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Emergency Department Management Of Acute Infective Endocarditis

Abstract

Infective endocarditis has a high rate of mortality, and most patients suspected of having the disease will require hospital admission. This review examines the literature as it pertains specifically to emergency clinicians who must maintain vigilance for risk factors and obtain a thorough history, including use of intravenous drugs, in order to guide the workup and treatment. Properly obtained cultures are critical during the evaluation, as they direct the course of antibiotic therapy. Although transthoracic echocardiography is widely available in United States emergency departments, it is not sensitive or specific enough to rule out a diagnosis of infective endocarditis. In high-risk patients, transesophageal echocardiography should be considered.

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CME Objectives

Upon completion of this article, you should be able to:

1. Cite major and minor criteria for the diagnosis of IE.
2. Recognize the manifestations of IE in patients with cardiac devices.
3. Implement current treatment recommendations for IE.

Case Presentations

A 28-year-old man presents to the ED for the third time this week with progressively worsening back pain that is not relieved by anti-inflammatory medications. Initially, this back pain was rather vague, but now he localizes pain to the L4 to L5 region, with associated lower extremity weakness. He notes intermittent fevers, with a maximum temperature of 38.9°C, but states that ibuprofen has helped to control his temperature and alleviate the tooth pain from his recent root canal. He had normal radiographs of his back on his previous 2 visits. No laboratory studies were done. He is agitated and demands that someone "take care of my pain or I am going to sue." The fever concerns you, and you wonder if something else is going on.

After taking care of your first patient of the night, the nurse tells you of a 77-year-old woman who, he fears, may have meningococcemia. The patient is tachycardic, tachypneic, and febrile, with petechiae on her arms and legs. She complains of chest pain and palpitations similar to symptoms she had prior to placement of her pacemaker. The nurse has already drawn 2 sets of blood cultures from her and is asking what antibiotics you would like to administer. Should you go ahead with the antibiotics? You doubt that this is meningococcemia, but you aren't sure what else might be going on and which antibiotics are most appropriate - if any.

A 46-year-old man presents to the ED with symptoms suggestive of pneumonia. A chest x-ray confirms the diagnosis. His records indicate that he has been to the ED 3 times in the past month: once for previous pneumonia, once for phlebitis, and once for pyelonephritis. On examination, you note a murmur, and the patient denies any history of past murmurs. As the department fills up, you consider sending him home with close follow-up care with his primary care physician, but you worry that the new murmur might be enough of a red flag to warrant more aggressive management. Should this patient remain in the ED for further workup?

Introduction

Infective endocarditis (IE) is a disease that may affect both native and prosthetic cardiac valves and ranges in severity from subacute to acute. While it is relatively rare in occurrence, the etiologies of the disease, which include poor dental hygiene, invasive dental procedures, and intravenous drug use, are broad enough to put a wide spectrum of the population at risk.

There does not appear to be consensus in the literature as to the distinction between subacute and acute IE. For the purposes of this review, presentations beyond 4 to 6 weeks of symptom onset will be considered subacute. Acute IE is a much more aggressive disease. Patients present with acute onset of high-grade fever and chills, rapid onset of congestive heart failure, and possible neuropsychiatric complications resulting from involvement of the central nervous system. Delays in diagnosis may be detrimental to patient outcomes, so the emergency clinician must consider this diagnosis in the appropriate clinical setting.

Critical Appraisal Of The Literature

MEDLINE® and PubMed databases were searched using the subject heading *endocarditis*. Major search terms included the following: *cardiac, valve, infective, acute, subacute, intravascular, intravenous drug use, intravenous drug abuse,* and *ultrasound.* Varying combinations of these terms yielded several thousand results. Initially, the search was limited to titles from the past 30 years that were deemed relevant based on their abstracts. Relevant references from these articles, as well as from major textbooks and significant primary literature, were then reviewed. Searches included observational studies, case series, and randomized trials that were available in English. The Cochrane Database of Systematic Reviews was also searched.

Current guidelines directed at the management of chronic disease were reviewed for recommendations and citations relevant to care in the emergency department (ED). When available, higher-quality prospective data were used to make recommendations. Retrospective studies were cited when no prospective data were available, and data from case reports and case series were utilized only when higher-quality prospective and retrospective studies were not available. The majority of the literature consists of retrospective-based studies. Very little high-quality prospective data exist, other than a very few randomized controlled trials. References to high-quality data will be noted.

Several major medical societies currently provide clinical guidelines on this topic, including the American Heart Association (AHA), American College of Cardiology (ACC), European Society of Cardiology (ESC), and the Infectious Diseases Society of America (IDSA). There are also several joint clinical policy statements. However, large portions of the major clinical guidelines are based on retrospective and lower-quality data.

Epidemiology

Reports on the incidence of IE vary, depending on study design. One review of cases that occurred from 1970 to 2000 reported a rate of 5 to 7 incidents per 100,000 person-years.[1] In a study covering over 8 million hospitalizations in the United States from the Nationwide Inpatient Sample, Bor et al noted that hospitalizations rose from 25,511 in 1998 to 38,976 in 2009 (12.7 per 100,000 people in 2009). Even when adjusted for age, the authors noted an

average annual increase of 2.4% in hospital admissions for IE.[2] While IE from intravenous drug use and HIV fell, the number of patients with infected intracardiac devices rose. Mortality rates and valve replacement rates remained unchanged at 14.5% and 9.6%, respectively.

