antimicrobial resistance (AMR); (3) the origin of the infection; (4) the patient's clinical condition; and (5) the host's immune status. Assessment should be continuous to optimize management (Very low-quality evidence, Strong recommendation).

Origin of the infection

The term “intra-abdominal infections” includes several different pathologic conditions ranging in severity from uncomplicated appendicitis to diffuse fecal peritonitis [5]. The WISS study [1] confirmed that acute appendicitis is the most frequent cause of IAIs; one-third of cases are complicated. Acute appendicitis is usually caused by obstruction of the appendiceal lumen by an appendicolith or some other mechanical cause. Appendiceal primary tumors such as carcinoid tumors or adenocarcinoma, intestinal parasites, or hypertrophied lymphatic tissue may also cause luminal obstruction. Acute appendicitis is postulated to develop when the obstructed appendiceal lumen develops bacterial overgrowth that, combined with luminal hypertension from mucus secretion and resulting cessation of venous outflow, causes acute infection with gangrene or perforation, and abscess formation or diffuse peritonitis. The natural history of appendicitis has been described in three stages, from: (1) Normal; to (2) uncomplicated acute appendicitis; and (3) eventually, complicated appendicitis [6].

Acute cholecystitis is the second most common cause of IAI, but most cases are uIAI. Gallstone-associated cystic duct obstruction is responsible for 90-95% of cases of acute cholecystitis. Approximately 5-10% of patients with cholecystitis have acute acalculous cholecystitis (AAC) defined as ischemic inflammation of the gallbladder in the absence of gallstones, typically in the setting of critical illness [7]. Rarely, AAC has a viral pathogenesis

(e.g., cytomegalovirus, Epstein-Barr virus). Cystic duct obstruction precipitates prostaglandin-mediated gallbladder wall inflammation and edema. Early in the course of disease, one-half or more of acute cholecystitis cases are culture-negative, with bacterial invasion being a secondary phenomenon. The most common pathogens are *Escherichia coli*, *Klebsiella* spp., and *Enterococcus* spp. If untreated, mural ischemia leads to gangrene, although perforation (complicated acute cholecystitis) is uncommon. A gangrenous gallbladder may become infected by gas-forming organisms (e.g., *Clostridium* spp.) causing acute emphysematous cholecystitis, which can have a fulminant course. Gallbladder perforation can quickly become life-threatening if not contained by local host defenses (subhepatic abscess); perforation with free rupture and generalized peritonitis has a high rate of mortality comparable to other causes of diffuse bacterial peritonitis.

Acute diverticulitis begins with inspissation and inflammation of colonic diverticuli, which may cause local ischemia and progress to colonic micro- or macro-perforation. It may be classified according to the extent of inflammation and related complications that it induces, ranging from mild uncomplicated episodes to major complications (e.g., abscess or peritonitis). In Western societies, most diverticula are found in the sigmoid and left colon, whereas diverticula of the right colon are more common in Asian populations [5].

Gastroduodenal ulcer perforations have decreased recently, owing to the widespread prescribing of proton pump inhibitors (and over-the-counter availability), a decreasing incidence of *Helicobacter pylori* infection in Western countries, and effective multi-drug therapy when diagnosed in the non-acute setting [5]. However, perforated gastroduodenal ulcer disease is still a common emergency condition worldwide and is associated with high mortality if not treated promptly. The main causal factors include non-steroidal anti-inflammatory drugs, systemic corticosteroids, tobacco smoking, *H. pylori* infection, and high-sodium diets, all of which are associated with gastric acid hypersecretion. The above-mentioned medications also disrupt the gastric mucus barrier and mucosal H⁺ efflux pumps. Most community-onset gastroduodenal perforations are sterile if source control is achieved within the first 24 h after perforation, with antibacterial therapy for invasive infection (as opposed to prophylaxis) only necessary thereafter. The most common microbial isolate after gastroduodenal perforation is *Candida* spp., which is usually a contaminant from the esophago-gastric microbiome that does not require antifungal therapy. By contrast, stress-related gastric mucosal injury (stress “ulceration,”) now rare even among critically ill patients in intensive care units (ICUs), is caused by gastric ischemia/reperfusion injury. Characterized by

diffuse erosive gastritis rather than discrete ulcers, stress gastritis is more likely to result in upper GI hemorrhage than gangrene or perforation.

Small bowel perforations are less common as causes of peritonitis in Western countries compared with other areas of the world. In Western countries, most small intestinal perforations are due to unrecognized intestinal ischemia (mesenteric or obstruction/strangulation) inflammatory bowel disease (e.g., Crohn disease) or occasionally from ingested foreign bodies or small intestinal diverticulitis (e.g., Meckel type). By contrast, in most of the world, small bowel perforations are usually due to typhoid fever (*Salmonella typhimurium*). Typhoid fever is endemic in Asia, Africa, Latin America, the Caribbean, and Oceania [5]. Typhoid ileal perforation is a major global public health problem because of high morbidity and a mortality rate up to 60% [8], and it can present literally anywhere worldwide owing to international travel.

Post-operative peritonitis (PP) is a life-threatening, hospital-acquired cIAI with high rates of mortality [5]. As it is rare compared with community-onset cIAI and patients with PP can become critically ill, the condition is often excluded from registrational trials of new antimicrobial agents, and thus under-studied. The most common cause of PP is anastomotic leak [5], which is most frequent after rectal resection, but it may complicate any GI anastomosis or suture line. Other causes include bile or urine leaks in the appropriate context, and failed source control from the index procedure. The diagnosis of PP may be challenging owing to a lack of specific confirmatory clinical signs. Atypical or unrecognized clinical presentations may result in hazardous diagnostic and therapeutic delays. Management of PP includes supportive therapy of organ dysfunction, source control of infection, antimicrobial therapy, and the possibility of open-abdomen management and complex, staged abdominal wall reconstruction.

Pelvic inflammatory disease (PID) is an infection of the upper part of the female genital tract, including the uterus, fallopian tubes, or adjacent pelvic structures causing peritonitis that may spread from the pelvis to the abdomen [5]. The cause is ascending bacterial infection from the vagina in 85% of cases, most commonly from sexually transmitted pathogens (*Neisseria gonorrhoeae*, *Chlamydia trachomatis*). Endogenous vaginal and cervical flora, especially anaerobes, cause PID in most of the remaining cases. Most cases are treated as outpatients with antibiotics alone. Indications for hospitalization include failure of outpatient management, severe illness, and pregnancy (owing to the risk of pregnancy loss). Pelvic (tubo-ovarian) abscess may be an indication for surgery.

Trauma, a major global public health problem, can be associated with high morbidity and mortality depending

on mechanism, injury pattern, time to stabilization, and host frailty regardless of socioeconomic status [5]. Both blunt and penetrating mechanisms may result in bowel injury; motor vehicle crashes are the most common of blunt intestinal injury, followed by falls [5]. The small intestine is more likely than colon to be injured by either mechanism. Infection is considered established (as opposed to contamination by enteric contents) after 12 h for colon injury and 24 h for other locations; within those time frames only surgical antimicrobial prophylaxis (maximum 24 h; ideally a single dose) is required, even if the colon is lacerated. Blunt hollow viscus injury may have a more insidious presentation in this setting, possibly resulting in delayed diagnosis and intervention and consequent adverse outcomes.

Statement 2

IAI is the setting where source control is most impactful. Achievement of source control is the single most important determinant of patients' outcomes from cIAI, allowing for short-course antibiotic therapy that reduces antibiotic selection pressure. Source control should be undertaken promptly to remove devitalized tissue and infected fluid and prevent ongoing contamination (Low-quality evidence, Strong recommendation).

Source control encompasses all measures aiming to identify and eliminate the source of infection, and control the ongoing contamination [9].

Achievement of source control is of utmost importance in the management of cIAIs. In these settings, source control improves patient outcomes. Although not tested definitively by randomized controlled trials (RCTs) the magnitude of the increased (up to 10-fold) risk of death and other adverse outcomes associated with delayed or inadequate source control makes clear its primacy. Moreover, source control is associated with shorter-course antibiotic therapy [10]. Although appropriate source control is the standard of care for patients with cIAIs, some selected patients with uIAIs (e.g., mild appendicitis and diverticulitis) can be treated successfully with antibiotic therapy alone.

The goals of any source control procedure are to remove infected or devitalized tissues, opening of spaces and compartments to mitigate sequestration or persistent infection, evacuation of pus or other fluids, and irrigation ("washing out") of the abdominal cavity. Selection of a specific source control procedure should be based for each patient on the characteristics of the infection and the patient, as well as the availability of technical expertise. Technical options for source control, alone or in combination with antimicrobial therapy (depending on the circumstance) include: (1) Resection or suture plication of a perforated viscus; (2) removal of an infected

organ (e.g., appendix, gallbladder); (3) debridement of necrotic tissue or resection of infarcted bowel; (4) drainage of an abscess or infected peritoneal fluid; and (5) primary anastomosis or fecal diversion after bowel resection. Copious intraoperative peritoneal lavage is no longer recommended for localized infection. Several recent series and one prospective trial [11–13] of patients with perforated appendicitis found that aspiration and limited irrigation to remove gross contamination were as effective as lavage. More extensive lavage may be needed for diffuse peritonitis.

Source control can be also achieved sometimes by a less-invasive technical approach such as ultrasound (US)- or computed tomography (CT)-guided percutaneous drainage [4]. Percutaneous drainage is a safe and mostly (~85%) effective procedure that allows minimally invasive evacuation of abdominopelvic abscesses and fluid collections with lower morbidity and mortality when appropriate anatomically and feasible technically, depending on the preference of the performing radiologist or surgeon and the location of the abscess/fluid collection. Successful source control (curative drainage) is defined as complete, definitive resolution of infection by an index procedure that requires no further intervention. In most studies, source control is achieved in more than 80% of patients [14]. Partial success is defined as adequate temporizing drainage to stabilize the patient, with surgery performed subsequently to repair the underlying problem. Partial success rates vary, but generally range from 5 to 10% of patients [14]. In certain conditions, the expectation of drainage is to serve as a “bridge” until definitive surgical treatment can be performed. For the purposes of these statements, “bridge” therapy is considered partial success even though the treatment plan may include multiple, staged interventions. Failure occurs about equally because of persistent or recurrent collections. These results are similar for abdominal and chest percutaneous drainage [14].

Statement 3

The origin of the infection should be always investigated for treatment planning. In physiologically deranged patients (i.e., septic shock), early exploration may be performed even if the source of infection is not defined (Very low-quality evidence, Strong recommendation).

The diagnosis of cIAI is based primarily on clinical and radiologic assessment. A typical patient is admitted to the emergency department with abdominal pain and a systemic inflammatory response, including two or more of fever, tachycardia, tachypnea, and leukocytosis or leukopenia (i.e., systemic inflammatory response syndrome). Abdominal tenderness and involuntary guarding suggest the presence of a cIAI. A complete blood count

is the most common laboratory investigation, although it is insensitive and relatively non-specific in cIAI. Inflammatory biomarkers such as C-reactive protein and procalcitonin (PCT) have been evaluated [15, 16]. US and CT are essential diagnostic tools. US is portable and can be performed at the bedside by surgery or radiology. Impediments to US are ileus (increased bowel gas) and obesity, which may mask visualization. It is also strongly operator-dependent, with imaging and interpretation performed ideally by the same individual. US has been the preferred initial diagnostic modality for children and for acute cholecystitis of adults, but increasingly, and for most other indications within cIAI, the higher diagnostic accuracy of CT for identification of the source of infection has been established [17–20], especially for stable patients for whom CT with intravenous contrast is the imaging modality of choice. Intravenous contrast-enhanced CT provides superior anatomic detail [21]. CT not only supports the diagnosis but also informs (and facilitates, in the circumstance of percutaneous drainage) treatment [21]. A step-up strategy with CT performed after an inconclusive or negative US has been proposed as a safe alternative approach for patients with IAIs, especially in the setting of acute diverticulitis [22, 23]. Magnetic resonance imaging may be useful for diagnosis of the acute abdomen [24], but its routine application is limited by the challenges imposed by the emergency setting.

Rapid, accurate identification of the infection source is especially crucial in managing critically ill patients with cIAI. Delay in achieving surgical source control (i.e., > 6 h from sepsis onset) [25] portends worse outcomes. For critically ill, physiologically deranged patients (i.e., septic shock), early exploration may be recommended even if the source of infection remains unclear despite imaging [26].

Anatomic extent of infection

Assessing the origin and extent of the infectious process is important to define the treatment approach. In uIAIs, the infectious process only involves a single organ, not extending beyond. In cIAIs, the infectious process extends beyond the organ into the peritoneal cavity, leading to abscess formation or diffuse peritonitis [4]. A limitation of this classification is that it does not describe patients' complexity. On the other hand, in its simplicity, extension of the infectious process identifies those patients who need both source control and antibiotic therapy. In principle, patients with uIAIs (e.g., most cases of acute appendicitis and cholecystitis) can be managed with either surgical source control or antibiotics alone [27–29]. Patients with uncomplicated appendicitis or acute cholecystitis undergoing adequate source control do not need post-operative antibiotics [30–32].

