PATIENT CARE, PRACTICE MANAGEMENT AND EDUCATION

Identification and Management of Sepsis in the Interventional Radiology Patient

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Abstract

Sepsis is frequently encountered in the hospital setting and can be community-acquired, health-care-associated, or hospital-acquired. The annual incidence of sepsis in the United States population ranges from 300 to 1031 per 100,000 and is increasing by 13% annually. There is an associated inhospital mortality of 10% for sepsis and >40% for septic shock. Interventional radiology is frequently called on to treat patients with sepsis, and in rarer circumstances, interventional radiologists themselves may cause sepsis. Thus, it is essential for interventional radiologists to be able to identify and manage septic patients to reduce sepsis-related morbidity and mortality. The purpose of this paper is to outline procedures most likely to cause sepsis and delineate important clinical aspects of identifying and managing septic patients.

Key words: Interventional radiology, management, resuscitation, sepsis

INTRODUCTION

Conventionally, sepsis has been defined as the systemic response to infection. However, the language defining sepsis has been inconsistent. As our understanding of the pathobiology of sepsis has increased, our definitions of sepsis continue to evolve and yet still remain imprecise.[1] The latest iteration in 2016, sepsis-3, now defines sepsis as a syndrome of life-threatening organ dysfunction caused by dysregulated host response to infection. Organ dysfunction is represented by an increase of two or greater in the sequential (sepsis-related) organ failure assessment (SOFA) score (Table 1). The term severe sepsis was previously used to describe sepsis associated with organ dysfunction. This term has been discontinued and sepsis is now thought of as a continuum ending in septic shock. Septic shock, a subset of sepsis, occurs when vasopressors are required to maintain a mean arterial pressure (MAP) of 65 mm Hg or greater and a serum lactate >2 mmol/L in the absence of hypovolemia.[2]

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Sepsis epidemiology and mortality estimates are imprecise due to the heterogeneity in definitions, with incidence estimates from nationwide date from 2004 to 2009 ranging from 300 to 1031 per 100,000 US population.[3] It is clear that the incidence of sepsis has been increasing at an approximate annual rate of 13%, now exceeding admissions for stroke or acute coronary syndrome.[1,3] At least 14% of critical care unit admissions are due to sepsis.[4] Inhospital mortality for

sepsis is 10% and increases to >40% with septic shock, for an annual total of 750,000 fatalities and $20 billion in health-care costs.[2] Furthermore, sepsis survivors have been shown to have emotional, cognitive, and functional disabilities further augmenting costs.[4]

Interventional radiology teams are frequently involved in controlling infection source, often in severely ill patients who are already septic or at a high risk to become septic. The increasing incidence of sepsis in hospitalized patients combined with the inherent risk sepsis secondary to interventional radiology procedures makes it imperative for interventional radiologists to be competent in identifying and managing sepsis. This paper will discuss procedures documented to have higher rates of sepsis complications and the prevention, identification, and management of sepsis with the overarching goal of reducing sepsis morbidity and mortality.

PROCEDURES ASSOCIATED WITH INCREASED SEPSIS RISK

Procedures involving percutaneous drainage of infected collections or passage through highly vascularized organs, such as the liver and kidney, are most likely to be associated with increased sepsis risk (Table 2).[4] Percutaneous catheter nephrostomy (PCN) is associated with sepsis in 1-3% of cases. Of pyonephrosis-associated PCN tube placements, 7-9% of cases are associated with septic shock.[5] Emergent PCN cases are also associated with higher sepsis rates, 3.6%; in the emergent PCN placement series, 100% of patients developed a transient post-procedural increase in body temperature, necessitating close monitoring for worsening of symptoms.[5]

Biliary interventions, such as percutaneous transhepatic cholangiogram and percutaneous bile duct catheter insertion,

