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Editorial Update

Source Control for Surgical Infections

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Abstract. The concept of source control encompasses all of the physical interventions, surgical and otherwise, that are used to treat infection. Although source control is one of the most important aspects of the treatment of serious infection, it has received relatively little attention. It is the topic of this overview, which draws heavily on a book we edited recently: *Source Control: A Guide to the Management of Surgical Infection* (Springer-Verlag, 2002). The first section focuses on general considerations: historical perspective, scientific basis, and surgical principles of source control. The second section highlights specific considerations of source control in various situations.

The best infectious disease specialist for the surgical patient is the educated surgeon.

Surgical infections are infections that develop in surgical patients. They may develop before the operation or occur postoperatively. In fact, many surgical infections arise in patients who did not undergo an operation or who do not need one. Using such a broad definition, surgical infections form an integral, significant part of any general, thoracic, or vascular surgery practice. The concept of source control encompasses all of those physical interventions—surgical and otherwise—that are used to treat infection. Although source control is one of the most important aspects of the treatment of serious infection, it has received relatively little attention. It is the topic of this overview, which draws heavily on a book we edited recently: *Source Control: A Guide to the Management of Surgical Infection* (Springer-Verlag, 2002) [1].

Historical Perspective

Most of the interventions used during routine management of infection are recent innovations. Principles of hemodynamic resuscitation and support trace their origins to the work of such pioneers as Alfred Blalock during the early twentieth century, who established that shock reflected an absolute or relative intravascular volume deficit, rather than a severe fright [2]. The antibacterial activity of penicillin was identified by Fleming during the 1920s, and agents with antimicrobial activity were used to treat peritonitis during the early decades of the twentieth century [3]. Specific antimicrobial therapy did not become practical until World War II and the ensuing decades [4–6]. Successful modulation of the host response elicited by infection remains a largely unfulfilled dream, although recent promise has been shown by a variety of strategies [7, 8].

The surgical management of infection dates to antiquity. Evidence of trephination has been identified in skulls that are upward of 10,000 years old, and the management of abscesses and infected wounds was well codified in the medical practice of the Egyptians, Babylonians, Greeks, and Romans. Ambroise Paré, during the fifteenth century, undertook the first empiric comparisons of the management of infected wounds, and the drainage of intracavitary abscesses had become an accepted practice even before the microorganisms that caused them were identified during the mid-nineteenth century. Incision and drainage of an appendiceal abscess was recorded in 1530, and the first definitive management of appendicitis by appendectomy appears to have been accomplished by Groves in rural Canada in 1883 [9], almost 50 years before the discovery of penicillin.

Scientific Basis of Surgical Source Control

Source control of infection has a long and enduring history of empiric efficacy; yet it has been little studied in well designed randomized trials, and the principles of its application are implicit, rather than explicit. Surgical procedures such as appendectomy are accepted unquestioningly because they make sense and because clinicians believe, not without reason, that patients benefit from their use. With a few important exceptions deriving from common diseases where the rationale for surgical intervention may be questioned [10, 11], it is unlikely that randomized controlled trials comparing interventional to noninterventional strategies will be undertaken.

The formal evaluation of specific approaches to source control is also confounded by the nature of the decisions that must be made [12]. Clinical trials compare *populations of patients*, but source control decisions must be made for the *individual patient*, in whom factors such as diagnostic uncertainty, physiologic stability, premorbid health status, previous surgical interventions, the surgeon's experience and skills, and the availability of operating time and support-

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Table 1. Definitions of terms.

Source control	All physical measures undertaken to eliminate a source of infection, control ongoing contamination, and restore premorbid anatomy and function
Sinus	Abnormal communication to an epithelial cell-lined surface
Fistula	Abnormal communication between two epithelial cell-lined surfaces
Abscess	Fluid-filled collection of tissue fluid, tissue debris, neutrophils, and bacteria contained within a fibrous capsule
Drainage	Creation of a controlled sinus or fistula
Débridement	Removal of devitalized tissue, foreign bodies, or other areas advantageous to bacterial growth

ive care combine to create circumstances that are unique to a single patient. The approach to management of a patient with a diverticular abscess, for example, may well differ for a previously healthy patient with localized findings on physical examination and computed tomography (CT) scan versus management of the same problem in a patient who has had a prior renal transplant and a history of peritoneal dialysis. In the former, percutaneous catheter drainage or resection and primary anastomosis are reasonable options, whereas in the latter the optimal choice may be a Hartman procedure. Moreover, we hear the voices of those who question this assertion: They only serve to underline the truism that surgical decision-making is based on the marriage of evidence from clinical studies, inferences from biology, and the elusive element of surgical experience.