Statement 4

In the event of uAIAs, such as acute appendicitis or acute cholecystitis, if the focus of infection is controlled by appropriate surgical management, post-operative antibiotic therapy is not necessary. In the event of cAIAs, treatment generally involves source control and antibiotic therapy. Selected patients with perforated diverticulitis (including those with an abscess < 4 cm in diameter), a peri-appendiceal mass or phlegmon, or a perforated gastroduodenal ulcer (i.e., no sepsis, peritonitis, or extravasation by water-soluble contrast gastroduodenography) can be managed without definitive source control if responding satisfactorily to antibiotic therapy and other supportive measures (Low-quality evidence, Strong recommendation).

Statement 5

For patients with uncomplicated acute appendicitis, appendectomy is the standard treatment. If source control is adequate, post-operative antibiotic therapy is not necessary. Treatment by antibiotics alone may be used in selected non-pregnant patients with uncomplicated acute appendicitis and no appendicolith. However, non-operative management (NOM) is less effective than surgery in the long term due to a high recurrence rate (High-quality evidence, Strong recommendation).

Statement 6

In patients with uncomplicated acute cholecystitis, early laparoscopic cholecystectomy is the standard treatment. If source control is adequate, post-operative antibiotic therapy is not necessary. If early cholecystectomy is not performed, interval cholecystectomy should be planned between 6 and 12 weeks after the episode of acute cholecystitis (Moderate-quality evidence, Strong recommendation).

Statement 7

In immunocompetent patients with uncomplicated mild acute diverticulitis, antibiotic therapy may be omitted (Moderate-quality evidence, Weak recommendation).

Although the “gold standard” treatment of acute appendicitis is appendectomy [33], antibiotic therapy alone has been proposed for uncomplicated acute appendicitis of non-pregnant patients without an appendicolith. However, NOM of acute appendicitis, which requires CT confirmation, is demonstrably less effective in the long term due to 1-year recurrence rates of up to 40% [30–32].

For therapy of acute uncomplicated cholecystitis, two options have been proposed. The early option includes laparoscopic or open cholecystectomy within a few days

of symptom onset, providing immediate, definitive treatment in the same hospital admission. The delayed option includes antibiotic therapy, possibly with a temporizing percutaneous cholecystostomy, followed by cholecystectomy after an interval of 6–12 weeks, during which time the acute inflammation subsides [4]. Early laparoscopic cholecystectomy is the treatment of choice for acute cholecystitis, due to shorter hospitalization and no increased morbidity compared with delayed cholecystectomy. However, RCTs and meta-analysis reported a wide array of timing in performing early cholecystectomy for acute cholecystitis, up to 96 h from admission or up to 1 week from symptom onset. Lyu et al. [34], who included 15 RCTs (1,669 patients) in a systematic review and meta-analysis, found that early laparoscopic cholecystectomy was comparably safe and effective compared with delayed cholecystectomy when performed within 7 days of presentation. No differences were found in terms of bile duct injury, surgical site infection, total complications, or conversion to open surgery. Early cholecystectomy was associated with a significantly shorter duration of hospital stay, due entirely to minimizing preoperative delay.

For some cases of uncomplicated acute diverticulitis, NOM without antibiotics is effective [35–38]. A 2017 RCT (DIABOLO trial) of observation *versus* systemic antibiotic treatment [37] for a first episode of CT-proved acute left-sided colonic diverticulitis of Hinchey grades 1a and 1b included 528 patients. Median time to recovery was 2 days longer for observation (hazard ratio [HR] for recovery of 0.91, $p=0.151$), but hospital stay was significantly shorter. No differences were found for secondary endpoints of complicated, ongoing, or recurrent diverticulitis; sigmoid resection; readmission; adverse events, or mortality. Outcomes of DIABOLO study enrollees at 24 months’ follow-up [39] showed no differences in rates of recurrent or complicated diverticulitis, or sigmoid resection.

Approximately 15–20% of patients admitted with acute diverticulitis have an abscess by CT scan [40]. Smaller diverticular abscesses may be treated by systemic antibiotics alone with or without percutaneous drainage, depending on the diameter of the abscess, with up to ~4 cm accepted as a reasonable limit for treatment with antibiotic therapy alone [40]. Although the prevalence of perforated diverticulitis complicated by generalized peritonitis (Hinchey 3–4) is low, there is a risk of mortality regardless of the surgical approach. However, distant free air by CT (a known predictor of failure of NOM) does not obligate surgical intervention. Dharmarajan et al. [41] described successful NOM for patients with acute diverticulitis and pneumoperitoneum, excluding those with hemodynamic instability. Sallinen et al. [42] reported results of NOM in patients with CT-verified extra-luminal gas. NOM was feasible for hemodynamically stable

patients with pericolic extra-luminal gas, or only a “small amount” of distant intraperitoneal gas in the absence of clinical diffuse peritonitis or fluid in the fossa of Douglas. However, a large amount of distant intra- or retroperitoneal gas was associated with a high failure rate (~60%) of NOM, even in the absence of generalized peritonitis.

Antibiotics alone may be used to treat selected patients with uncomplicated acute appendicitis, although there is a significant risk (~40%) of subsequent recurrence [43]. In patients with complicated appendicitis presenting with abscess or phlegmon, optimal management is controversial. One study showed that NOM for a peri-appendiceal abscess or mass resulted in fewer complications and shorter hospitalization [43].

Statement 8

In patients with cIAIs undergoing adequate source control, 4 days of fixed-duration antibiotic therapy is sufficient. In the setting of complicated acute appendicitis, the duration of antibiotic therapy may be shortened further in selected patients (High-quality evidence, Strong recommendation).

Statement 9

Ongoing signs of abdominal infection or systemic illness after 7 days of antibiotic therapy warrant cessation of therapy and a diagnostic investigation rather than prolongation or modification of antibiotic therapy (Low-quality evidence, Strong recommendation).

Statement 10

Biomarkers such as procalcitonin can guide antibiotic duration in patients with signs of ongoing infection (Low-quality evidence, Weak recommendation).

Short-duration antimicrobial treatment of cIAIs improves outcomes while adhering to the principles of antimicrobial stewardship [44]. The prospective STOP-IT trial [45] demonstrated that, for patients with cIAIs undergoing adequate source control, outcomes after ~4 days of fixed-duration antibiotic therapy were similar to outcomes after a longer course (~8 days) of antibiotics that extended until 48 h after the resolution of physiochemical abnormalities. STOP-IT trial data were also evaluated retrospectively to identify risk factors identified with treatment failure [46], which included corticosteroid use, Acute Physiology and Chronic Health Evaluation (APACHE)-II score ≥ 5 points, hospital-acquired infection, or a colon source of cIAI. Despite the presence of risk factors, there were no differences in treatment failure rates between groups, indicating that even patients at high risk of treatment failure do not benefit from longer-duration therapy.

The course of antibiotic therapy may possibly be shortened in the setting of acute appendicitis. A recent

open-label, non-inferiority trial of patients with complicated appendicitis (aged ≥ 8 years) showed that 2 days of postoperative intravenous antibiotics was non-inferior to 5 days of therapy in terms of infectious complications and 90-day mortality [47]. However, a majority of enrolled patients had gangrenous (non-perforated) appendicitis that requires only 24 h of antimicrobial therapy. Given the paucity of data regarding optimal duration of therapy for critically ill patients with cIAI, there may be considerable practice variation. Critically ill surgical patients often receive antibiotics longer than necessary. Antibiotic therapy may be truncated in these patients also, as demonstrated by the DURAPOP RCT of critically ill patients with postoperative IAIs [48].

Patients who have ongoing signs of infection after a source control procedure and appropriate fixed-duration antibiotic treatment need investigation to assess for an ongoing source of infection (failed source control *versus* untreated resistant pathogen[s]) to determine whether re-operation is necessary, rather than prolongation or modification of the antibiotic treatment regimen. PCT may be useful for individualizing antibiotic use. Clinical PCT-based algorithms are used as part of antibiotic stewardship programs in various settings. Serum PCT concentration in healthy unoperated individuals is typically <0.05 mcg/L, but may be higher postoperatively due to a PCT response to tissue injury. In the presence of bacterial infection, higher PCT concentrations correlate with severity of bacterial infection, whereas a decreasing concentration usually reflects improvement and resolution of infection.

Evidence shows that PCT monitoring can reduce antibiotic duration safely in critically ill patients [49–53]. Furthermore, PCT can inform the duration of antibiotic therapy in cIAIs [54–56], and can be particularly useful for patients with ongoing inflammation, in that decreasing concentrations in the postoperative period can guide the cessation of therapy. Three studies show that a PCT-based algorithm may decrease antibiotic exposure in patients with cIAIs. Huang et al. [54] conducted a prospective study to investigate whether a PCT algorithm could reduce antibiotic therapy duration in patients with cIAIs undergoing surgery. PCT concentrations were evaluated pre-operatively, serially for the first week post-operatively, and subsequently if needed. Antibiotic therapy was discontinued if [PCT] was <1.0 ng/L or decreased by 80% *versus* day 1 with resolution of clinical signs. The PCT algorithm significantly reduced antibiotic therapy duration (PCT group, 3.4 days *versus* 6.1 days in the control group). Masada et al. [55] published a retrospective study of 121 consecutive critically ill surgical patients (ICU duration >48 h) treated for cIAI. Treatment duration was reduced by 50% in the PCT group regardless of hemodynamics. Sliker et al.

[56] investigated whether PCT could tailor postoperative antibiotic therapy in surgical patients with cIAs. In a subgroup of patients with GI perforation, duration of antibiotic therapy was 3 days shorter (7 d *versus* 10 d) in the PCT group.

Individual patient risk for presumed pathogens involved and risk factors for antimicrobial resistance

Accurate patient stratification is crucial to optimize empiric antibiotic therapy in this era of AMR [57].

Statement 11

Narrow-spectrum antibiotic regimens having activity against typical gram-negative *Enterobacterales*, gram-positive cocci, and obligate anaerobes should be used to treat patients with community-acquired cIAs. In this setting, broad-spectrum or additional agents to provide anti-pseudomonal or anti-enterococcal coverage or antifungal therapy should not be used routinely (Low-quality evidence, Strong recommendation).

Statement 12

For patients with hospital-acquired IAIs, agent(s) with broad-spectrum activity are preferred (Moderate-quality evidence, Strong recommendation).

Statement 13

Patients who have received recent broad-spectrum antimicrobial therapy, had prolonged hospitalizations, underwent multiple invasive interventions, or are known to have been colonized or infected with a resistant gram-negative organism should be considered at risk for infection from a resistant gram-negative pathogen (Moderate-quality evidence, Strong recommendation).

Statement 14

Antibiotic regimens with activity against multidrug-resistant (MDR) bacteria should be used for selected patients with IAIs who are strongly suspected or proved to be harbouring a resistant pathogen (Moderate-quality evidence, Strong recommendation).

Initial antibiotic therapy for cIAs is typically empiric in nature because standard microbiologic data and susceptibility results generally require 24–72 h after peritoneal fluid specimen collection. Blood cultures are seldom positive in cIAI (<10%) and therefore largely unreliable. Typical bacterial pathogens in IAIs reflect endogenous gut flora including *Enterobacterales* such as *E. coli* and *Klebsiella* spp., viridans group *Streptococcus*, and anaerobes (especially *Bacteroides* spp.) [4]. Historically, cIAI pathogens tended to have greater susceptibility in community- as opposed to hospital-acquired infections.

IAIs caused by susceptible bacteria may be managed by beta-lactam/beta-lactamase inhibitor combinations (e.g., ticarcillin/clavulanic acid or piperacillin/tazobactam), or a non-pseudomonal carbapenem (e.g., ertapenem) [4]. Increasing AMR to amoxicillin/clavulanic acid among *E. coli* and other *Enterobacterales* worldwide has compromised its clinical utility for empiric therapy; it should only be prescribed as targeted therapy based on demonstrated susceptibility. The comparably broad-spectrum activity of piperacillin/tazobactam makes it still useful in managing severe IAIs. However, the anti-pseudomonal activity of piperacillin/tazobactam is unnecessary for most community-acquired cIAs, and its use in hospital-acquired infections should be determined based on local microbiologic epidemiology [58].

Many isolates of *E. coli* and other *Enterobacterales* are susceptible to third-generation cephalosporins that, in combination with metronidazole, may be options for empiric therapy of non-severe IAIs. Cefepime is a fourth-generation cephalosporin with a broader spectrum of activity than third-generation cephalosporins. Compared to ceftriaxone, cefepime is poorly hydrolysed by AmpC beta-lactamase, allowing it to be effective against AmpC-producing organisms. For empiric therapy, cefepime must also be given with metronidazole [59]. Fluoroquinolones have been prescribed widely for the treatment of IAIs because of their putative activity against aerobic gram-negative bacteria, tissue penetration, and high oral bioavailability. However, resistance of *E. coli* and *Klebsiella* spp. to fluoroquinolones has increased substantially over time [4, 59], limiting their use for empiric treatment of IAIs.