Table 1: SOFA tool

System	Score				
	0	1	2	3	4
Respiration					
PaO_2/FiO_2 mm Hg	≥400	<400	<300	<200 with respiratory support	<100 with respiratory support
Coagulation					
Platelets, $\times10^3$/uL	≥150	<150	<100	<50	<20
Liver					
Bilirubin, mg/dL	<1.2	1.2-1.9	2.0-5.9	6.0-11.9	>12.0
Cardiovascular					
Blood pressure	MAP≥70 mm Hg	MAP<70 mm Hg	Dopamine<5 or any dose dobutamine	Dopamine 5.1-15 or epinephrine≤0.1 or norepinephrine≤0.1[a]	Dopamine>15 or epinephrine>0.1 or norepinephrine>0.1[a]
Central nervous system					
Glasgow coma scale[b]	15	13-14	10-12	6-9	<6
Renal					
Creatinine, mg/dL	<1.2	1.2-1.9	2.0-3.4	3.5-4.9	>5.0
Urine output, mL/day				<500	<200

[a]Epinephrine and norepinephrine given in doses ug/kg/min for at least an hour. [b]Glasgow coma scale ranges from 3 to 15 with a higher score indicating superior functioning. Adapted from Singer *et al.* PaO_2: Partial pressure oxygen, FiO_2: Fraction of inspired oxygen, MAP: Mean arterial pressure

Table 2: Sepsis rates in interventional radiology procedures

Procedure	Sepsis rate
PCN	1-3%[5]
PTC and PBD catheter	0.8-2.3%[6,7]
Arterial-venous fistulas	Rare[8]
Hepatic abscess	0-21%[9,10]
Radiofrequency ablation - hepatic and renal	Rare[7]
TAE and TACE	Rare, usually delayed>1-week post-procedure[7]
UFE	2.5%, but no cases until>1-week post-procedure[13]

PCN: Percutaneous catheter nephrostomy, PTC: Percutaneous transhepatic cholangiogram, PBD: Percutaneous bile duct, TAE: Transarterial embolization, TACE: Transarterial chemoembolization, UFE: Uterine fibroid embolization

are associated with rates of sepsis ranging from 0.8% to 2.3%.[6,7] Age >70, prior biliary instrumentation, diabetes mellitus, acute cholecystitis, and obstructive jaundice increase the risk for positive bile cultures and sepsis.[6] It is believed that bacteremia is caused by a combination of biliary system obstruction leading to retrograde bile flow into the sinusoids and multiple passages of the needle through the hepatic vasculature during access attempts.[7]

In general, vascular stenting procedures are rarely associated with infectious complications. However, cases of intraprocedural sepsis have been reported in dialysis arteriovenous fistulas that require thrombolysis of infected thrombus or pseudoaneurysm manipulation.[8]

Sepsis is an associated complication of hepatic abscess drainage, though reported rates vary. Thomas *et al*. reported sepsis in 7 of 33 patients following percutaneous hepatic abscess drainage.[9] A series by Bissada and Bateman documented no occurrences of sepsis in the 24 patients treated with percutaneous hepatic abscess drainage.[10]

Radiofrequency ablation (RFA) of hepatic and renal tumors rarely causes sepsis. Reported development of hepatic abscesses or cholangitis is <2% and renal abscesses <1%.[7] However, post-ablation syndrome occurs in roughly one-third of patients following hepatic and renal ablation. The most common symptoms are nausea, vomiting, pain, fever, and malaise. In patients following ablation, Wah *et al*. reported nausea, vomiting, and malaise in 81% and fever in 42%.[7,11] Similar symptoms, referred to as post-embolization syndrome, are reported following transarterial embolization (TAE) and transarterial chemoembolization (TACE).[7] The symptoms of both syndromes mimic early signs of sepsis. It is important to remember the natural progression of infection in these patients, with abscess formation and/or sepsis occurring >1 week after the procedure.[12] Similarly, uterine fibroid embolization (UFE) has a 2.5% rate of delayed infectious complications beginning over 1 week post-procedure.[13]

Sepsis prevention

The best treatment for sepsis is prevention, namely, sterile preparation and technique alterations which are delineated in Table 3 and are followed by the majority of interventional radiology departments.[14,15] In addition, it is common practice for antibiotic prophylaxis to be administered for procedures involving biliary, urinary, or hepatic systems. Antibiotics should be administered once the patient has arrived at the interventional suite rather than on the hospital floors. Additional doses of antibiotics should be administered according to their dosing schedule for the duration of the procedure. Continued drainage of infected material requires antibiotic coverage until drainage is complete due to continued risk of bacteremia and sepsis.[14]

Table 3: Recommendations for sterile technique and infection control during interventional radiology procedures