What Is Source Control?

It is important to agree on the meanings of the words used (Table 1). We use the term "source control" for all those physical measures that are undertaken to eliminate a focus of infection, to control ongoing contamination, and to restore premorbid anatomy and function [13]. Although many of these interventions are surgical procedures, the scope of source control includes such nonsurgical interventions as radiologically directed drainage of intracavitary abscesses, removal of colonized urinary or vascular catheters, and removal of devitalized tissue by frequent dressing changes.

Principles of Source Control

Source control is the applied biology of inflammation. Its foundations lie in optimal exploitation of the processes of inflammation and tissue repair to expedite the resolution of infection. It is based on three principles.

1. Drainage of abscesses
2. Débridement of nonviable or infected tissue
3. Definitive management of the anatomic abnormality responsible for ongoing microbial contamination, thereby restoring normal function and anatomy

Drainage

Local activation of inflammation results in a coordinated series of biologic responses that serve to bring cells of the innate immune system, predominantly neutrophils, to the site of infectious challenge and to isolate the resulting melange of microorganisms and host immune cells from the rest of the host. Changes in endothelial cell expression of adhesion molecules and reciprocal changes in recruited neutrophils favor neutrophil localization and emigration into the tissues to the site of challenge [14]. Local activation of coagulation, supported by macrophage-derived cytokines, circulating coagulation factors, reduced endothelial anticoagulant activity, and up-regulation of tissue factors on local macrophages serve to convert fibrinogen to fibrin, creating a barrier between the host and the mixture of tissue fluid, neutrophils, bacteria, and cellular debris that reflect the local battle being waged [15]. The result is an *abscess*, its contents contained within a fibrous capsule. Formation of an abscess effectively isolates the microbial challenge from the systemic circulation, but it also isolates it from the further influx of host immune cells or antibiotics.

Drainage provides egress to the exterior for the contents of the abscess, converting a contained collection to a controlled *fistula* (if there is internal communication with an epithelial cell-lined surface) or a *sinus* if there is not. Drainage of an abscess is simply the creation of a controlled sinus or fistula. Several self-evident inferences can be made from this observation.

1. Drainage alone is successful only in circumstances when creation of a controlled sinus or fistula is possible; drainage of the free peritoneal cavity is not possible, nor does drainage alone suffice if the contents of the collection to be drained include solid necrotic tissue in addition to liquid pus.
2. The prosthesis used to create the controlled sinus—the drain—must permit free flow of the abscess contents to the exterior; soft Penrose drains maintain a potential space, but they do not produce a well controlled sinus.
3. If the objective is simply to create a controlled sinus, the intervention that accomplishes this end with minimum risk and physiologic derangement to the patient is the best therapeutic option; usually this means an initial attempt at percutaneous drainage.
4. With modern imaging techniques, virtually all collections of clinical significance can be visualized preoperatively and many of them adequately drained.
5. Although it is sometimes difficult to resist the urge to operate, particularly in an unstable and ill patient, the act of surgery itself accomplishes nothing more than the creation of controlled sinuses or fistulas and the removal of dead tissue. Therefore the operation should be limited to this objective.

Débridement

Devitalized tissue and extravasated blood provide an excellent culture medium for microbial growth, which is protected from circulating phagocytes or antibiotics by virtue of the lack of a blood supply. Similarly, the presence of a foreign body greatly increases the risk of developing an established infection [16]. Débridement is the process of removing nonviable tissue, and, by extension, foreign bodies or devices that promote bacterial growth. Whereas the principles of drainage eliminate the fluid components of an infection, those of débridement are directed against its solid components.