In a 2019 multinational observational cohort study of IAIs in 2,621 ICU patients [60], infection was community-acquired in 31.6% of patients and hospital-acquired in 68.4%. Culture and susceptibility testing were performed for 1,982 (75.6%) of patients. Gram-negative organisms were the most frequent bacteria isolated (58.6%). *Enterobacterales* was the most common bacterial order (51.7%) and *E. coli* was the pathogen isolated most frequently (36.8%). Gram-positive aerobic bacteria were isolated from 39.4% of patients. AMR was common (26.3%), without significant differences between community- and hospital-acquired IAIs.

In 2012, the European Centre for Disease Prevention and Control (ECDC) and the U.S. Centers for Disease Control and Prevention (CDC) developed standardized nomenclature to describe acquired resistance profiles in bacteria [61]. MDR was defined as acquired non-susceptibility to at least one antibiotic in three or more antibiotic classes (e.g., cephalosporins, fluoroquinolones, tetracyclines). Extensively drug-resistant (XDR) bacteria were defined as non-susceptible to at least one antibiotic in all but two or fewer antibiotic classes (bacterial isolates

remain susceptible to only one or two classes). Pan-drug-resistant (PDR) bacteria were defined as non-susceptible to all antibiotics in all antibiotic classes.

In the past, predicting potential resistance patterns was based on establishing whether the infection was community- or hospital-acquired. Given the increasing rate of extended-spectrum beta-lactamase (ESBL)-producing *Enterobacterales* and carbapenem-resistant *Enterobacterales* (CRE) observed in community-acquired infections [59], the choice of empiric antibiotic therapy has been complexified. Factors that should be considered to identify risk for resistant bacteria include previous colonization with an MDR pathogen, recent exposure to antibiotics or invasive procedures, and comorbidities or poor functional status [62]. Also, international travel affects the gut microbiota and is considered a risk factor for the acquisition of MDR pathogens [63]. Screening for carriage of CREs is an important global infection prevention and control tactic in endemic regions [64].

In the context of IAIs, the most common resistance phenotype is Extended-Spectrum Beta-Lactamases (ESBLs), which are widely prevalent in nosocomial infections and increasingly so in community-acquired infections [59, 65]. Among patients with risk factors for ESBL-producing *Enterobacterales*, especially if unstable, empiric antibiotics should have an anti-ESBL spectrum. However, among non-critically ill patients, a survival benefit from empiric antibiotic therapy has not been demonstrated consistently, and empiric anti-ESBL coverage may be unnecessary [66]. Carbapenems have been considered the antibiotics of choice to treat ESBL-producing *Enterobacterales*. Group 1 carbapenems include ertapenem, a once daily-carbapenem sharing the same activity of Group 2 carbapenems against ESBL-producing *Enterobacterales* [67] and anaerobes. Group 2 carbapenems include imipenem-cilastatin, meropenem, and doripenem. Compared to ertapenem, Group 2 agents have activity against *P. aeruginosa*. Unlike meropenem and doripenem, imipenem-cilastatin is active against ampicillin-susceptible enterococci.

The role of piperacillin/tazobactam in treating patients with ESBL-producing *Enterobacterales* has been debated [59]. Gram-negative bacteria may express multiple ESBLs as well as AmpC beta-lactamases concomitantly, and can manifest other mechanisms of resistance, limiting the activity of piperacillin/tazobactam [63]. On the other hand, the activity of beta-lactam agents, including piperacillin/tazobactam, is influenced by the “inoculum effect”, an increase in the minimum inhibitory concentration (MIC) of an antibiotic when the inoculum size is larger [63]. A RCT conducted in patients with ESBL-producing *Enterobacterales* blood stream infections showed inferior results of piperacillin/tazobactam compared to carbapenems [68]. Although piperacillin/tazobactam is

not considered the first-choice antibiotic to treat ESBL-producing *Enterobacterales* [69], it may be an option for IAIs with adequate source control when bacteria are susceptible ($MIC \leq 4$ mg/L) [59]. A high dose or prolonged/continuous infusion should be prescribed to optimise pharmacokinetics (PK) targeting in critically ill patients [70].

Aminoglycosides have in vitro activity against aerobic gram-negative bacteria, including ESBL-producing *Enterobacterales*, and can act synergistically with beta-lactam agents against certain gram-positive bacteria. Because of their toxicity, including nephro- and ototoxicity, aminoglycosides are not recommended for the empiric treatment of IAIs [59]. They are generally prescribed for patients with beta-lactam allergies or used for synergy for brief periods in combination with beta-lactam agents against difficult-to-treat pathogens.

Tigecycline remains a limited option for treating patients with MDR cIAIs, due to its favorable coverage against anaerobic organisms, enterococci (including vancomycin non-susceptible strains), and ESBLs [71]. It is not active against *P. aeruginosa* or certain unusual IAI pathogens including *Proteus* spp. and *Serratia* spp. Excess mortality was observed in 12/13 phase 3 and 4 clinical trials of tigecycline, especially to treat bacteremic ventilator-associated pneumonia [72]. Tigecycline should be considered only when other therapeutic alternatives do not exist, and are contraindicated for treating hospital-acquired pneumonia or bacteremia. Eravacycline, a broad-spectrum fluorocycline, is structurally similar and demonstrates comparable broad-spectrum activity, including inactivity against *P. aeruginosa* [73], but a better safety profile. Eravacycline was investigated for cIAI treatment by 2 RCTs, in which it was non-inferior at test-of-cure (TOC) compared with 2 carbapenems (IGNITE 1: 87.0% for eravacycline versus 88.8% for ertapenem; IGNITE 4 90.8% versus 91.2% for meropenem) [74, 75]. Also, a low risk of *Clostridioides difficile* infection was observed after eravacycline treatment [76].

Fosfomycin is a broad-spectrum antibiotic with a wide therapeutic range and excellent tissue penetration [77]. Fosfomycin is administered frequently in Europe, in combination with other antibiotics, to combat severe bacterial infections, but seldom in North America. Monotherapy with Fosfomycin is not recommended owing to the rapid emergence of resistance.

Both ceftolozane/tazobactam and ceftazidime/avibactam have appropriate activity to treat cIAIs caused by ESBL-producing *Enterobacterales* [78, 79]. These agents evade carbapenemases that hydrolyze penicillins, cephalosporins, first-generation beta-lactamase inhibitors, and carbapenems. New agents for CRE, especially *K. pneumoniae*, include meropenem/vaborbactam and imipenem-cilastatin/relebactam [80, 81].

CRE usually possesses multiple potential mechanisms of antibiotic resistance [82]. Meropenem-vaborbactam and imipenem-cilastatin/relebactam are active against most *Enterobacterales* producing *K. pneumoniae* carbapenemases (KPC) but not those producing OXA-48-like carbapenemases.

Metallo-beta-lactamases (MBLs) are unique because they are zinc-dependent enzymes. MBLs hydrolyze most beta-lactam agents, including carbapenems, except for aztreonam. Ceftazidime/avibactam plus aztreonam, or cefiderocol are treatment options for MBL-producing *Enterobacterales*, although the latter has not been studied in cIAI. Cefiderocol is a novel cephalosporin that overcomes three distinct mechanisms of carbapenem resistance-avoiding porin channels and efflux pumps by entering bacterial cells via iron transport mechanisms and stability to all four classes of beta-lactamases [83]. The new agent sulbactam/durlobactam and the investigational combinations of aztreonam/avibactam [76] and cefepime/taniboribactam show promise against MDR gram-negative bacilli, but none have been studied in cIAI.

Alarming rates of resistance have been described for non-fermenting gram-negative bacteria, including *P. aeruginosa*, *Stenotrophomonas maltophilia*, and *Acinetobacter baumannii* complex. These difficult-to-treat MDR bacteria are intrinsically resistant to many antibiotics, but also can acquire resistance to most classes of antibiotic agents. Multiple mechanisms may be present simultaneously, conferring resistance to several classes of antibiotics [63], including membrane permeability defects, expression of efflux pumps, and production of antibiotic-hydrolysing enzymes such as AmpC beta-lactamases or carbapenemases. *S. maltophilia* and *A. baumannii* complex are rare cIAI pathogens, but can cause postoperative pneumonia among high-risk critically ill patients with cIAI.

Among gram-positive bacteria, *Enterococcus* spp. is associated with increased morbidity in IAIs, but the effect on mortality is uncertain [84–86]. Whereas the role of enterococci in high-risk patients is well documented, their role in cIAIs in low-risk patients is doubtful [87]. Zhang et al. found by meta-analysis that anti-enterococcal regimens provide no improvement in cIAI treatment success, with similar mortality and adverse effects, in RCTs enrolling young patients with lower-risk community-acquired infections (median APACHE-II score, 6 points) [87]. Malignant disease, corticosteroid use, surgery, any antibiotic treatment, admission to an ICU, and an indwelling urinary catheter each predisposed patients with cIAI to a higher risk of enterococcal infection. The prevalence of enterococcal isolation was 2- to 5-fold higher from hospital-acquired IAIs.

Empiric anti-enterococcal therapy for cIAI is not necessary for most community-acquired infections, but is indicated in hospital-acquired IAIs and may be considered for immunocompromised patients, critically ill patients with sepsis and previous antimicrobial therapy lacking enterococcal coverage, or patients with valvular heart disease or intravascular prosthetics at high risk for endocarditis or blood-borne device-associated infection. The ideal regimen for high-risk patients is undetermined. *E. faecalis* is generally susceptible to ampicillin whereas *E. faecium*, encountered increasingly, is almost always ampicillin-resistant [46] and 70% of strains are resistant to vancomycin. The first-line treatment of glycopeptide-susceptible *E. faecium* is vancomycin. Linezolid or daptomycin may be used to treat vancomycin-resistant *E. faecium*, but occasional resistance has been reported to both agents. The glycolcyclines also have useful activity against vancomycin-resistant *E. faecium*.

Statement 15

In patients with cIAIs at risk of resistant pathogens, culture and susceptibility testing of peritoneal fluid at the site of infection should always be obtained. If resources are available, cultures should be obtained from all patients with cIAIs to analyze epidemiologic data that can be used to guide empiric antibiotic therapy (Low-quality evidence, Weak recommendation).

Obtaining cultures from fluid allows escalation of an antimicrobial regimen if the initial choice is too narrow, and conversely de-escalation or discontinuation if the empiric regimen is too broad. When a microorganism is identified in culture, antimicrobial susceptibility testing should always be performed and reported to guide antibiotic therapy. Reporting is not without controversy, as selective non-disclosure (cascading) of antimicrobial susceptibilities is sometimes undertaken by antimicrobial stewardship programs to influence prescribing.

Although susceptibility testing has little impact on the treatment of community-acquired cIAIs such as appendicitis [88, 89], MDR bacteria can also cause community-acquired infections. In patients with cIAIs at risk of resistant pathogens, cultures of peritoneal fluid from the site of infection should always be obtained. Furthermore, susceptibility tests promote knowledge of local microbiologic epidemiology. Therefore, cultures should be obtained in all patients with cIAIs if resources are available.

Because early, targeted antibiotic therapy is crucial for improving patient outcomes especially in critically ill patients, prompt availability of diagnostic test results is a central theme in policy initiatives to combat infections, especially in sepsis [90].

Statement 16

For adults with sepsis (multiple organ dysfunction syndrome) or shock due to hospital-acquired cIAIs, empiric antifungal therapy for *Candida* spp. should be considered, especially those with recent abdominal surgery or gastrointestinal anastomotic leak. Empiric antifungal therapy may be considered for high-risk patients with community-acquired infections (Low-quality evidence, Strong recommendation).

Intra-abdominal candidiasis is a rare but serious infection with a high mortality rate, especially of critically ill patients. The most common risk factors are GI perforation, anastomotic leak, and previous exposure to antifungal or antibacterial agents [91]. The challenge of intra-abdominal candidiasis is related partly to the diagnostic difficulty of differentiating between contamination and infection when *Candida* spp. is isolated. Invasive intra-abdominal candidiasis (as opposed to contamination) requires aggressive antifungal treatment, even though adequate source control is the most important factor in improving outcomes of these patients [92]. Unfortunately, early diagnosis of intra-abdominal candidiasis remains a challenge. Numerous risk factors for intra-abdominal candidiasis have been identified. Some clinical prediction rules were developed and validated to identify ICU patients at high risk of intra-abdominal candidiasis. In 2006, a Spanish group, using the database of the Estudio de Prevalencia de CANDidiasis project, proposed the “Candida score” to identify patients with high risk of intra-abdominal candidiasis; this score was calculated as $1 \times (\text{total parenteral nutrition}) + 1 \times (\text{surgery}) + 1 \times (\text{multifocal Candida colonization}) + 2 \times (\text{severe sepsis})$ [93].