Interventional suite
• Pre-prepared sterile instrument "back" table prepared <1 h before procedure within interventional radiology suite by person (s) in sterile attire
• Minimal traffic through suite
• Procedure suite and work surface disinfection between procedures
Patient
• 2% chlorhexidine or povidone-iodine solution for skin preparation
• Sterile draping
• Dressing application post-procedure with sterile gloves
Providers
• Scrub attire
• Hair coverings and face masks
• Hand antisepsis before gloving
• Sterile gowns and gloves

The rising incidence of antibiotic-resistant bacterial strains has prompted reevaluation of antibiotic prophylaxis in surgical literature.[14] One option to improve our antibiotic stewardship, one option is to risk-stratify patients. In a study, evaluating sepsis incidence in patients who received or did not receive prophylactic antibiotics before PCN placement, Cochran *et al*. stratified patients into high-risk (age >70, diabetes, indwelling catheter, bacteriuria, stones, or ureterointestinal conduit) and low-risk (none of the aforementioned characteristics) groups. The high-risk group showed a statistically significant difference in sepsis with antibiotics (10%) versus without antibiotics (50%). The low-risk group did not show statistically significant results.[5] More studies of this nature are needed to determine for using risk stratification to determine antibiotic prophylaxis.

Common pathogens and their prophylactic regimens are delineated in Table 4. However, there are continued caveats to these choices, and further research is needed. Rather than as depth discussion of prophylactic regimens, this section aims to highlight areas needing further research and caveats in antibiotic choice. No trials have evaluated the effectiveness of prophylaxis in TAE/TACE at preventing infection.[7] Hepatic and renal RFA patients have unclear infection reduction with prophylactic antibiotics, but the SIR clinical practice guidelines recommend antibiotic prophylaxis.[7,16] Similarly, prophylaxis is contentious in UFE since infectious complications are delayed from procedure by 2 to 3 weeks. However, fatal sepsis in the absence of antibiotics at the time of UFE has been documented.[17] Third-generation cephalosporins, such as ceftriaxone, have enhanced biliary excretion, which along with their easy dosing schedule, makes them ideal for biliary interventions;[14] biliary cultures are useful in directing antibiotic choice and yet are rarely collected before procedure.[18] Using cultures

Table 4: Prophylactic antibiotic options by procedure type

Procedure	Organisms encountered	Antibiotic choices
Hepatic tumor ablation	*Staphylococcus aureus*, *Staphylococcus epidermidis, Streptococcus* species, *Escherichia coli, Proteus* species, *Klebsiella* species, *Enterococcus* species	1.5 g ampicillin/sulbactam IV
Renal tumor ablation	*Staphylococcus aureus, Staphylococcus epidermidis, Corynebacterium* species	1 g ceftriaxone IV
Embolization and chemoembolization	*Staphylococcus epidermidis, Streptococcus* species, and *Corynebacterium* species	Hepatic: (i) 1.5-3 g ampicillin/sulbactam IV, (ii) 1 g cefazolin and 500 mg metronidazole IV, (iii) 2 g ampicillin IV and 1.5 mg/kg gentamicin Renal: 1 g ceftriaxone IV Both: If penicillin-allergic, vancomycin, or clindamycin plus aminoglycoside
UFE	*Staphylococcus aureus, Staphylococcus epidermidis, Streptococcus* species, *Escherichia coli*	(i) 1 g cefazolin, (ii) 900 mg clindamycin + 1.5 mg/kg gentamycin, (iii) 3 g ampicillin, (iv) 1.5-3 g ampicillin/sulbactam, (v) if penicillin allergic, vancomycin
Percutaneous nephrostomy tube	*Escherichia coli* and *Proteus, Klebsiella,* and *Enterococcus* species	(i) 1 g cefazolin IV, (ii) 1 g ceftriaxone IV, (iii) 1.5-3 g ampicillin/sulbactam IV, (iv) 2 g ampicillin IV and 1.5 mg/kg gentamicin, (v) if penicillin allergic, vancomycin, or clindamycin + aminoglycoside
Biliary interventions	*Enterococcus* species, *Candida,* Gram-negative bacilli, *Streptococcus viridians*, *Escherichia coli*, *Clostridium* species, *Klebsiella* species, *Pseudomonas, Enterobacter cloacae*, bacteroides	(i) 1 g ceftriaxone IV, (ii) 1.5-3 g ampicillin/sulbactam IV, (iii) 1 g cefotetan IV + 4 g mezlocillin IV, (iv) 2 g ampicillin IV and 1.5 mg/kg gentamicin, (v) if penicillin allergic, vancomycin or clindamycin + aminoglycoside
Vascular interventions	*Staphylococcus aureus, Staphylococcus epidermidis*	No routine prophylaxis, unless stent infection risk is high. Then, use 1 g cefazolin IV or if penicillin allergic, vancomycin, or clindamycin[7,17]