Early in the course of a process that creates tissue injury, the demarcation between viable and nonviable tissue may be far from absolute. Areas of frankly necrotic tissue may be found in larger islands of viable tissue, or tissues may appear ischemic but potentially salvageable. The problem of distinguishing viable from nonviable tissue and the consequences of failing to do so reliably can create significant clinical dilemmas. When necrotic tissue is on the surface of the wound and the technique of débridement is gentle (e.g., the use of wet to dry saline dressings) the dilemma is obviated. Surgical débridement of necrotizing soft tissue infections is somewhat more challenging, as the surgeon tries to remove all necrotic tissue but minimize the resulting defect, making reconstruction easier. Bleeding from viable tissues is readily controlled when it occurs in the skin or muscle, so it is generally decided to err on the side of removing viable tissue rather than fail to débride necrotic material. Serial evaluation and débridement facilitates surgical decision-making. The excision of necrotic bowel is more complex, particularly when the cause of the compromised state is venous thrombosis or a low-flow state. The benefits of resection must be weighed against the consequences of loss of bowel length; the dilemma is usually best resolved by a planned second-look laparotomy. Finally, peripancreatic retroperitoneal necrosis is remarkably well tolerated, whereas blind exploration in the retroperitoneum carries a significant risk of provoking uncontrollable hemorrhage: Hence, delayed débridement has become the preferred management for patents with suspected infected necrosis.

Similar principles underlie the decision to remove an infected foreign body. When the foreign body is a urinary or vascular catheter, the risks are minimal; when it is an infected aortic graft or heart valve, they are not.

Definitive Management

Infections requiring source control measures typically arise because of a definable anatomic lesion, such as a perforated appendix or a duodenal ulcer, a bullet wound to the esophagus, or a colonized joint prosthesis. The ultimate aim of therapy is to restore function with the least risk and to correct the abnormality that created the infection. Once again, the optimal decision-making process weighs the long-term benefits against the short-term risks. Excision of a perforated appendix is a relatively straightforward undertaking, and so removing the focus of infection by appendectomy is the standard approach to the management of appendicitis. For the patient with long-standing symptoms and a well circumscribed appendiceal abscess seen on CT scans, the safer procedure may be percutaneous drainage followed by appendectomy at a later date. On the other hand, the physiologically unstable patient with multiple gunshot wounds to the colon is best managed by damage control alone, leaving reconstruction for later. Anticipating the long-term needs for reconstruction and making the appropriate decisions that ultimately facilitate them is the hallmark of an experienced surgeon. It directs such decisions as the siting of stomas and the placement of incisions.

Time and Mother Nature are the surgeon's two greatest allies. By exercising careful patience, many a seemingly impossible situation can be converted to one that is merely a challenge.

Specific Considerations

A meaningful overview of all specific considerations involved with source control in surgical infections would require the writing of yet another book. The editors of the *World Journal of Surgery* asked us for an "Editorial Update" (not for a book), so we include here only highlights from the various contributions to our book on source control.

Biologic Rationale

Host defenses are occasionally incapable of combating the introduction of microbes and establishment of infection, particularly when a large number of microbes are present or host defenses are diminished, or when an ongoing source of microbial contamination exists. Inadequate source control increases morbidity and mortality as much as sevenfold [17].

Experimental Models

The CLP (cecal ligation and puncture) model of sepsis is associated with cellular dysfunction (e.g., hepatocellular depression) and upregulation of proinflammatory cytokines [e.g., tumor necrosis factor (TNF)]. Furthermore, the ligated and punctured cecum can be excised at various intervals to serve as a source control model of sepsis. Such a model can be used for testing pharmacologic agents in the management of sepsis [18].

Drainage

Percutaneous abscess drainage (PD) is the preferred option in most cases [19]. Operative intervention is indicated when PD has failed or when there are absolute contraindications to PD. PD can temporize, permitting delayed definitive management of an infectious focus.

Débridement and "Peritoneal Toilet"

The degree of peritoneal contamination correlates with the severity of infection and outcome [20]. The host responds to peritoneal infection by absorbing pathogens into the bloodstream and by mounting a local peritoneal inflammatory reaction; both responses kill bacteria but affect the host adversely. The goal of peritoneal toilet is to remove mechanically as many contaminants as possible, thereby reducing the severity of the infection and limiting adverse host responses.