Empiric antifungal therapy for *Candida* spp. is typically not recommended for patients with IAIs, with the exceptions of immunocompromised patients, those with multiple risk factors, and critically ill patients. The guidelines of the European Society of Intensive Care Medicine (ESICM) and the Critically Ill Patients Study Group of the European Society of Clinical Microbiology and Infectious Diseases (ESCMID) suggest empiric antifungal therapy in patients with septic shock and multiple organ dysfunction syndrome [94]. By contrast, the guidelines of the Infectious Diseases Society of America (IDSA) suggest empiric antifungal therapy for patients with clinical evidence of IAI and multiple risk factors for candidiasis, including recent abdominal surgery, anastomotic leak, or necrotizing pancreatitis, who are doing poorly despite treatment for bacterial infection [95].

Guidelines recommend echinocandins as first-line treatment in for invasive candidiasis [94, 95]. However, their role has been debated. Antifungal resistance is a growing concern in *Candida* spp [96]. . Moreover, echinocandin exposure has been reported to be suboptimal

in critically ill patients. Dose adjustments supported by therapeutic drug monitoring (TDM) (if available) are suggested in treating patients with intra-abdominal candidiasis [97]. The PK and antifungal activity of the three echinocandins: anidulafungin, micafungin, and caspofungin were assessed in ascites fluid and plasma of critically ill adults treated for suspected or proved invasive candidiasis [98], showing that standard daily doses of anidulafungin, micafungin, and caspofungin may result in ascites fluid concentrations that inhibit proliferation of *C. albicans* and *C. glabrata*, but are not fungicidal.

Azole antifungal agents are not recommended as empiric therapy because activity against non-*albicans Candida* spp. is not universal. Isavuconazole penetration into ascites fluid is variable [99]. Overall success of treatment with isavuconazole in cases of intra-abdominal candidiasis depends on the interplay of the susceptibility of the isolate, the immune status of the host, and possibly other factors yet to be elucidated. Whereas azoles are not considered first-choice therapy due to the possibility of resistance and numerous drug-drug interactions (especially with fluconazole), an alternative may be lipid formulations of amphotericin B [100]. The IDSA guidelines recommend the use of a standard-dose echinocandin as initial therapy, and a lipid formulation of amphotericin B (3–5 mg/kg daily) for patients with suspected azole- and echinocandin-resistant *Candida* infections [95]. The ESICM/ESCMID guidelines make a “strong” recommendation for the use of echinocandins and a “moderate” strength recommendation for lipid-formulation amphotericin B (L-amB) [94]. Recently, a single 5 mg/kg/kg administration of L-amB whilst waiting for the result of 1,3-beta-D-glucan testing was reported to be safe and cost-effective in a single-center experience [101].

Clinical conditions**Statement 17**

Sepsis and septic shock are time-dependent emergencies and resuscitation should start immediately (High-quality evidence, Strong recommendation).

Statement 18

Fluid administration should be individualized for every patient, based on the evaluation of a need for fluid and on any pre-morbid conditions (Low-quality evidence, strong recommendation).

The WISS study [1] showed that mortality was increased significantly by sepsis and that mortality was increased further in patients who developed severe sepsis or septic shock. Sepsis-related mortality was as follows: no sepsis, 1.2%; sepsis, 4.4%; severe sepsis, 27.8%; septic shock, 67.8%. Since that time, clinical severity grading of patients with sepsis has been re-defined by SEPSIS-3

[102, 103], which eliminated “severe sepsis” as a redundant category and re-defined “sepsis” as infection associated with organ dysfunction. Under SEPSIS-3, sepsis is defined as life-threatening organ dysfunction due to a dysregulated host response, stressing the potential lethality of this condition and the need for urgent recognition and intervention. Organ dysfunction is defined as an increase in the Sequential Organ Failure Assessment (SOFA) score of 2 points or more [104], whereas septic shock is characterised by a vasopressor requirement to maintain mean arterial pressure (mAP) ≥ 65 mm Hg and a serum lactate concentration < 2 mmol/L (> 18 mg/dL) after restoration of euvolemia. Human immune responses to infection can vary among individuals. Some patients can “overreact” by generating a massive “cytokine storm,” whereas other patients may be less reactive, or can restore homeostasis promptly, appearing to have a lesser response to a similar infection. Prompt identification of patients for resuscitation and surgical intervention substitutes for deranged or failing host responses, particularly of the peritoneal cavity, and may improve patient outcomes via prompt restoration of homeostasis [105, 106] and maintenance of peritoneal toilet.

Prompt intravenous fluid administration is mandatory in patients with sepsis and septic shock.

Two randomized single-center trials [107, 108] compared balanced crystalloid solution to isotonic saline in critically ill adults, finding that mortality, new-onset kidney replacement therapy, and persistent kidney dysfunction were each lower with balanced crystalloids. Although albumin is theoretically more efficient than crystalloid in sustaining oncotic pressure, it is more expensive and there is no clear benefit to its use [106].

Statement 19

Vasopressor agents should be administered to restore organ perfusion as soon as possible if blood pressure is not restored after initial fluid resuscitation (Low-quality evidence, Strong recommendation).

If fluid resuscitation fails or is protracted, vasopressor agents should be administered to restore organ perfusion, maintaining but usually not exceeding the aforementioned target for mAP. The initial vasopressor of choice is norepinephrine, which has a beta-agonist effect at low doses but is increasingly an alpha-agonist at escalating doses [109, 110]. Although most patients in shock show improvement in hemodynamics after starting norepinephrine, a proportion of patients remains with a poor clinical response to catecholamines, e.g., requiring large doses (> 0.5 mcg/Kg/min of norepinephrine) to achieve mAP of 65 mm Hg, if the threshold is reached at all [111]. In refractory cases, addition of a second vasopressor may be advantageous rather than increasing further the norepinephrine dose. Low-dose arginine vasopressin

(0.03–0.06 IU/min by continuous infusion) has a “catecholamine-sparing” effect, and also reduces mortality [112].

Statement 20

Fluid overload should be avoided in adults with sepsis or septic shock of abdominal origin (Very low-quality evidence, Strong recommendation).

To avoid an adverse outcome, fluid overload should be avoided in adults with sepsis or septic shock of abdominal origin for several reasons. Especially for patients requiring urgent surgical intervention, overly aggressive fluid resuscitation may increase intra-abdominal pressure and heighten the inflammatory response, which is associated with a higher risk of complications [113]. The systemic inflammatory response, increased vascular permeability, and aggressive fluid resuscitation predispose to intraluminal and extravascular fluid sequestration, ascites formation, and bowel wall edema. These changes, if the abdominal wall has been closed, may result in intra-abdominal hypertension (IAH) and abdominal compartment syndrome (compromised organ function, primarily respiratory and renal).

Statement 21

Specific adjunctive therapy can be considered in selected patients, evaluating the potential benefit and possible harm. (Low quality evidence, Weak recommendation)

In sepsis, mortality is higher when both pro- and anti-inflammatory cytokine concentrations are elevated [114, 115]. The rationale of using extracorporeal blood purification in patients with septic shock is twofold: Clearance of bacterial lipopolysaccharides or other mediators, and modulation of the immune response. Blood purification for sepsis has consisted of various techniques: High-volume hemofiltration, high-adsorption hemofiltration, high cut-off membrane hemofiltration, plasma exchange, and hybrid systems [116]. A systematic review and meta-analysis of RCTs between various blood purification techniques and all-cause mortality in human beings with sepsis [117] included 10 single- and 6 multicenter studies; techniques used included hemoperfusion (10 studies), hemofiltration (4 studies), and plasma exchange (2 studies). Overall, blood purification decreased mortality, but results were driven mainly by hemoperfusion in trials conducted in Japan.

Polymyxin B hemoperfusion (PMB-HP) is controversial [118, 119]. A French multi-center RCT (ABDOMIX) enrolled 243 patients with septic shock within 12 h after emergency surgery for perforated viscus [120], but no benefit was demonstrated. The EUPHRATES RCT of PMB-HP in patients with septic shock and confirmed endotoxemia also failed to show improved survival [121].

However, some patients with septic shock had extremely high burdens of endotoxin activity ($EA \geq 0.9$). In a post-hoc analysis of the EUPHRATES trial evaluating 194 patients with EA between 0.60 and 0.89 who completed two treatments (active or sham), at 28 days, 23/88 patients (26.1%) in the active group died *versus* 39/106 (36.8%) in the sham group. Twenty-eight-day survival of the active group was longer than survival of the sham group (HR 0.56, 95% CI 0.33–0.95, $p=0.03$) [122]. The in-progress TIGRIS RCT of endotoxic shock (EA 0.60–0.89) (Clinical Trials.gov identifier: NCT03901807) may be more informative.

Intravenous immunoglobulin (IVIg), another mechanism for neutralization of endotoxin and other bacterial toxins [123] is controversial for surgical sepsis. In a meta-analysis of the clinical effectiveness of IVIg [123] (18 RCTs), IVIg reduced sepsis mortality, but low study quality, heterogeneous Ig preparations and dosing regimens, and different comparators (placebo *versus* albumin) confounded interpretation. The available evidence is insufficient to support the widespread use of IVIg as therapy for sepsis.

Statement 22

For adults with septic shock, early and properly administered empiric antibiotic therapy has a significant impact on outcome (Moderate-quality evidence, Strong recommendation).

Early, appropriate empiric antibiotic therapy for septic shock can have a substantial beneficial impact on outcome, independent of the anatomic origin of infection [124]. Given the high risk of death from septic shock and the strong association of delayed antibiotic therapy with mortality, prompt antibiotic administration is crucial. However, for sepsis without shock, the association between time to antibiotic administration and mortality is less pronounced [125, 126]. Therefore, absent shock and if source control is adequate, it may be possible to defer antibiotic therapy until culture and susceptibility testing can inform targeted therapy [126].

Statement 23

In adults with sepsis or septic shock, appropriate dosing and administration of antibiotics should include a loading dose and extended or continuous infusion for beta-lactam agents. (Low-quality evidence, Strong recommendation)

Critically ill patients with sepsis or septic shock may exhibit altered antibiotic PK. Therefore, higher-than-standard loading doses of beta-lactam agents should be considered regardless of renal function [127]. Once the regimen is established, it is important to reassess daily, because fluctuating fluid balance and organ function may affect antibiotic PK. In critically ill patients, plasma

creatinine is an unreliable marker of renal function. For beta-lactams, appropriate dosing supports time-dependent bactericidal activity. Beta-lactam antibiotic bactericidal activity is optimal when antibiotic concentrations are maintained (just) above the MIC of the pathogen for at least 70% of the dosing interval ($fT \geq 70\%$) [129]. For beta-lactam agents, prolonged or continuous infusions optimize $fT > MIC$ [128–131].

Tissue distribution is another important aspect to consider in prescribing antibiotics because high concentrations at the infection site may prevent resistance development. Tissue distribution is higher for lipophilic than hydrophilic agents, but disease-related factors (e.g., binding to plasma proteins, serum albumin concentration) may influence tissue distribution. In a 2020 prospective observational study of critically ill patients with cIAI who required surgery and received empiric beta-lactam antibiotic therapy [132] high doses of beta-lactams ensured 100% $fT > 4 \times MIC$ for 78% of patients within the first 24 h. TDM of beta-lactams, as a dose optimization and individualization tool, has been recommended, but despite potential benefit, not all centers perform TDM for beta-lactams [133].

Statement 24

After rapid patient stabilization, adults with sepsis and septic shock should undergo a source control procedure within 6 h. Time from admission to initiation of surgery for source control is a crucial determinant of survival in from sepsis and septic shock (Low-quality evidence, Strong recommendation).

Comprehensive knowledge of disease and sepsis pathophysiology, the range of surgical and nonsurgical options, and how to balance benefit and risk are all necessary to devise a treatment plan and achieve source control as soon as possible following resuscitation. Limited data suggest that source control should be obtained within six hours for optimal results. Bloos et al. [134] demonstrated that the median time from onset of severe sepsis or septic shock to source control for 1,011 patients from 44 German ICUs was 2 h for survivors and 5.7 h for non-survivors. Time to source control > 6 h was independently associated with increased mortality (as were age and disease severity). A 2017 trial [135] demonstrated that achievement of surgical source control was significantly related to 28-day mortality, with 1% increased mortality per hour of delay to source control. A 2014 prospective observational study of 154 patients with GI perforation [136] demonstrated that each hour of delay correlated with decreased survival, with the target time for a favourable outcome within 6 h from admission. A 2022 post-hoc analysis of a multi-center observational study (Abdominal Sepsis Study, AbSeS) of 2,621 adult ICU patients with cIAIs (306 ICUs, 42 countries) [137]

included 1,077 cases of microbiology-confirmed secondary peritonitis. Mortality was 29.7%. A stepwise increase in mortality was observed with increasing SOFA scores. The highest odds of death were associated with septic shock, late-onset hospital-acquired peritonitis, and failed source control. Compared with “emergency” source control intervention (within <2 h of diagnosis), “urgent” source control was the only modifiable covariate associated with lower odds of mortality.

Arguably the strongest available evidence for achieving source control within 6 h comes from a planned post-hoc analysis of the MEDUSA trial [138], including forty German hospitals, 4,792 patients who received antimicrobial therapy, and 1,595 patients who underwent surgical source control. 28-day mortality increased by 0.42% for each hour of delay, and was significant in patients with and without shock. Delays >6 h significantly increased mortality. Each hour of delay in antimicrobial therapy also increased the risk of progression from sepsis to shock. However, time to surgical source control was not associated with decreased odds of successful source control or increased odds of death when adjusted for confounders. Only among septic shock patients was delay of source control significantly related to mortality.