IV: Intravenous, UFE: Uterine fibroid embolization

from initial tube placement to guide subsequent prophylaxis choice for tube exchanges may decrease the use of broad spectrum antibiotics.

The following suggestions have been made in response to anecdotal procedure. During biliary interventions, the use of ultrasound rather than fluoroscopy has been noted to decrease the number of passes through hepatic parenchyma and thus lower infection risk by minimizing introduction of bacteria into hepatic vasculature.[19] For all procedures, manipulation of infected systems should be minimized to decrease the risk of spillage. Overdistention of collecting systems with contrast material injection should be avoided, as it is correlated with increased sepsis risk.[20,21] Draining of urine and not performing a routine nephrostogram may also decrease the risk of sepsis.[21]

Diagnosis

High clinical suspicion and close patient monitoring are needed for the diagnosis of sepsis. The systemic inflammatory response syndrome (SIRS) criteria (Table 5) have been used since 1991 as a means of identifying patients with possible sepsis. However, SIRS criteria are non-specific and are present in many of the ill patients routinely treated in interventional radiology suites. Furthermore, the recent studies have shown that the criteria are not as sensitive as one would hope, with a study based in critical care units in Australia and New Zealand reported 1 out of 8 patients admitted to the unit had infection and new organ failure, yet did not meet the required 2 SIRS criteria.[22] A Dutch study showed similar results with 17% of intensive care unit patients with known infection and organ dysfunction not meeting SIRS criteria.[23] Currently, there is debate in the literature regarding whether or not the emphasis on SOFA and quick SOFA (qSOFA) (Table 6) will improve sepsis diagnosis. It should be mentioned that qSOFA is not intended for use as a diagnostic or screening tool and has been shown to have a low sensitivity; it was designed as a clinical outcome predictor. At this stage, the new definition of sepsis is of highest utility in patient classification for research and trials, not in altering clinical practice or making the initial diagnosis.[24]

A combination of physical examination findings and laboratory values is used in the diagnosis of sepsis. Not every

Table 5: SIRS criteria

Two or more of:
Body temperature >38°C or <36°C
Heart rate >90 beats/min
Respiratory rate >20 breaths/min or hyperventilation with $PaCO_2$ <32 mm Hg
White blood cell count >12,000 or <4000 per mm^3 or >10% immature bands

Adapted from Singer *et al.* SIRS: Systemic inflammatory response syndrome, PaO_2: Partial pressure oxygen

Table 6: qSOFA criteria

Respiratory rate ≥22 breaths/min
AMS with Glasgow coma score <13
Systolic blood pressure ≤100 mm Hg

Adapted from Singer *et al.* qSOFA: Quick sequential (sepsis-related) organ failure assessment, AMS: Altered mental status

patient will demonstrate the symptoms and signs classically associated with sepsis.[4] Furthermore, our use of sedatives, pain killers, and drugs altering heart rate variability (HRV) may obscure the host response.

Altered mental status (AMS), especially in older adults, is a common early manifestation of sepsis, and its severity is often correlated with the severity of illness. Delirium occurs in 30-50% of patients with sepsis.[2] Care must be taken to distinguish AMS secondary to infection from medication-induced AMS.