Device Removal

Make sure the diagnosis of infection is secure. Determine whether device removal [21] would pose a significant risk. Assess complicating factors (e.g., virulence of infection, debilitation or immunosuppression of the patient) and the history (Has an attempt at conservative therapy failed?). When in doubt, take it out.

Definitive Versus Temporizing Therapy

Surgical choices at the time of achieving source control may require that the procedure be *temporizing* with the knowledge that a subsequent procedure is required. Alternatively, the choice may be *definitive*, with the procedure designed to control the source and manage the underlying disease [22]. The judgment to select a temporizing versus a definitive procedure requires an integrated assessment of (1) the surgeon's knowledge about the underlying disease, (2) systemic host factors, and (3) the severity of the local inflammatory response.

Extent of Surgical Therapy

The more extensive the initial intervention, the greater is the challenge of subsequent reconstruction: the optimal intervention is that which accomplishes the source control objectives in the simplest manner [23].

Failed Source Control

Failure of source control is more important than "antibiotic failure" when defining the outcome of surgical infections in general and intraabdominal infections in particular [24]. Source control of an intraabdominal infection may fail because of a poor choice of operation or the correct operation performed poorly or with poor timing. Systemic consequences of failed source control include nosocomial infections, nutritional and metabolic disorders, and multiple organ dysfunction syndrome.

Diffuse Peritonitis

Aggressive initial surgical source control including extensive intraoperative lavage is sufficient in most cases (about 90%). Continuous lavage, laparostomy, planned reexploration, or a combination of these procedures is needed only if source control is not possible at the initial operation [25].

Gastric and Proximal Small Bowel

Primary closure can usually be performed for peritonitis originating from a gastric and proximal small bowel source [26].

Colon

Colonic perforations [27] can be classified as traumatic perforation, perforation following localized necrosis from disease, or perforation due to transmural ischemic necrosis caused by impaired vascular flow. The choice of therapy depends on the general condition of the patient, the inflammatory response of the peritoneum, the magnitude of the increased intraabdominal pressure, and the pathology itself. Treatment options include simple suture closure, resection with anastomosis, exteriorization of the colon segment that is perforated, resection without anastomosis and formation of a terminal colostomy with or without a mucous fistula, and staged abdominal repair (STAR) to secure source control by daily inspection during abdominal reentries.

Rectum and Anus

Perianal abscess and infected fistulas. Incision and curettage for drainage of abscess, lay open an associated low fistula, insert a seton in a high fistula, no drains or packing of wounds. Antibiotics are of uncertain value.

Fornier's gangrene. Emergency action, broad-spectrum antibiotics, wide excision of necrotic tissue, leave wounds open and plan for revision. A diverting stoma usually is not necessary.

Anal and perineal trauma. Débridement of devitalized tissue, suture of external sphincter if possible, leave wounds open. A diverting stoma usually is not necessary.

Rectal trauma. Defunctioning sigmoidostomy, suture of rectal wounds, drainage of presacral space, rectal washout. See Nystrom [28] for more details.

Acute appendicitis

Early appendectomy, open or laparoscopic, is standard therapy for acute appendicitis [29]. Appendiceal phlegmon commonly resolves with antibiotic therapy alone. An appendiceal abscess may also respond to antibiotic therapy but requires percutaneous (or surgical) drainage in many instances. Appendicitis occasionally manifests as a more severe, potentially life-threatening problem that may include generalized peritonitis, bacteremia, pylephlebitis, or liver abscesses. It requires appropriate surgical, antibiotic, and supportive therapy.

Bariatric Surgery

Gastrointestinal leaks after bariatric operations [30] can kill. Suture repair of leaks at the gastrojejunostomy site is rarely successful in the face of florid infection. Conversely, leaks in the gastric staple line usually can be closed with sutures. If the leak involves the distal bypassed stomach, tube gastrostomy should be performed. Note that failure to demonstrate a leak radiologically in a patient with signs of a systemic inflammatory response, especially if progressive, should be followed by exploratory laparotomy. Anastomotic leaks are the Achilles' heel of this procedure as far as mortality is concerned.