Statement 25

For adults with abdominal sepsis or septic shock, on-demand re-laparotomy (as opposed to scheduled reoperation) should be the first-choice approach to re-operation (Moderate quality evidence, Strong recommendation).

Statement 26

Damage control surgery may be an option in selected physiologically deranged patients with sepsis of abdominal origin (Very low-quality evidence, Strong recommendation).

Statement 27

Based on the complexity of IAI (variable clinical presentations depending on the original site of infection, the causative organism, the pattern of acute organ dysfunction, and the underlying health status of the patient), an individualized, carefully designed approach to source control is the best pathway to follow (Very low-quality evidence, Strong recommendation).

After successful implementation in trauma, damage control laparotomy (DCL) has been used increasingly to manage non-traumatic emergencies, including critically ill patients with cIAIs [139]. DCL for cIAI, sepsis, and critical illness, meaning abbreviated laparotomy with subsequent reoperation for delayed definitive repair after physiologic resuscitation is completed [140], can be

lifesaving. DCS is linked closely to the “open abdomen” approach, which provides manual peritoneal toilet while intraperitoneal host defenses recover from the infectious insult. The open abdomen, plicated with an easily removed/replaced temporary abdominal closure device, facilitates early identification and drainage of any residual infection and removal of peritoneal fluid, reducing the risk of abdominal compartment syndrome. Definitive intervention and anastomosis are deferred until the patient is resuscitated, vital signs and hemodynamics are normal, and peritoneal contamination is controlled. However, open-abdomen techniques may require multiple returns to the operating room, or bedside laparotomy in the ICU. The potential downside of repetitive DCL is substantive potential complications, including “entero-atmospheric” fistula, loss of abdominal wall domain, and large abdominal wall hernias, encouraging early (within 7 days) abdominal wall reconstruction to prevent those complications. The COOL study may clarify the role of open abdomen management in the setting of sepsis of abdominal origin [141].

Host immune status

Statement 28

Immunocompromised patients with IAIs are at increased risk of morbidity and mortality and may fail standard NOM when otherwise indicated. (Low-quality evidence, Strong recommendation)

Host immune status is important to consider, but difficult to quantify. Immunocompromised patients represent heterogeneous states that include congenital conditions (T- or B-cell defects or macrophage dysfunction), and can afflict newborns, children, and adults. Acquired conditions include human immunodeficiency virus/acquired immunodeficiency syndrome, patients with malignant liquid or solid tumors undergoing chemotherapy [142], solid-organ transplant (SOT) recipients, or patients with inflammatory or rheumatologic disease treated with immunomodulators [143]. Notably, immune checkpoint inhibitor therapy has been associated rarely with the development of acute appendicitis [144].

Diagnosis and treatment in immunocompromised patients can be challenging. Immunocompromised patients with IAIs are at increased risk of morbidity and mortality [145–147], and may fail standard NOM when otherwise indicated. As such, most patients require surgical intervention. Recent multi-society source control guidelines [9] proposed a categorization of patients into 3 classes according to current condition, comorbidities, and ongoing therapies (e.g., anticoagulants or steroids), together with their immunologic state (Table 1).

SOT is an established option for patients with end-stage organ dysfunction. Patient survival has increased

Table 1 Proposed Patient Classification for Comorbidities and Immunocompromise [9]

| Patient stratification | |
|------------------------|--|
| CLASS A | Healthy patients with none or well-controlled comorbidities, and no immunocompromise, where the infection is the principal problem. |
| CLASS B | Patients with major comorbidities or moderate immunocompromise, but stable clinically, in whom the infection, without control, can worsen the prognosis rapidly. |
| CLASS C | Patients with major comorbidities in advanced stages or severe immunocompromise, in which the infection worsens an already severe clinical condition. |

in recent years due to improved surgical techniques, perioperative management, immunosuppressive agents and tactics, and anti-infective prophylaxis to prevent opportunistic infection. Although the incidence of post-SOT cytomegalovirus infection has decreased, infections linked to MDR gram-negative bacteria are increasing. Considering that SOT recipients are exposed frequently to antibiotics in the healthcare setting [148], the vulnerability of SOT recipients to MDR infections is a crucial determinant of decisions to start antimicrobial therapy.

Conclusions

cIAI, a condition that is sometimes difficult to manage, requires more than antimicrobial therapy to guide the treatment of the patient, even in the era of AMR. Therapy should be individualized if possible. The anatomic extent of infection, the presumed pathogens involved and risk factors for AMR, the origin of the infection, the patient's clinical condition, the host's immune status, and available treatment options should be always assessed to optimize the management of patients with cIAIs.

Abbreviations

| | |
|--------|--|
| AAC | Acute Acalculous Cholecystitis |
| AMR | Antimicrobial Resistance |
| APACHE | Acute Physiology and Chronic Health Evaluation |
| CDC | Centers for Disease Control and Prevention |
| CI | Confidence Interval |
| cIAIs | Complicated Intra-abdominal Infections |
| CRE | Carbapenem-Resistant Enterobacteriales |
| CT | Computed Tomography |
| DAP | Device-Associated Peritonitis |
| DCL | Damage Control Laparotomy |
| ECDC | European Centre for Disease Prevention and Control |
| ESBLs | Extended-Spectrum Beta-Lactamases |
| ESCMID | European Society of Clinical Microbiology and Infectious Diseases |
| ESICM | European Society of Intensive Care Medicine |
| GI | Gastrointestinal |
| GRADE | Grading of Recommendations Assessment, Development, and Evaluation |
| HR | Hazard Ratio |
| IAH | Intra-Abdominal Hypertension |
| IAIs | Intra-Abdominal Infections |
| ICU | Intensive Care Unit |
| IDSA | Infectious Disease Society of America |
| IVg | Intravenous Immunoglobulin |
| KPC | <i>K. pneumoniae</i> Carbapenemase |
| mAP | Mean Arterial Pressure |
| MBLs | Metallo-Beta-Lactamases |

| | |
|--------|--|
| MDR | Multidrug-Resistant |
| MIC | Minimal Inhibitory Concentration |
| NOM | Non-Operative Management |
| OR | Odds Ratio |
| PCT | Procalcitonin |
| PDR | Pan Drug-Resistant |
| PID | Pelvic Inflammatory Disease |
| PK | Pharmacokinetics |
| PMB-HP | Polymyxin B Hemoperfusion |
| PP | Post-operative Peritonitis |
| RCT | Randomized Controlled Trial |
| SOFA | Sequential Organ Failure Assessment |
| SOT | Solid-Organ Transplant |
| TDM | Therapeutic Drug Monitoring |
| TOC | Test-Of-Cure |
| uIAIs | Uncomplicated Intra-Abdominal Infections |
| US | Ultrasonography |
| XDR | Extensively Drug-Resistant |

Author contributions

M.S. wrote the original draft. All authors were contributors in reviewing and editing the manuscript. All authors read and approved the final manuscript.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

A.W.K. serves as the PI of the COOL trial, which previously was partially supported by the 3 M/Acelity Corporation until Aug 2022. A.W.K. is also a member of the Canadian Forces Medical Services and has consulted for the 3 m/Acelity Corporation, Zoll Medical, Innovative Trauma Care, and CSL Behring. A.W.K. is the Director of the TeleMentored Ultrasound Supported Medical Interventions (TMUSMI) Research group and serves in the Canadian Forces Medical Services. R.G.S. conflicts are on Data Management and Safety Board for Advarra. R.C.M. received research support (paid to Institution) from AiCuris, GeoVax and Biotest. He received honoraria for participation in a scientific advisory board organized by Shionogi. All the other authors declare that they have no competing interests. R.G.S. conflicts are on Data Management and Safety Board for Advarra. R.C.M. received research support (paid to Institution) from AiCuris, GeoVax and Biotest. He received honoraria for participation in a scientific advisory board organized by Shionogi. All the other authors declare that they have no competing interests.

Author details

¹Department of Surgery, Macerata Hospital, Via Santa Lucia 2, Macerata 62100, Italy

²Department of Surgery, Weill Cornell Medicine, New York, NY, USA

³Anesthesia and Intensive Care Unit, Bufalini Hospital - AUSL della Romagna, Cesena, Italy

⁴Department of Internal Medicine, University of South Carolina School of Medicine, Columbia, SC, USA

⁵Department of General and Emergency Surgery, Fondazione IRCCS San Matteo, Pavia, Italy

⁶Division of Trauma and Acute Care Surgery, Scripps Clinic Medical Group, La Jolla, CA, USA

⁷Emergency, Urgency and Trauma Surgery, School of Medicine, University of Buenos Aires, Buenos Aires, Argentina

⁸Department of Internal Medicine and Pediatrics, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium

- ⁹Department of Surgery, School of Medicine, University of Louisville, Louisville, KY, USA
- ¹⁰Comparative Effectiveness and Clinical Outcomes Research Center - CECORC - Riverside University Health System, Moreno Valley, CA, USA
- ¹¹Department of Surgery, Loma Linda University School of Medicine, Loma Linda, CA, USA
- ¹²Department of Surgery, Rimini "Infermi" Hospital, Rimini, Italy
- ¹³Department of Surgery, Medical City Plano, Plano, TX, USA
- ¹⁴First Department of Internal Medicine-Infectious Diseases, Hygeia General Hospital, Athens, Greece
- ¹⁵Department of Surgical Sciences, Nelson R Mandela School of Clinical Medicine, University of KwaZulu-Natal, and Inkosi Albert Luthuli Central Hospital, Durban, South Africa
- ¹⁶Department of General and Thoracic Surgery, University Hospital of Giessen, Giessen, Germany
- ¹⁷Department of Surgery, University of Southern California, Los Angeles, CA, USA
- ¹⁸Department of Surgery and Critical Care Medicine, University of Calgary, Foothills Medical Centre, Calgary, AB, Canada
- ¹⁹Global Alliance for Infections in Surgery, Macerata, Italy
- ²⁰Department of Anaesthesia and Intensive Care Unit, AP-HM, Aix-Marseille University, North Hospital, Marseille, France
- ²¹Department of Intensive Care Medicine, Multidisciplinary Intensive Care Research Organisation, St James's Hospital, Dublin, Ireland
- ²²Trinity College Dublin, Dublin, Ireland
- ²³Centro de Investigación Biomedica En Red Entermedades Respiratorias, Institute of Health Carlos III, Madrid, Spain
- ²⁴Pulmonary Department, Hospital Clinic, Universitat de Barcelona, Barcelona, Spain
- ²⁵Department of Surgery, Harborview Medical Centre, University of Washington, Seattle, USA
- ²⁶Pandit Bhagwat Dayal Sharma Postgraduate Institute of Medical Sciences, Rohtak, India
- ²⁷Section of Infectious Diseases, Department of Internal Medicine, Wake Forest University School of Medicine, Winston-Salem, NC, USA
- ²⁸Emergency Department, Policlinico Umberto I, Sapienza University, Rome, Italy
- ²⁹Anesthesiology and Critical Care Medicine Department, DMU PARABOL, Bichat Hospital, AP-HP, Université Paris Cité, Paris, France
- ³⁰Division of Trauma and Acute Care Surgery, Department of Surgery, Fundación Valle del Lili, Cali, Colombia
- ³¹Department of Surgical Science, University of Cagliari, Cagliari, Italy
- ³²Global Health eCore, Vall d'Hebron University Hospital Campus, Barcelona 08035, Spain
- ³³Medicine Department, Universitat Internacional de Catalunya, Sant Cugat del Valles, Spain
- ³⁴Department of Surgery, Western Michigan University Homer Stryker M.D. School of Medicine, Kalamazoo, MI, USA
- ³⁵Emergency Surgery and Trauma, Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome, Italy
- ³⁶Infectious Disease and Intensive Care Unit, Pontchaillou University Hospital, Rennes, France
- ³⁷Department of Medicine, MetroHealth Medical Center, Cleveland, OH, USA
- ³⁸Division of Infectious Diseases and Geographic Medicine, University of Texas Southwestern Medical Center, Dallas, TX, USA
- ³⁹Emergency Surgery department, Meilahti Tower Hospital, HUS Helsinki University Hospital, Haartmaninkatu 4, Helsinki, Finland
- ⁴⁰First Department of Surgery, Department of Abdominal, Thoracic Surgery and Traumatology, First Faculty of Medicine, Charles University and General University Hospital, Prague, Czech Republic
- ⁴¹Emergency and General Surgery Department, Bufalini Hospital, Cesena, Italy
- ⁴²Department of Medicine, Division of Infectious Diseases, Northeast Ohio Medical University, Rootstown, OH, USA
- ⁴³General, Emergency and Trauma Surgery Unit, Pisa University Hospital, Pisa, Italy