Hyperventilation can be the earliest marker. Respiratory rate is a variable marker and underlying patient etiology and use of respiratory depressants must be taken into consideration. In a study of 946 septic emergency department patients, only 22% had a respiratory rate >20 as required by SIRS. Many of the patients had a respiratory rate of 19 or 20, placing them just below the threshold.[25]

Fever, defined as body temperature >38°C, is another sign that prompts an infectious evaluation of a patient. However, many septic patient may be euthermic or more worrisome, hypothermic.[2] Older adults, immunosuppressed, patients using anti-inflammatories or antipyretics, and those with many comorbid conditions are more likely to remain euthermic while septic. This patient population encompasses many of the individuals cared for by interventional radiologists. Hypothermia, defined as body temperature <36°C, is a worrisome sign of sepsis. As such, patients that begin to shiver during a procedure should be evaluated for sepsis and other causes of shivering, such as transfusion reaction.[4]

Sepsis can produce many hemodynamic changes. Hypotension, defined as systolic blood pressure <90 mm Hg or a reduction >40 mm Hg from baseline, results from sepsis-mediated venodilation, increased vascular permeability, and decreased arteriolar resistance. Tachycardia, one of the SIRS criteria, serves to increase cardiac output and counteract hypotension. End-organ damage occurs when the heart is not able to augment cardiac output enough to overcome the decrease in systemic vascular resistance. Sepsis refractoriness to fluid resuscitation is due to large part to the increase in venous capacitance and resulting inadequate return of blood to the heart.[25] Recently, there has been an increased focus on a decline in HRV as a marker of sepsis. However, many pharmaceutical interventions, such as beta-blockers, or sick sinus syndrome will decrease HRV confounding this tool.[2,25]

A hematologic sign prompting an investigation for sepsis/infection is leukocytosis. This sign is not always present, especially in older patients, chronically ill patients, and immunosuppressed. Of particular importance to interventional radiologists, the prevalence of disseminated intravascular coagulopathy in patients with sepsis reaches 30-50%, with the most common adverse effect being hemorrhage.[2]

The fact that many of the clinical changes heralding sepsis are changes in vital signs or mental status emphasizes the role of nursing. Nurses are more in tune with the patients' mental status and vital signs. Furthermore, nurses are monitoring the patients in the recovery area. It is essential to have a protocol for nurses to alert physicians for quick assessment and administration of antibiotics and fluids to septic patients.

Management

Despite increased understanding of the pathophysiology of sepsis, management has remained largely unchanged. There are three cornerstones to treatment: (1) Source control, (2) antibiotic usage, and (3) maintaining hemodynamic stability through fluids and arterial vasoconstrictors.

Source control is often the reason for the septic patient or the patient at high risk of becoming septic is sent to interventional radiology. Interventional radiologists are extremely adept at accessing fluid collections throughout the body. The question faced by interventional radiologists when dealing with a septic patient is whether or not to continue the procedure. If the patient is stable, it could be argued that the procedure should be continued and the fluid collection drained. If, however, the patient has signs of hemodynamic instability, they may warrant further intensive care and stabilization before another drainage attempt. The answer to this dilemma will vary widely from patient to patient, institutional preference and among interventionalists.[4]

Antibiotics are the second cornerstone to sepsis management, and their timely administration is the single strongest predictor of outcome.[2] The use of antibiotic prophylaxis has previously been discussed in this paper. This section will

discuss management if the patient becomes septic despite prophylaxis or if they never received prophylaxis. If sepsis is suspected, broad-spectrum antibiotics are administered early, preferably after blood cultures have been drawn, but should not be delayed unnecessarily waiting on cultures. Each hour of delay has been associated with an 8% increase in mortality.[2] Antibiotics can later be tailored if a specimen is isolated.

If the patient has received prophylaxis, either repeating the dose or assuming the organism is resistant to the antibiotic and broadening the coverage are both prudent options. The concern for resistance will depend on the patient's history and the institution's antibiogram. If a Gram-positive organism is suspected, give 1 g intravenous (IV) vancomycin. If Gram-negative or mixed flora is suspected, then give 1 g ampicillin IV and 1.2 mg/kg gentamicin.[26] Care must be taken with frequently hospitalized patients, or one has been in the hospital for a prolonged course. These individuals are more likely to be resistant to first- and second-generation penicillins and will need to be treated with third- or fourth-generation penicillins or a cephalosporin. Another consideration is the nephrotoxic side effect profile of gentamicin, especially when combined with poor renal perfusion in sepsis and the use of radiocontrast dye in interventional procedures. A general rule of thumb is to avoid aminoglycosides in patients with a creatinine >1.5 mg/dL. Instead, aztreonam or a fourth-generation cephalosporin can be administered.[4,26]