Gallbladder and the Biliary Tree

Early cholecystectomy is the treatment of choice for acute cholecystitis. Endoscopic sphincterotomy is the treatment of choice for ascending cholangitis [31].

Pancreatic Infection

Prompt débridement is appropriate when pancreatic infection is diagnosed [32]. Late débridement, when possible, is easier and safer. Sterile necrosis infrequently requires débridement, and then it is done late in the course of the disease. Remove necrotic, infected tissue. Avoid acute morbidity associated with necrotic tissue débridement, including bleeding, fistula formation, devascularization of viscera, and splenic injury.

Liver Abscess

Liver abscesses [33] are either pyogenic or parasitic. Early diagnosis and prompt treatment of the underlying cause reduce morbidity and mortality. Source control consists of drainage using surgical or ultrasound/CT-guided aspiration and antibiotic therapy. Hydatid cysts of the liver can be managed surgically as well as percutaneously.

Acute Mesenteric Ischemia

Maintain a high degree of suspicion of acute mesenteric ischemia [34]. The primary goal is diagnosis prior to bowel infarction, a complication that carries a mortality rate of up to 90%. Aggressive use of angiography is appropriate to make the correct diagnosis and to plan surgical intervention. Restoration of bowel perfusion requires not only surgical intervention but also aggressive use of invasive monitoring to ensure adequate resuscitation. Following resection of devitalized bowel, make a plan for a second-look procedure based on the appearance of the bowel.

Esophagus

Early diagnosis, within 24 hours (no associated esophageal diseases), allows primary repair. Delayed diagnosis requires débridement and drainage, reinforced primary repair, or exclusion and diversion. Associated cancer, megaesophagus, and caustic stenosis indicate the need for one-stage esophagectomy with immediate or delayed reconstruction. Always leave adequate drainage [35]. Note that, in fact, we believe that the time of perforation should not enter into treatment decisions to any significant degree. An attempt should be made to close every perforation, and esophageal diversion should be reserved for patients who are almost certainly going to die unless diversion is done.

Pleural Empyema

Primary management of para- or postpneumatic empyemas is with antibiotics [36]. Source control is a secondary measure whose aims are the evacuation of pus and full expansion of the lung. The approach to source control must be adapted to the stage of the disease. The objective of source control in postresectional empyema is to close any bronchopleural fistula and reexpand the lung; after pneumectomy it is to stabilize or obliterate the thoracic space.

Soft Tissue Infections

Necrotizing soft tissue infections (NSTIs) generally involve the subcutaneous tissue, fascia, or deeper tissues [37]. Therefore an NSTI may not be readily apparent on external inspection of the skin. Treatment consists of urgent surgical exploration with drainage and débridement of nonviable or infected tissue. Wounds require frequent inspection until one is assured that tissues remain viable and infection is no longer spreading.

Diabetic Foot

The diabetic foot is a syndrome involving pain, deformation, inflammation, infection, ulceration, and tissue loss of the foot in a diabetic patient [38]. Neuropathy, ischemia, and infection are the principal pathogenic factors. Clinical features include neuropathic and ischemic ulcers and the infected diabetic foot itself. For a diagnosis, one should identify and grade the neuropathology, osteopathy, and vascular pathology. Treatment is aimed at relieving weight from the ulcerated area, eradicating the infection (surgically and with antibiotics), and restoring arterial perfusion.

Hand Infections

For hand infections, determine the nature and extent of the infection. Institute appropriate antimicrobial treatment, and perform surgical débridement and start drainage if necessary. Institute early measures to preserve hand function [39].

Head and Neck

Head and neck cellulitis is treated with antibiotics, with no need for surgical drainage. Progression to an abscess indicates the need of surgical drainage to achieve source control [40].