References

- Meng R, Guan X, Sun L, Fei Z, Li Y, Luo M, et al. The efficacy and safety of eravacycline compared with current clinically common antibiotics in the treatment of adults with complicated intra-abdominal infections: a bayesian network meta-analysis. *Front Med (Lausanne)*. 2022;9:935343.
- Barie PS. Outcomes of surgical sepsis. *Surg Infect (Larchmt)*. 2018;19(2):230–5.
- Sartelli M, Abu-Zidan FM, Catena F, Griffiths EA, Di Saverio S, Coimbra R, et al. Global validation of the WSES Sepsis Severity score for patients with complicated intra-abdominal infections: a prospective multicentre study (WISS Study). *World J Emerg Surg*. 2015;10:61.
- Sartelli M, Coccolini F, Kluger Y, Agastra E, Abu-Zidan FM, Abbas AES, WSES/GAIS/SIS-, et al. E/WSES/AAST global clinical pathways for patients with intra-abdominal infections. *World J Emerg Surg*. 2021;16(1):49.
- Sartelli M, Chichom-Mefire A, Labricciosa FM, Hardcastle T, Abu-Zidan FM, Adesunkanmi AK, et al. The management of intra-abdominal infections from a global perspective: 2017 WSES guidelines for management of intra-abdominal infections. *World J Emerg Surg*. 2017;12:29.
- Bhangu A, Søreide K, Di Saverio S, Assarsson JH, Drake FT. Acute appendicitis: modern understanding of pathogenesis, diagnosis, and management. *Lancet*. 2015;386(10000):1278–87.
- Gallagher JR, Charles A. Acute cholecystitis: a review. *JAMA*. 2022;327(10):965–75.
- Gupta S, Kaushik R. Peritonitis-the eastern experience. *World J Emerg Surg*. 2006;26:13.
- Coccolini F, Sartelli M, Sawyer R, Rasa K, Viaggi B, Abu-Zidan F, et al. Source control in emergency general surgery: WSES, GAIS, SIS-E, SIS-A guidelines. *World J Emerg Surg*. 2023;18(1):41.
- Coccolini F, Sartelli M, Kirkpatrick AW. What do we mean by source control and what are we trying to accomplish with an open abdomen in severe complicated intra-abdominal sepsis? *J Trauma Acute Care Surg*. 2024 Jan 10.
- Moore CB, Smith RS, Herbertson R, Toevs C. Does use of intraoperative irrigation with open or laparoscopic appendectomy reduce post-operative intra-abdominal abscess? *Am Surg*. 2011;77(1):78–80.
- St Peter SD, Adibe OO, Iqbal CW, Fike FB, Sharp SW, Juang D, et al. Irrigation versus suction alone during laparoscopic appendectomy for perforated appendicitis: a prospective randomized trial. *Ann Surg*. 2012;256(4):581–5.
- Hartwich JE, Carter RF, Wolfe L, Goretsky M, Heath K, St Peter SD, Lanning DA. The effects of irrigation on outcomes in cases of perforated appendicitis in children. *J Surg Res*. 2013;180(2):222–5.
- Dariusshnia SR, Mitchell JW, Chaudry G, Hogan MJ. Society of Interventional Radiology quality improvement standards for image-guided percutaneous drainage and aspiration of abscesses and fluid collections. *J Vasc Interv Radiol*. 2020;31(4):662–e6664.
- Schuetz P, Beishuizen A, Broyles M, Ferrer R, Gavazzi G, Gluck EH, et al. Procalcitonin (PCT)-guided antibiotic stewardship: an international expert consensus on optimized clinical use. *Clin Chem Lab Med*. 2019;57(9):1308–18.
- Simon L, Gauvin F, Amre DK, Saint-Louis P, Lacroix J. Serum procalcitonin and C-reactive protein levels as markers of bacterial infection: a systematic review and meta-analysis. *Clin Infect Dis*. 2004;39(2):206–17.
- Rud B, Vejborg TS, Rappoport ED, Reitsma JB, Wille-Jørgensen P. Computed tomography for diagnosis of acute appendicitis in adults. *Cochrane Database Syst Rev*. 2019;2019(11):CD009977.
- Shaish H, Ream J, Huang C, Troost J, Gaur S, Chung R, et al. Diagnostic accuracy of Unenhanced computed tomography for evaluation of Acute Abdominal Pain in the Emergency Department. *JAMA Surg*. 2023;158(7):e231112.
- Childs DD, Lalwani N, Craven T, Arif H, Morgan M, Anderson M, Fulcher A. A meta-analysis of the performance of ultrasound, hepatobiliary scintigraphy, CT and MRI in the diagnosis of acute cholecystitis. *Abdom Radiol (NY)*. 2024;49(2):384–98.
- Arruzza E, Milanese S, Li LSK, Dizon J. Diagnostic accuracy of computed tomography and ultrasound for the diagnosis of acute appendicitis: a systematic review and meta-analysis. *Radiography (Lond)*. 2022;28(4):1127–41.
- Reitz KM, Kennedy J, Li SR, Handzel R, Tonetti DA, Neal MD, et al. Association between time to source control in sepsis and 90-day mortality. *JAMA Surg*. 2022;157(9):817–26.
- Andeweg CS, Wegdam JA, Groenewoud J, van der Wilt GJ, van Goor H, Bleichrodt RP. Toward an evidence-based step-up approach in diagnosing diverticulitis. *Scand J Gastroenterol*. 2014;49(7):775–84.
- Laméris W, van Randen A, van Es HW, van Heesewijk JP, van Ramshorst B, Bouma WH, et al. Imaging strategies for detection of urgent conditions in patients with acute abdominal pain: diagnostic accuracy study. *BMJ*. 2009;338:b2431.

Received: 8 April 2024 / Accepted: 1 June 2024

Published online: 08 June 2024

24. Uyeda JW. Utility of MR imaging in abdominopelvic emergencies. *Radiol Clin North Am.* 2019;57(4):705–15.
25. Pouli S, Kozana A, Papakitsou I, Daskalogiannaki M, Raissaki M. Gastrointestinal perforation: clinical and MDCT clues for identification of aetiology. *Insights Imaging.* 2020;11(1):31.
26. Sartelli M, Catena F, Di Saverio S, Ansaloni L, Malangoni M, Moore EE, et al. Current concept of abdominal sepsis: WSES position paper. *World J Emerg Surg.* 2014;9(1):22.
27. Andersen BR, Kallehave FL, Andersen HK. Antibiotics versus placebo for prevention of postoperative infection after appendectomy. *Cochrane Database Syst Rev.* 2005;3:CD001439.
28. Mazeh H, Mizrahi I, Dior U, Simanovsky N, Shapiro M, Freund HR, Eid A. Role of antibiotic therapy in mild acute calculus cholecystitis: a prospective randomized controlled trial. *World J Surg.* 2012;36(8):1750–9.
29. Regimbeau JM, Fuks D, Pautrat K, Mauvais F, Haccart V, Msika S, et al. Effect of postoperative antibiotic administration on postoperative infection following cholecystectomy for acute calculous cholecystitis: a randomized clinical trial. *JAMA.* 2014;312(2):145–54.
30. de Almeida Leite RM, Seo DJ, Gomez-Eslava B, Hossain S, Lesegretain A, de Souza AV, et al. Nonoperative vs Operative Management of uncomplicated Acute appendicitis: a systematic review and Meta-analysis. *JAMA Surg.* 2022;157(9):828–34.
31. Sallinen V, Akl EA, You JJ, Agarwal A, Shoucair S, Vandvik PO, et al. Meta-analysis of antibiotics versus appendectomy for non-perforated acute appendicitis. *Br J Surg.* 2016;103(6):656–67.
32. Salminen P, Paajanen H, Rautio T, Nordström P, Aarnio M, Rantanen T, et al. Antibiotic therapy vs appendectomy for treatment of uncomplicated Acute appendicitis: the APPAC Randomized Clinical Trial. *JAMA.* 2015;313(23):2340–8.
33. Yeh DD, Vasileiou G, Qian S, Zhang H, Abdul Jawad K, Dodgion C, et al. Appendectomy versus nonoperative management of simple appendicitis: a post hoc analysis of an Eastern Association for the Surgery of Trauma multicenter study using a hierarchical ordinal scale. *J Trauma Acute Care Surg.* 2022;92(6):1031–8.
34. Lyu Y, Cheng Y, Wang B, Zhao S, Chen L. Early versus delayed laparoscopic cholecystectomy for acute cholecystitis: an up-to-date meta-analysis of randomized controlled trials. *Surg Endosc.* 2018;32(12):4728–41.
35. Chabok A, Pählman L, Hjern F, Haapaniemi S, Smedh K, AVOD Study Group. Randomized clinical trial of antibiotics in acute uncomplicated diverticulitis. *Br J Surg.* 2012;99(4):532–9.
36. Mali JP, Mentula PJ, Leppäniemi AK, Sallinen VJ. Symptomatic treatment for uncomplicated acute diverticulitis: a prospective cohort study. *Dis Colon Rectum.* 2016;59:529–34.
37. Daniels L, Ünlü Ç, de Korte N, van Dieren S, Stockmann HB, Vrouwenraets BC, et al. Randomized clinical trial of observational versus antibiotic treatment for a first episode of CT-proven uncomplicated acute diverticulitis. *Br J Surg.* 2017;104(1):52–61.
38. Barie PS, Kao LS, Moody M, Sawyer RG. Infection or inflammation: are uncomplicated acute appendicitis, acute cholecystitis, and acute diverticulitis infectious diseases? *Surg Infect (Larchmt).* 2023;24(2):99–111.
39. van Dijk ST, Daniels L, Ünlü Ç, de Korte N, van Dieren S, Stockmann HB, et al. Long-Term effects of omitting antibiotics in uncomplicated Acute Diverticulitis. *Am J Gastroenterol.* 2018;113(7):1045–52.
40. Sartelli M, Weber DG, Kluger Y, Ansaloni L, Coccolini F, Abu-Zidan F, et al. WSES guidelines for the management of acute left sided colonic diverticulitis in the emergency setting. *World J Emerg Surg.* 2016;11:37.
41. Dharmarajan S, Hunt SR, Birnbaum EH, Fleshman JW, Mutch MG. The efficacy of nonoperative management of acute complicated diverticulitis. *Dis Colon Rectum.* 2011;54(6):663–71.
42. Sallinen VJ, Mentula PJ, Leppäniemi AK. Nonoperative management of perforated diverticulitis with extraluminal air is safe and effective in selected patients. *Dis Colon Rectum.* 2014;57:875–81.
43. Ahmed A, Feroz SH, Dominic JL, Muralidharan A, Thirunavukarasu P. Is emergency appendectomy better than elective appendectomy for the treatment of appendiceal phlegmon? A review. *Cureus.* 2020;12(12):e12045.
44. Ra JH, Rattan R, Patel NJ, Bhattacharya B, Butts CA, Gupta S, et al. Duration of antimicrobial treatment for complicated intra-abdominal infections after definitive source control: a systematic review, meta-analysis, and practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg.* 2023;95(4):603–12.
45. Sawyer RG, Claridge JA, Nathens AB, Rotstein OD, Duane TM, Evans HL, et al. Trial of short-course antimicrobial therapy for intraabdominal infection. *N Engl J Med.* 2015;372(21):1996–2005.
46. Hassinger TE, Guidry CA, Rotstein OD, Duane TM, Evans HL, Cook CH, et al. Longer-duration antimicrobial therapy does not prevent treatment failure in high-risk patients with complicated intra-abdominal infections. *Surg Infect (Larchmt).* 2017;18(6):659–63.
47. de Wijckerslooth EML, Boerma EG, van Rossem CC, van Rosmalen J, Baeten CIM, Beverdam FH, et al. 2 days versus 5 days of postoperative antibiotics for complex appendicitis: a pragmatic, open-label, multicentre, non-inferiority randomised trial. *Lancet.* 2023;401(10374):366–76.
48. Montravers P, Tubach F, Lescot T, Veber B, Esposito-Farèse M, Seguin P, DURAPOP Trial Group, et al. Short-course antibiotic therapy for critically ill patients treated for postoperative intra-abdominal infection: the DURAPOP randomised clinical trial. *Intensive Care Med.* 2018;44(3):300–10.
49. Nobre V, Harbarth S, Graf JD, Rohner P, Pugin J. Use of procalcitonin to shorten antibiotic treatment duration in septic patients: a randomized trial. *Am J Respir Crit Care Med.* 2008;177:498–505.
50. Oliveira CF, Botoni FA, Oliveira CR, Silva CB, Pereira HA, Serufo JC, Nobre V. Procalcitonin versus C-reactive protein for guiding antibiotic therapy in sepsis: a randomized trial. *Crit Care Med.* 2013;41:2336–43.
51. Qu R, Ji Y, Ling Y, Ye CY, Yang SM, Liu YY, et al. Procalcitonin is a good tool to guide duration of antibiotic therapy in patients with severe acute pancreatitis. A randomized prospective single-center controlled trial. *Saudi Med J.* 2012;33(4):382–7.
52. Schroeder S, Hochreiter M, Koehler T, Schweiger AM, Bein B, Keck FS, von Spiegel T. Procalcitonin (PCT)-guided algorithm reduces length of antibiotic treatment in surgical intensive care patients with severe sepsis: results of a prospective randomized study. *Langenbecks Arch Surg.* 2009;394(2):221–6.
53. Shehabi Y, Sterba M, Garrett PM, Rachakonda KS, Stephens D, Harrigan P, et al. Procalcitonin algorithm in critically ill adults with undifferentiated infection or suspected sepsis. A randomized controlled trial. *Am J Respir Crit Care Med.* 2014;190:1102–10.
54. Huang TS, Huang SS, Shyu YC, Lee CH, Jwo SC, Chen PJ, Chen HY. A procalcitonin-based algorithm to guide antibiotic therapy in secondary peritonitis following emergency surgery: a prospective study with propensity score matching analysis. *PLoS ONE.* 2014;9(3):e90539.
55. Maseda E, Suarez-de-la-Rica A, Anillo V, Tamayo E, García-Bernedo CA, Ramasco F, et al. Procalcitonin-guided therapy may reduce length of AB treatment in intensive care unit patients with secondary peritonitis: a multicenter retrospective study. *J Crit Care.* 2015;30:537–42.
56. Slieker JC, Aellen S, Eggimann P, Guarnero V, Schäfer M, Demartines N. Procalcitonin-guided antibiotics after surgery for Peritonitis: a randomized controlled study. *Gastroenterol Res Pract.* 2017;2017:3457614.
57. Blot S, De Waele JJ, Vogelaers D. Essentials for selecting antimicrobial therapy for intra-abdominal infections. *Drugs.* 2012;72(6):e17–32.
58. Montravers P, Grall N, Kantor E, Augustin P, Boussion K, Zappella N. Microbiological profile of patients treated for postoperative peritonitis: temporal trends 1999–2019. *World J Emerg Surg.* 2023;18(1):58.
59. Sartelli M, Cristini F, Coccolini F, Labricciosa FM, Siquini W, Catena F. A proposal for a classification guiding the selection of Appropriate Antibiotic Therapy for Intra-abdominal infections. *Antibiot (Basel).* 2022;11(10):1394.
60. Blot S, Antonelli M, Arvaniti K, Blot K, Creagh-Brown B, de Lange D, et al. Epidemiology of intra-abdominal infection and sepsis in critically ill patients: AbSeS, a multinational observational cohort study and ESICM trials Group Project. *Intensive Care Med.* 2019;45(12):1703–17.
61. Magiorakos AP, Srinivasan A, Carey RB, Carmeli Y, Falagas ME, Giske CG, et al. Multidrug-resistant, extensively drug-resistant and pan-drug-resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. *Clin Microbiol Infect.* 2012;18(3):268–81.
62. Giannella M, Trearich EM, De Rosa FG, Del Bono V, Bassetti M, Lewis RE, et al. Risk factors for carbapenem-resistant Klebsiella pneumoniae bloodstream infection among rectal carriers: a prospective observational multicentre study. *Clin Microbiol Infect.* 2014;20(12):1357–62.
63. Sartelli M, Weber DG, Ruppé E, Bassetti M, Wright BJ, Ansaloni L, et al. Antimicrobials: a global alliance for optimizing their rational use in intra-abdominal infections (AGORA). *World J Emerg Surg.* 2016;11:33.
64. Magiorakos AP, Burns K, Rodríguez Baño J, Borg M, Daikos G, Dumpis U, et al. Infection prevention and control measures and tools for the prevention of entry of carbapenem-resistant Enterobacteriaceae into healthcare settings: Guidance from the European Centre for Disease Prevention and Control. *Antimicrob Resist Infect Control.* 2017;6:113.