In addition to antibiotics, fluids are the other mainstay management for sepsis. Fluids act to restore intravascular volume, optimize cardiac output, and improve end-organ perfusion.[2] Studies in animals have demonstrated that fluids plus antibiotics yield better outcomes than either fluids or antibiotics alone.[27] Crystalloids, either lactated Ringer solution or 0.9% sodium chloride solution, are the fluids of choice. Due to their higher cost and no mortality improvement, colloids are not the preferred resuscitation method.[1,2] The goal is to maintain a MAP of 65 mm Hg or higher, with the exception of patients with long-standing hypertension who will require a higher MAP. Achieving this requires 2-3 L of crystalloid within the first hour and up to 6-10 L over the first 24 h.[2,4] Judicious use of fluids is required in patients with a history of congestive heart failure and overuse of fluids has been shown to increase mortality.[2] To avoid over-resuscitation, patients should only receive fluids for as long as they are fluid responsive.[1]

If hypotension continues after administration of fluids, an arterial vasoconstrictor needs to be used. Norepinephrine is the current agent preferred by critical care clinicians. Previously, dopamine was the preferred agent, but head-to-head trials have shown improved 28 days survival in patients that received norepinephrine and a 2 times higher occurrence of arrhythmias in patients receiving dopamine.[1,28,29] Norepinephrine functions predominately as an alpha-1 agonist, with additional alpha-2 properties at higher doses, allowing it to increase cardiac output in addition to vasoconstriction.[2]

Aside from source control, antibiotics and maintaining hemodynamic stability, and interventional radiologists must coordinate with the necessary entities in their hospital to get the patients higher levels of care quickly. Before leaving the interventional suite, it may also be pertinent to assess the patient's need for arterial lines and central venous catheters that can be placed with greater ease in an interventional radiology suite than on the floors.

SUMMARY

Sepsis is a syndrome that heralds poor patient outcomes if not identified and managed quickly. Many patients seen in interventional radiology are already septic or are at high risk of becoming septic making it quintessential for interventional radiologists to be adept at sepsis identification and initial stages in management. Judicious use of antibiotics and minimization of system disturbance can decrease the risk. Close clinical monitoring by clinicians and nurses will aid in detecting vital sign aberrations consistent with sepsis. Induction of broad spectrum antibiotics and judicious use of fluids and arterial vasoconstrictors are the cornerstones of sepsis management, along with involving critical care teams for higher levels of care.

REFERENCES

1. Berry M, Patel BV, Brett SJ. New consensus definitions for sepsis and septic shock: Implications for treatment strategies and drug development? Drugs 2017;77:353-61.
2. Munford R, Suffredini A. Sepsis, severe sepsis and septic shock. In: Bennett JE, Dolin R, Blaser MJ, editors. Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases. 8th ed., Ch. 75. Philadelphia, PA: Elsevier Health Sciences; 2014. p. 914-34.
3. Kempker JA, Martin GS. The changing epidemiology and definitions of sepsis. Clin Chest Med 2016;37:165-79.
4. Miller MJ, Smith TP, Ryan MJ. Sepsis in the interventional radiology patient. Tech Vasc Intervent Radiol 2006;9:4-8.
5. Millward SF. Percutaneous nephrostomy: A practical approach. J Vasc Interv Radiol 2000;11:955-64.
6. Hamlin JA, Friedman M, Stein MG, Bray JF. Percutaneous biliary drainage: Complications of 118 consecutive catheterizations. Radiology 1986;158:199-202.
7. Huang SY, Philip A, Richter MD, Gupta S, Lessne ML, Kim CY. Prevention and management of infectious complications of percutaneous interventions. Semin Intervent Radiol 2015;32:78-88.