Vascular Graft Infections

Computed tomographic scanning is currently the most useful test for detecting vascular graft infections [41]. Infections due to methicillin-resistant *Staphylococcus aureus* (MRSA) and *Pseudomonas aeruginosa* are more virulent than other graft infections. Total graft removal is more frequently required for infections involving these organisms. Infections due to *Staphylococcus epidermidis* are more localized and can frequently be managed with partial graft removal followed by extraanatomic or in situ reconstruction. Repeated radical débridement of the tissues surrounding an infected graft as well as débridement of all infected arterial tissue is pivotal for controlling a graft infection. Graft preservation is becoming increasingly popular to avoid extensive extirpative procedures in association with complex extraanatomic reconstructions in frail patients. Arterial stents represent an infrequent but potentially catastrophic source of sepsis.

Bone and Joints

For infections of bone and joints, remove all dead tissue and scar tissue. Provide optimal soft tissue conditions around the infected area. Stabilize infected fractures, and mobilize infected joints. Antibiotics comprise only complementary treatment and do not replace sound surgical practice [42].

Incisional Surgical Site Infections

Incisional infections [43] develop because host defenses cannot eradicate contaminating pathogens. Intraoperative contamination of normally sterile tissues by pathogenic microbes is the most frequent antecedent of incisional infections. Detection of incisional infections relies on the fact that infection is one cause of wound healing failure. Infection must be ruled out when routine postoperative incision examination suggests that healing is not proceeding as expected. Treatment of incisional infections is based on a simple anatomic classification. Source control always includes an element of mechanically altering the geometry and content of infected spaces.

Timing of Intervention

As a general principle, every established source of infection should be controlled as soon as possible [44]. The urgency of intervention is determined by the rapidity of the evolution of clinical symptoms. With complicated infections, additional insults must be kept to a minimum. Thus rapid, minimally invasive, temporizing or palliative measures may be superior to definitive but lengthy, more traumatizing procedures. If the clinical signs of infection diminish, the need for intervention must be reconsidered. There will be ample time for a thorough diagnostic workup and careful planning of the therapeutic strategy. The time course of an infection can never be predicted reliably in the clinical setting.

Complications of Source Control

Complications of source control [45] often result from technical errors or local factors that impair healing. Diagnosis and drainage of local infection and correction of fluid and electrolyte disorders are important for successful treatment. Control of fistulous drainage and provision of appropriate nutritional support are important secondary goals of management.

Reconstructive Surgery after Source Control

In general, reoperation should be delayed for several months following resolution of all complications arising from the source control operation [46]. In all reoperative cases, it is critically important for the operating surgeon to understand fully the nature of the prior surgeries. It is preferable to enter the peritoneal cavity through a "virgin area" of the abdominal wall. Reoperative surgery requires comprehensive preoperative preparation of the patient plus skill and patience in the operating room.

Timing is everything in the operative management of these patients. Indeed, there are rewards for those who enter the operating room with a prepared mind. At times it seems as though there is a brain in the suction tip that allows it to find the perfectly appropriate adhesion plane between bowel wall and parietal peritoneum. Lysis of all small bowel adhesions is not required because we believe that the bowel is "locked in the open position" by these chronic adhesions. If a granulating abdominal wound is allowed to granulate chronically, it substantially increases the chance of enterocutaneous fistula development.

Trauma

An early assessment of the extent of anatomic injury, the degree of physiologic derangement, and the ability of the patient to tolerate a prolonged operative procedure are critical factors to be addressed during the decision-making process [47]. Primary restoration of gastrointestinal continuity may be safely achieved for most injuries. Early source control is of secondary importance to hemorrhage control. Note that there is no magic potion for source control following trauma. Antibiotics, drains, massive irrigation, and colostomy all play limited and secondary roles.

Burn Wound

Important risk factors for the development of burn wound infection include patient age, co-morbidities, and the extent of the burn [48]. Burn wound sepsis is prevented through use of topical antimicrobials, early excision of the burn eschar, and barrier isolation precautions. Differentiation between wound colonization and invasive infection can be made by biopsying the burn wound. Treatment of a burn wound infection entails the use of subeschar clysis and excision of the wound. Note that infection remains the most common cause of death in extensively burned patients, even though invasive burn wound sepsis can be "controlled" by current techniques.