65. Morrissey I, Hackel M, Badal R, Bouchillon S, Hawser S, Biedenbach D. A review of ten years of the study for Monitoring Antimicrobial Resistance trends (SMART) from 2002 to 2011. *Pharmaceuticals (Basel)*. 2013;6(11):1335–46.
66. Cain SE, Kohn J, Bookstaver PB, Albrecht H, Al-Hasan MN. Stratification of the impact of inappropriate empirical antimicrobial therapy for Gram-negative bloodstream infections by predicted prognosis. *Antimicrob Agents Chemother*. 2015;59(1):245–50.
67. Karaiskos I, Giamarellou H. Carbapenem-sparing strategies for ESBL producers: when and how. *Antibiot (Basel)*. 2020;9:61.
68. Harris PNA, Tambyah PA, Lye DC, Mo Y, Lee TH, Yilmaz M, et al. Effect of piperacillin-tazobactam vs. meropenem on 30-day mortality for patients with *E. Coli* or *Klebsiella pneumoniae* bloodstream infection and ceftriaxone resistance: a randomized clinical trial. *JAMA*. 2018;320:984–94.
69. Tamma PD, Aitken SL, Bonomo RA, Mathers AJ, van Duin D, Clancy CJ. Infectious Diseases Society of America 2022 Guidance on the treatment of extended-spectrum β -lactamase Producing *enterobacterales* (ESBL-E), Carbapenem-Resistant *Enterobacterales* (CRE), and *Pseudomonas aeruginosa* with difficult-to-treat Resistance (DTR-*P. aeruginosa*). *Clin Infect Dis*. 2022;75(2):187–212.
70. Gatti M, Viaggi B, Rossolini GM, Pea F, Viale P. An evidence-based Multidisciplinary Approach focused at creating algorithms for targeted therapy of BSIs, cUTIs, and cIAls caused by *enterobacterales* in critically ill adult patients. *Infect Drug Resist*. 2021;14:2461–98.
71. Heizmann WR, Löschnann PA, Eckmann C, von Eiff C, Bodmann KF, Petrik C. Clinical efficacy of tigecycline used as monotherapy or in combination regimens for complicated infections with documented involvement of multiresistant bacteria. *Infection*. 2015;43:37–43.
72. McGovern PC, Wible M, El-Tahtawy A, Biswas P, Meyer RD. All-cause mortality imbalance in the tigecycline phase 3 and 4 clinical trials. *Int J Antimicrob Agents*. 2013;41:463–7.
73. Scott LJ, Eravacycline. A review in complicated intra-abdominal infections. *Drugs*. 2019;79:315–24.
74. Solomkin J, Evans D, Slepavicius A, Lee P, Marsh A, Tsai L, et al. Assessing the efficacy and safety of Eravacycline vs Ertapenem in complicated intra-abdominal infections in the investigating gram-negative infections treated with eravacycline (IGNITE 1) trial: a Randomized Clinical Trial. *JAMA Surg*. 2017;152(3):224–32.
75. Solomkin JS, Gardovskis J, Lawrence K, Montravers P, Sway A, Evans D, Tsai L. IGNITE4: results of a phase 3, Randomized, Multicenter, prospective trial of Eravacycline vs Meropenem in the treatment of complicated Intraabdominal infections. *Clin Infect Dis*. 2019;69(6):921–9.
76. Hobbs ALV, Gelfand MS, Cleveland KO, Saddler K, Sierra-Hoffman MA. A retrospective, multicentre evaluation of eravacycline utilisation in community and academic hospitals. *J Glob Antimicrob Resist*. 2022;29:430–3.
77. Shorr AF, Pogue JM, Mohr JF. Intravenous fosfomycin for the treatment of hospitalized patients with serious infections. *Expert Rev Anti Infect Ther*. 2017;15(10):935–45.
78. Solomkin J, Hershberger E, Miller B, Popejoy M, Friedland I, Steenberg J, et al. Ceftolozane/tazobactam plus metronidazole for complicated intra-abdominal infections in an era of multidrug resistance: results from a randomized, double-blind, phase 3 trial (ASPECT-cIAI). *Clin Infect Dis*. 2015;60:1462–71.
79. Mazuski JE, Gasink LB, Armstrong J, Broadhurst H, Stone GG, Rank D, et al. Efficacy and safety of ceftazidime-avibactam plus metronidazole versus meropenem in the treatment of complicated intra-abdominal infection: results from a randomized, controlled, double-blind, phase 3 program. *Clin Infect Dis*. 2016;62:1380–9.
80. Giurazza R, Mazza MC, Andini R, Sansone P, Pace MC, Durante-Mangoni E. Emerging treatment options for multi-drug-resistant bacterial infections. *Life (Basel)*. 2021;11(6):519.
81. Motsch J, Murta de Oliveira C, Stus V, Köksal I, Lyulko O, Boucher HW, et al. RESTORE-IMI 1: a Multicenter, Randomized, double-blind trial comparing efficacy and Safety of Imipenem/Relebactam vs Colistin Plus Imipenem in patients with Imipenem-nonsusceptible bacterial infections. *Clin Infect Dis*. 2020;70(9):1799–808.
82. Tzouveleki LS, Markogiannakis A, Piperaki E, Souli M, Daikos GL. Treating infections caused by carbapenemase-producing *Enterobacteriaceae*. *Clin Microbiol Infect*. 2014;20(9):862–72.
83. Iregui A, Khan Z, Landman D, Quale J. Activity of cefiderocol against *Enterobacterales*, *Pseudomonas aeruginosa*, and *Acinetobacter baumannii* endemic to medical centers in New York City. *Microb Drug Resist*. 2020;26(7):722–6.
84. Sanders JM, Tessier JM, Sawyer R, Dellinger EP, Miller PR, Namias N, et al. Does isolation of *Enterococcus* affect outcomes in intra-abdominal infections? *Surg Infect (Larchmt)*. 2017;18(8):879–85.
85. Dupont H, Friggeri A, Touzeau J, Airapetian N, Tinturier F, Lobjoie E, et al. *Enterococci* increase the morbidity and mortality associated with severe intra-abdominal infections in elderly patients hospitalized in the intensive care unit. *J Antimicrob Chemother*. 2011;66(10):2379–85.
86. Morvan AC, Hengy B, Garrouste-Orgeas M, Ruckly S, Forel JM, Argaud L, et al. Impact of species and antibiotic therapy of enterococcal peritonitis on 30-day mortality in critical care-An analysis of the OUTCOMEREA database. *Crit Care*. 2019;23(1):307.
87. Zhang J, Yu WQ, Chen W, Wei T, Wang CW, Zhang JY, et al. Systematic review and Meta-analysis of the efficacy of appropriate empiric anti-enterococcal therapy for intra-abdominal infection. *Surg Infect (Larchmt)*. 2021;22(2):131–43.
88. Bancke Laverde BL, Maak M, Langheinrich M, Kersting S, Denz A, Krautz C, et al. The role of intraoperative swab during appendectomy in patients with uncomplicated and complicated appendicitis. *Int J Colorectal Dis*. 2023;38(1):272.
89. Davies HO, Alkhamisi NA, Dawson PM. Peritoneal fluid culture in appendicitis: review in changing times. *Int J Surg*. 2010;8:426–9.
90. Bassetti M, Rello J, Blasi F, Goossens H, Sotgiu G, Tavoschi L, et al. Systematic review of the impact of appropriate versus inappropriate initial antibiotic therapy on outcomes of patients with severe bacterial infections. *Int J Antimicrob Agents*. 2020;56(6):106184.
91. Bassetti M, Vena A, Giacobbe DR, Trucchi C, Ansaldi F, Antonelli M, et al. Risk factors for intra-abdominal candidiasis in intensive care units: results from EUCANDICU study. *Infect Dis Ther*. 2022;11(2):827–40.
92. Lagunes L, Rey-Pérez A, Martín-Gómez MT, Vena A, de Egea V, Muñoz P, et al. Association between source control and mortality in 258 patients with intra-abdominal candidiasis: a retrospective multi-centric analysis comparing intensive care versus surgical wards in Spain. *Eur J Clin Microbiol Infect Dis*. 2017;36(1):95–104.
93. León C, Ruiz-Santana S, Saavedra P, et al. A bedside scoring system (Candida score) for early antifungal treatment in nonneutropenic critically ill patients with Candida colonization. *Crit Care Med*. 2006;34:730–7.
94. Martin-Loeches I, Antonelli M, Cuenca-Estrella M, Dimopoulos G, Einav S, De Waele JJ, et al. ESICM/ESCMID task force on practical management of invasive candidiasis in critically ill patients. *Intensive Care Med*. 2019;45(6):789–805.
95. Pappas PG, Kauffman CA, Andes DR, Clancy CJ, Marr KA, Ostrosky-Zeichner L, et al. Clinical practice guideline for the management of candidiasis: 2016 update by the Infectious Diseases Society of America. *Clin Infect Dis*. 2016;62:e1–50.
96. Shields RK, Nguyen MH, Press EG, Clancy CJ. Abdominal candidiasis is a hidden reservoir of echinocandin resistance. *Antimicrob Agents Chemother*. 2014;58(12):7601–5.
97. Gioia F, Gomez-Lopez A, Alvarez ME, de la Gomez-García E, Martín-Dávila P, Cuenca-Estrella M, et al. Pharmacokinetics of echinocandins in suspected candida Peritonitis: a potential risk for resistance. *Int J Infect Dis*. 2020;101:24–8.
98. Welte R, Oberacher H, Gasperetti T, Pfisterer H, Griesmacher A, Santner T, et al. Pharmacokinetics and antifungal activity of echinocandins in ascites fluid of critically ill patients. *Antimicrob Agents Chemother*. 2021;65(7):e0256520.
99. Lahmer T, Batres Baires G, Schmid RM, Wiessner JR, Ulrich J, Reichert M, et al. Penetration of isavuconazole in ascites fluid of critically ill patients. *J Fungi (Basel)*. 2021;7(5):376.
100. Maseda E, Martín-Loeches I, Zaragoza R, Pemán J, Fortún J, Grau S, et al. Critical appraisal beyond clinical guidelines for intraabdominal candidiasis. *Crit Care*. 2023;27(1):382.
101. Rinaldi M, Bartoletti M, Bonazzetti C, Carocchia N, Gatti M, Tazza B, et al. Tolerability of pulsed high-dose L-AmB as pre-emptive therapy in patients at high risk for intra-abdominal candidiasis: a phase 2 study (LAMBDA study). *Int J Antimicrob Agents*. 2023;62(6):106998.
102. Singer M, Deutschman CS, Seymour CW, Shankar-Hari M, Annane D, Bauer M, et al. The third international consensus definitions for sepsis and septic shock (SEPSIS-3). *JAMA*. 2016;315:801–10.
103. Ho VP, Kaafarani H, Rattan R, Namias N, Evans H, Zakrisson TL. Sepsis 2019: what surgeons need to know. *Surg Infect (Larchmt)*. 2020;21(3):195–204.
104. Esteban A, Frutos-Vivar F, Ferguson ND, Peñuelas O, Lorente JA, Gordo F, et al. Sepsis incidence and outcome: contrasting the intensive care unit with the hospital ward. *Crit Care Med*. 2007;35:1284–9.