8. Soulen MC, Zaetta JM, Amygdalos MA, Baum RA, Haskal ZJ, Shlansky-Goldberg RD. Mechanical declotting of thrombosed dialysis grafts: Experience in 86 cases. J Vasc Interv Radiol 1997;8:563-7.
9. Thomas J, Turner SR, Nelson RC, Paulson EK. Postprocedure sepsis in imaging-guided percutaneous hepatic abscess drainage: How often does it occur? AJR Am J Roentgenol 2006;186:1419-22.
10. Bissada AA, Bateman J. Pyogenic liver abscess: A 7-year experience in a large community hospital. Hepatogastroenterology 1991;38:317-20.
11. Wah TM, Arellano RS, Gervais DA, Saltalamacchia CA, Martino J, Halpern EF, *et al.* Image-guided percutaneous radiofrequency ablation and incidence of post-radiofrequency ablation syndrome: Prospective survey. Radiology 2005;237:1097-102.
12. Halpenny DF, Torreggiani WC. The infectious complications of interventional radiology based procedures in gastroenterology and hepatology. J Gastrointestin Liver Dis 2011;20:71-5.
13. Toor SS, Jaberi A, Macdonald DB, McInnes MD, Schweitzer ME, Rasuli P. Complication rates and effectiveness of uterine artery embolization in the treatment of symptomatic leiomyomas: A systematic review and meta-analysis. AJR Am J Roentgenol 2012;199:1153-63.
14. Beddy P, Ryan JM. Antibiotic prophylaxis in interventional radiology -Aanything new? Tech Vasc Interv Radiol 2006;9:69-76.
15. National Guideline Clearinghouse. Guideline summary: Joint practice guideline for sterile technique during vascular and interventional radiology procedures. In: National Guideline Clearinghouse. Rockville, MD: Agency for Healthcare Research and Quality; 2012.
16. Venkatesan AM, Kundu S, Sacks D, Wallace MJ, Wojak JC, Rose SC, *et al*. Practice guidelines for adult antibiotic prophylaxis during vascular and interventional radiology procedures. J Vasc Interv Radiol 2010;21:1611-30.
17. Vashisht A, Studd J, Carey A, Burn P. Fatal septicemia after fibroid embolization. Lancet 1999;354:307-8.
18. Brody LA, Brown KT, Getrajdman GI, Kannegieter LS, Brown AE, Fong Y, *et al*. Clinical factors associated with positive bile cultures during primary percutaneous biliary drainage. J Vasc Interv Radiol 1998;9:572-8.
19. Lorenz JM, Leef JA, Chou CH, Funaki B, Straus CM, Rosenblum JD. Sonographic needle guidance in cholangiography in children. J Vasc Interv Radiol 2001;12:342-6.
20. Vehmas T, Kivisaari L, Mankinen P, Tierala E, Somer K, Lehtonen T, *et al*. Results and complications of percutaneous nephrostomy. Ann Clin Res 1988;20:423-7.
21. Lee WJ, Patel U, Patel S, Pillari GP. Emergency percutaneous nephrostomy: Results and complications. J Vasc Interv Radiol 1994;5:135-9.
22. Kaukonen KM, Bailey M, Pilcher D, Cooper DJ, Bellomo R. Systemic inflammatory response syndrome criteria in defining severe sepsis. N Engl J Med 2015;372:1629-38.
23. Klein Klouwenberg PM, Ong DS, Bonten MJ, Cremer OL. Classification of sepsis, severe sepsis and septic shock: The impact of minor variations in data capture and definition of SIRS criteria. Intensive Care Med 2012;38:811-9.
24. Machado FR, Nsutebu E, AbDulaziz S, Daniels R, Finfer S, Kissoon N, *et al.* Sepsis 3 from the perspective of clinicians and quality improvement initiatives. J Crit Care 2017. pii: S0883-944130621-4.
25. Pinder M, Bellomo R, Lipman J. Pharmacological principles of antibiotic prescription in the critically ill. Anaesth Intensive Care 2002;30:134-44.
26. Danner OK, Hendren S, Santiago E, Nye B, Abraham P. Physiologically-based, predictive analytics using the heart-rate-to-systolic-ratio significantly improves the timeliness and accuracy of sepsis prediction compared to SIRS. Am J Surg 2017;213:617-21.
27. Perel P, Roberts I, Ker K. Colloids versus crystalloids for fluid resuscitation in critically ill patients. Cochrane Database Syst Rev 2013;2:CD000567.
28. Avni T, Lador A, Lev S, Leibovici L, Paul M, Grossman A. Vasopressors for the treatment of septic shock: Systematic review and meta-analysis. PLoS One 2015;10:e0129305.
29. Gamper G, Havel C, Arrich J, Losert H, Pace NL, Mullner M, *et al*. Vasopressors for hypotensive shock. Cochrane Database Syst Rev. 2016;2:CD003709.

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