Organ Transplantation

Transplant recipients frequently have surgical infections, requiring prompt control of the graft–host interface [49]. The decision to invoke an operative or interventional radiologic or endoscopic approach depends on patient factors. Controlling the source of the infection is key to successful resolution. Superinfection or concomitant systemic viral or fungal infection is common. The patient's underlying co-morbid diseases and nutrition are significant determinants of the successful management of surgical infection. Removal of the allograft and the cessation of immunosuppressive agents are rarely required but are options that must be contemplated.

Tertiary Peritonitis

The term tertiary peritonitis [50] has been applied to describe recurrent infection of the peritoneal cavity after a prior episode of secondary peritonitis. As tertiary peritonitis progresses, the opportunity for aggressive open surgical intervention decreases, and minimally invasive procedures are favored. The organisms associated with tertiary peritonitis are nosocomial in origin, often difficult to treat, and sometimes of unclear pathologic relevance. Tertiary peritonitis is rarely cured rapidly and frequently requires long rehabilitation and secondary procedures weeks to months after the initial presentation.

We have frequently thought that, apart from tertiary peritonitis, there was not much more we needed to study about the management of intraperitoneal infection. Correct application of initial therapy, proper application of algorithms, and optimal clinical care make tertiary peritonitis a rare entity.

Role of Laparoscopy

Laparoscopic evaluation of the peritoneal cavity enables magnified visualization of peritoneum and intraabdominal organs with less tissue trauma than is incurred during laparotomy [51]. Laparoscopy detects the presence of pus, feces, bile, or blood, thereby facilitating detection of the source of intraabdominal pathology and estimating its severity. Whether the therapeutic procedure chosen is laparoscopic or "conventional" depends on the findings, the patient's condition, and the complexity of the planned procedure.

Source control is most necessary for patients with the most severe assault on their peritoneal defense mechanisms and systemic sepsis. These patients, however, are those least likely to do well with a laparoscopic approach.

Pediatric Surgery

The systemic response to sepsis during early life is different [52]. The main challenge to abdominal source control is necrotizing enterocolitis. The peritoneal cavity of newborns can be effectively drained. Nonresective management of pan-necrotizing enterocolitis is a viable option.

Management of a child with a surgical infection does not differ from that of an adult. What makes the philosophy of source control in pediatric surgery considerably different is the approach to the newborn, especially the premature one.

AIDS Patients

Abdominal complaints are extremely common in the human immunodeficiency virus (HIV)-infected population, and clinical evaluation is often difficult [53]. Serial clinical evaluation and frequent use of CT scanning are essential to prevent nontherapeutic interventions. Early diagnosis and prompt intervention are essential for non-HIV-related surgical pathology such as acute appendicitis and cholecystitis. Surgical intervention is also essential for complications of opportunistic infections such as cytomegalovirus perforation. The morbidity and mortality for surgical procedures depends on the stage of the HIV disease and the nature of the pathology. Surgical interventions should not be denied to this population because of the risk of occupational transmission and the fear of high complication rates. Relief of symptoms and improved quality of life are the chief considerations.

Evaluating the Adequacy of Source Control

Unfortunately, no single test can provide the clinician with a clear answer to the question of whether adequate source control has been achieved. If ongoing intraabdominal infection is suspected on clinical grounds, an imaging procedure (usually CT) should be performed prior to undertaking operative intervention.

In today's world, the best tool for diagnosing intraabdominal sepsis is probably the third-generation CT scanner. Not only can the scanner detect "leaks," it can demonstrate rather subtle amounts of edema resulting from inflammation or infection [54].

Monitoring the Course of Inflammation

Complications resulting from inadequate source control result in a systemic inflammatory response; this response can be detected through changes in circulating levels of a variety of inflammatory mediators, including cytokines such as procalcitonin and interleukin 6. Systemic inflammation also manifests in changes in cellular expression of surface molecules such as HLA-DR and the receptor for TNF and in the ability to generate cytokines in response to microbial stimulation. Immunologic monitoring of the high-risk patient holds the promise of earlier detection of correctable complications and so may lead to improved clinical outcomes [55] .

Empiric Reexploration: Is There a Role?