105. Rubio I, Osuchowski MF, Shankar-Hari M, Skirecki T, Winkler MS, Lachmann G, et al. Current gaps in sepsis immunology: new opportunities for translational research. *Lancet Infect Dis*. 2019;19:e422–36.
106. Evans L, Rhodes A, Alhazzani W, Antonelli M, Coopersmith CM, French C, et al. Surviving Sepsis Campaign: International guidelines for Management of Sepsis and Septic Shock 2021. *Crit Care Med*. 2021;49(11):e1063–143.
107. Semler MW, Self WH, Wanderer JP, Ehrenfeld JM, Wang L, Byrne DW, et al. Balanced crystalloids versus saline in critically ill adults. *N Engl J Med*. 2018;378:829–39.
108. Self WH, Semler MW, Wanderer JP, Wang L, Byrne DW, Collins SP, et al. Balanced crystalloids versus saline in noncritically ill adults. *N Engl J Med*. 2018;378:819–28.
109. Jentzer JC, Coons JC, Link CB, Schmidhofer M. Pharmacotherapy update on the use of vasopressors and inotropes in the intensive care unit. *J Cardiovasc Pharmacol Ther*. 2015;20(3):249–60.
110. Weinberger J, Rhee C, Klompas M. A critical analysis of the literature on time-to-antibiotics in suspected sepsis. *J Infect Dis*. 2020;222(Suppl 2):S110–8.
111. Nandhabalan P, Ioannou N, Meadows C, Wyncoll D. Refractory septic shock: our pragmatic approach. *Crit Care*. 2018;22(1):215.
112. Gordon AC, Mason AJ, Thirunavukkarasu N, Perkins GD, Cecconi M, Cepkova M, et al. Effect of early vasopressin vs norepinephrine on kidney failure in patients with septic shock: the VANISH randomized clinical trial. *JAMA*. 2016;316(5):509–18.
113. Malbrain MLNG, Van Regenmortel N, Saugel B, De Tavernier B, Van Gaal PJ, Joannes-Boyau O, et al. Principles of fluid management and stewardship in septic shock: it is time to consider the four D's and the four phases of fluid therapy. *Ann Intensive Care*. 2018;8(1):66.
114. Kellum JA, Kong L, Fink MP, Weissfeld LA, Yealy DM, Pinsky MR, et al. Understanding the inflammatory cytokine response in pneumonia and sepsis: results of the genetic and inflammatory markers of Sepsis (GenIMS) study. *Arch Intern Med*. 2007;167(15):1655–63.
115. Gogos CA, Drosou E, Bassaris HP, Skoutelis A. Pro- versus anti-inflammatory cytokine profile in patients with severe sepsis: a marker for prognosis and future therapeutic options. *J Infect Dis*. 2000;181(1):176–80.
116. Peng Z, Pai P, Han-Min W, Jun Z, Hong-Bao L, Rong L, Chen H. Evaluation of the effects of pulse high-volume hemofiltration in patients with severe sepsis: a preliminary study. *Int J Artif Organs*. 2010;33(8):505–11.
117. Zhou F, Peng Z, Murugan R, Kellum JA. Blood purification and mortality in sepsis: a meta-analysis of randomized trials. *Crit Care Med*. 2013;41:2209–20.
118. Cruz DN, Perazella MA, Bellomo R, de Cal M, Polanco N, Corradi V, et al. Effectiveness of polymyxin B-immobilized fiber column in sepsis: a systematic review. *Crit Care*. 2007;11(2):R47.
119. Cruz DN, Antonelli M, Fumagalli R, Foltran F, Brienza N, Donati A, et al. Early use of polymyxin B hemoperfusion in abdominal septic shock: the EUPHAS randomized controlled trial. *JAMA*. 2009;301(23):2445–52.
120. Payen DM, Guillhot J, Launey Y, Lukaszewicz AC, Kaaki M, Veber B, et al. Early use of polymyxin B hemoperfusion in patients with septic shock due to peritonitis: a multicenter randomized control trial. *Intensive Care Med*. 2015;41(6):975–84.
121. Klein DJ, Foster D, Schorr CA, Kazempour K, Walker PM, Dellinger RP. The EUPHRATES trial (evaluating the Use of Polymyxin B Hemoperfusion in a Randomized controlled trial of adults treated for endotoxemia and septic shock): study protocol for a randomized controlled trial. *Trials*. 2014;15:218.
122. Klein DJ, Foster D, Walker PM, Bagshaw SM, Mekonnen H, Antonelli M. Polymyxin B hemoperfusion in endotoxemic septic shock patients without extreme endotoxemia: a post hoc analysis of the EUPHRATES trial. *Intensive Care Med*. 2018;44(12):2205–12.
123. Busani S, Damiani E, Cavazzuti I, Donati A, Girardis M. Intravenous immunoglobulin in septic shock: review of the mechanisms of action and meta-analysis of the clinical effectiveness. *Minerva Anestesiol*. 2016;82(5):559–72.
124. Kumar A. Antimicrobial delay and outcome in severe sepsis. *Crit Care Med*. 2014;42(12):e802.
125. Hranjec T, Rosenberger LH, Swenson B, Metzger R, Flohr TR, Politano AD, et al. Aggressive versus conservative initiation of antimicrobial treatment in critically ill surgical patients with suspected intensive-care-unit-acquired infection: a quasi-experimental, before and after observational cohort study. *Lancet Infect Dis*. 2012;12(10):774–80.
126. Seymour CW, Gesten F, Prescott HC, Friedrich ME, Iwashyna TJ, Phillips GS, et al. Time to treatment and mortality during mandated emergency care for sepsis. *N Engl J Med*. 2017;376(23):2235–44.
127. Pea F, Viale P, Furlanut M. Antimicrobial therapy in critically ill patients: a review of pathophysiological conditions responsible for altered disposition and pharmacokinetic variability. *Clin Pharmacokinet*. 2005;44(10):1009–34.
128. Yu Z, Pang X, Wu X, Shan C, Jiang S. Clinical outcomes of prolonged infusion (extended infusion or continuous infusion) versus intermittent bolus of meropenem in severe infection: a meta-analysis. *PLoS ONE*. 2018;13(7):e0201667.
129. Rhodes NJ, Liu J, O'Donnell JN, Dulhunty JM, Abdul-Aziz MH, Berko PY, et al. Prolonged infusion piperacillin-tazobactam decreases mortality and improves outcomes in severely ill patients: results of a systematic review and meta-analysis. *Crit Care Med*. 2018;46(2):236–43.
130. Vardakas KZ, Voulgaris GL, Maliaros A, Samonis G, Falagas ME. Prolonged versus short-term intravenous infusion of antipseudomonal β -lactams for patients with sepsis: a systematic review and meta-analysis of randomised trials. *Lancet Infect Dis*. 2018;18(1):108–20.
131. Yang H, Zhang C, Zhou Q, Wang Y, Chen L. Clinical outcomes with alternative dosing strategies for piperacillin/tazobactam: a systematic review and meta-analysis. *PLoS ONE*. 2015;10(1):e0116769.
132. Leon L, Guerci P, Pape E, Thilly N, Luc A, Germain A, et al. Serum and peritoneal exudate concentrations after high doses of β -lactams in critically ill patients with severe intra-abdominal infections: an observational prospective study. *J Antimicrob Chemother*. 2020;75(1):156–61.
133. Pai Mangalore R, Peel TN, Udy AA, Peleg AY. The clinical application of beta-lactam antibiotic therapeutic drug monitoring in the critical care setting. *J Antimicrob Chemother*. 2023;78(10):2395–405.
134. Bloos F, Thomas-Rüddel D, Rüddel H, Engel C, Schwarzkopf D, Marshall JC, et al. Impact of compliance with infection management guidelines on outcome in patients with severe sepsis: a prospective observational multi-center study. *Crit Care*. 2014;18(2):R42.
135. Bloos F, Rüddel H, Thomas-Rüddel D, Schwarzkopf D, Pausch C, Harbarth S, et al. Effect of a multifaceted educational intervention for anti-infectious measures on sepsis mortality: a cluster randomized trial. *Intensive Care Med*. 2017;43(11):1602–12.
136. Azuhata T, Kinoshita K, Kawano D. Time from admission to initiation of surgery for source control is a critical determinant of survival in patients with gastrointestinal perforation with associated septic shock. *Crit Care*. 2014;18:R87.
137. De Pascale G, Antonelli M, Deschepper M, Arvaniti K, Blot K, Brown BC, et al. Poor timing and failure of source control are risk factors for mortality in critically ill patients with secondary peritonitis. *Intensive Care Med*. 2022;48(11):1593–606.
138. Rüddel H, Thomas-Rüddel DO, Reinhart K, Bach F, Gerlach H, Lindner M, et al. MEDUSA study group. Adverse effects of delayed antimicrobial treatment and surgical source control in adults with sepsis: results of a planned secondary analysis of a cluster-randomized controlled trial. *Crit Care*. 2022;26(1):51.
139. Haltmeier T, Falke M, Quaile O, Candinas D, Schnüriger B. Damage-control surgery in patients with nontraumatic abdominal emergencies: a systematic review and meta-analysis. *J Trauma Acute Care Surg*. 2022;92(6):1075–85.
140. Weber DG, Bendinelli C, Balogh ZJ. Damage control surgery for abdominal emergencies. *Br J Surg*. 2014;101(1):e109–118.
141. Kirkpatrick AW, Coccolini F, Ansaloni L, Roberts DJ, Tolonen M, McKee JL, et al. Closed or open after source control laparotomy for severe complicated intra-abdominal sepsis (the COOL trial): study protocol for a randomized controlled trial. *World J Emerg Surg*. 2018;13:26.
142. Samdani T, Pieracci FM, Eachempati SR, Benaroch-Gampel J, Weiss A, Pietanza MC, et al. Colonic diverticulitis in chemotherapy patients: should operative indications change? A retrospective cohort study. *Int J Surg*. 2014;12(12):1489–94.
143. Coccolini F, Improta M, Sartelli M, Rasa K, Sawyer R, Coimbra R, et al. Acute abdomen in the immunocompromised patient: WSES, SIS-E, WSIS, AAST, and GAIS guidelines. *World J Emerg Surg*. 2021;16(1):40.
144. Mathew A, Shatila M, Lai Z. Characteristics of appendicitis after immune checkpoint inhibitor therapy among cancer patients. *J Cancer Res Clin Oncol*. 2023;149(8):4591–9.
145. Tartaglia D, Cremonini C, Annunziata E, Catena F, Sartelli M, Kirkpatrick AW, et al. Acute diverticulitis in immunocompromised patients: evidence from an international multicenter observational registry (web-based International Register of Emergency Surgery and trauma, WIRES-T). *Tech Coloproctol*. 2023;27(9):747–57.
146. Hwang SS, Cannom RR, Abbas MA, Etzioni D. Diverticulitis in transplant patients and patients on chronic corticosteroid therapy: a systematic review. *Dis Colon Rectum*. 2010;53:1699–707.

147. Oor JE, Atema JJ, Boermeester MA, Vrouwenraets BC, Ünlü Ç. A systematic review of complicated diverticulitis in post-transplant patients. *J Gastrointest Surg.* 2014;18(11):2038–46.
148. Pilmis B, Weiss E, Scemla A, Le Monnier A, Grossi PA, Slavin MA, et al. Multidrug-resistant enterobacteriales infections in abdominal solid organ transplantation. *Clin Microbiol Infect.* 2023;29(1):38–43.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.