The need for relaparotomy significantly worsens the outcome. Planned reexploration of all surgical patients with signs and symptoms of infection results in a small number of lives saved but at the cost of significant harm to others. Clear indications for planned relaparotomy do not exist. Reexploration based on localized radiologic or physical findings may be beneficial; directed percutaneous therapy may also be beneficial. Undirected relaparotomy for multiple organ dysfunction syndrome alone, without supporting clinical or radiologic data, results in a 50% to 90% rate of negative explorations without clear evidence of benefit. Supportive clinical findings include prolonged ileus and pain, wound infection, and positive peritoneal signs. A CT scan is the most important radiologic tool in the decision-making process for relaparotomy [56] .

Planned Relaparotomy and Laparostomy

A planned relaparotomy may be life-saving when the source cannot be adequately controlled during the first, index operation. The first week after the index operation—before the infective process has become localized and detectable by CT—offers a window of opportunity for a planned relaparotomy. When the source is controlled and the infection localized, a direct, "on demand" approach is safer. Laparostomy is indicated and beneficial when the abdomen cannot be closed or cannot be closed without creating significant intraabdominal hypertension [57].

Antibiotics

Antimicrobial therapy [58] is an adjunct to primary source control procedures when treating patients with intraabdominal infections. Therapeutic antimicrobial agents (> 24 hours) are required only for patients with established intraabdominal infections. Patients with limited exposure to contamination from a perforated viscus and those who have a removable focus of inflammation should be treated with prophylactic antimicrobials only (< 24 hours). The use of therapeutic antimicrobial drugs for intraabdominal infections should generally be limited to no more than 5 to 7 days. Ongoing clinical evidence of infection should prompt a search for a new or recurrent infection rather than arbitrary prolongation of antimicrobial therapy with new or different agents. Antimicrobial regimens for intraabdominal infections should cover common aerobic and anaerobic enteric flora. A number of regimens are available, but the choice of antimicrobial for most patients with community-acquired infections is dictated primarily by considerations of cost, convenience, and potential toxicity. Patients at high risk for therapeutic failure include those with preexisting physiologic compromise and those with difficult-to-eradicate organisms, which many times have been acquired nosocomially. Antimicrobial therapy may have to be intensified in some of these patients to cover resistant gram-negative aerobic organisms, enterococci, and yeasts.

Conclusions

This overview is unconventional. Instead of rewriting what experts say, we tell you what they have actually said. We have served you the highlights on the edge of the fork hoping to stimulate your appetite to read more.

The key to success when treating surgical infections is timely intervention to stop the delivery of bacteria and adjuvants of inflammation/infection into the peritoneal cavity and other infected spaces. All other measures are of little use if one does not successfully eradicate the source of infection, thereby allowing the patient's defenses, supported by antibiotic therapy, to deal with the residual infective agents. This is not controversial; all the rest may be.

Résumé. Le concept de "source control" (éradication du foyer d'infection) englobe toutes les interventions physiques—chirurgicale ou pas—qui peuvent être utilisées pour traiter une infection. Bien que la «source control» puisse être considérée comme un des aspects les plus importants du traitement des infections graves, ce sujet a reçu jusqu'à présent, peu d'attention. Dans cette revue, nous puisons dans un livre récent édité par nos soins: "Source Control: A guide to the management of surgical infection (Springer Verlag, 2002). La première section de ce livre traite les considérations générales, l'historique, les bases scientifiques et les principes chirurgicaux du concept de "source control». La deuxième section souligne les considérations spécifiques de «source control» dans d'autres circonstances.

Resumen. El concepto de control de la fuente comprende todas las intervenciones físicasquirúrgicas o de otra clase que se emplean en el tratamiento de la infección. Aunque el control de la fuente es uno de los aspectos más importantes en el tratamiento de una infección grave, es un tópico que en el pasado ha recibido relativamente escasa atención. Este

constituye es el tópico de esta revisión, que se basa fundamentalmente en un libro que hemos editado recientemente "Control de la fuente: Una guía para el manejo de la infección quirúrgica" (SpringerVerlag, 2002). La primera sección se refiere a consideraciones generales: perspectiva histórica, bases científicas y principios quirúrgicos del control de la fuente. La segunda sección resalta consideraciones del control de fuente en diferentes situaciones clínicas.

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