The most commonly identified organism in cases of IE is *Staphylococcus aureus,* with just over half of all cases caused by methicillin-resistant *Staphylococcus aureus* (MRSA). In 2009, the average hospital stay associated with IE cost $122,204.[2]

The AHA has been progressively narrowing the indications for prophylactic antibiotics. A prospective observational study found that there has been no increase in the incidence of streptococcal endocarditis even as guidelines scaled down the recommendation for antibiotic prophylaxis.[3] As such, it does not appear that decreasing the use of antibiotic prophylaxis has been detrimental.

Historically (and still in developing countries), IE was associated with rheumatic and congenital heart disease.[4] The demographics appear to be shifting. The aging population may be at risk due to alterations in immune system function or an increase in valve replacement therapy. In 2009, a prospective observational study of 2781 adults over a period of a little more than 5 years reported that the average age of onset was almost 58 years; that more than three-quarters of IE patients presented within 30 days of symptom onset with very few displaying the classic hallmarks of IE; and that one-quarter had recent exposure to healthcare environments before presentation, suggesting that there may be risk associated with hospitalization. The mitral valve was most commonly affected (41%), followed by the aortic valve (38%). Major complications were common and included stroke (17%), embolism without cerebrovascular accident (23%), heart failure (32%), and intracardiac abscess (14%). Almost half underwent surgical therapy, and almost 20% died.[5]

In children, IE remains a rare disease. A 1997 study that reviewed 35 years of inpatient records at a major children's hospital identified only 76 cases. Congenital heart disease was the major predisposing risk factor, accounting for 62 of the 76 total cases, compared with rheumatic heart disease, which was associated with only 4 cases. Mortality was 18%, and fewer than half recovered without complications.[6] IE is rare in the absence of risk factors or indwelling cardiac catheters. In the premature neonate, the incidence has been reported at 4.3 per 100 cases, most of which were caused by indwelling lines. In 1 case series, less than half of neonates with IE survived, once infected.[7] In children aged < 2 years, IE remains a largely hospital-acquired infection, with *Staphylococcus* the most common organism involved.[8]

Pathophysiology

The initial step in the development of IE is endocardial injury, followed by local adherence of platelets and fibrin.[9] The platelet-fibrin nidus becomes secondarily infected and produces vegetations, which, in turn, may directly damage the endocardial tissue or valves.[9] The most common mechanism of endocardial injury is turbulent blood flow from an acquired or congenital intracardiac abnormality. The most common site of injury and vegetation formation is the line of closure of a valve surface, typically on the atrial surface of atrioventricular valves or the ventricular surface of semilunar valves. Another mechanism of injury includes direct abrasion of the endocardium by an intravascular catheter or other device. In intravenous drug users, direct injection of contaminating debris may damage the tricuspid valve surface.[10] Additionally, a sterile thrombus can be induced, without direct trauma, by physiologic stresses such as hypersensitivity states, hormonal changes, and high altitude. Clinical states associated with sterile thrombus formation include malignancy, rheumatic diseases, and uremia.[11]

Although endocarditis typically refers to inflammation of the inner layer of the heart (usually involving the heart valves, both native and prosthetic), other cardiac structures may also be involved, including the chordae tendineae, the mural endocardium, the sinuses of Valsalva, and the interventricular septum. The typical lesion of endocarditis is the vegetation, which, in its earliest stages, consists of fibrin and platelets with no or few inflammatory cells. This beginning vegetation, characteristic of coagulopathic states, is known as nonbacterial thrombotic endocarditis or endocardiosis. These uncomplicated histopathologic features are typical of the vegetations occurring as a result of acute rheumatic fever and systemic lupus erythematosus, and are also known as Libman-Sacks endocarditis.[12] This initially sterile platelet-fibrin nidus becomes secondarily infected by micro-organisms circulating in the blood, either from a distant source of focal infection or as a result of transient bacteremia (usually from a mucosal or skin source).[13] Once infected, vegetations lead to persistent bacteremia, worsening cardiac damage, fragmentation that produces emboli, and immune complex formation. Deposition in the choroid plexus, skin, spleen, and kidneys can lead to glomerulonephritis.

The 3 most common organisms responsible for IE are *S aureus,* followed by viridans streptococci and coagulase-negative staphylococci. *Haemophilus* species, *Aggregatibacter* species, *Cardiobacterium hominis, Eikenella corrodens,* and *Kingella* species (HACEK) and fungi are seen less frequently.[5] *S aureus* originates most commonly from nosocomial sources such as intravenous and arterial catheters, pacemaker leads, and prosthetic valves. Endocarditis caused by

S aureus has a mortality rate of 20% to 40%.[14] In up to 40% of patients, IE caused by *S aureus* is associated with embolic complications, which increase the risk of death. The epidemiology and microbiology of *S aureus* are changing rapidly, and resistance to antibiotics (especially methicillin) is widespread.[14] Avoiding this resistance is the impetus behind the decrease in recommendations for antibiotic prophylaxis.

Infection with *Pseudomonas aeruginosa* has a high rate of neurological involvement, with 2 distinctive features: (1) mycotic aneurysms with a higher-than-average rate of rupture, and (2) panophthalmitis (10% of patients). The course of infection with *P aeruginosa* is much slower than that of *S aureus*.[15]

Differential Diagnosis

The diagnosis of IE can be a difficult one to make, given the varying signs, symptoms, and physical findings associated with the disease. Because of this, delay of diagnosis is not uncommon. The diagnosis should be considered in all at-risk populations, such as intravenous drug users, patients with previous cardiac surgery, and patients with long-term indwelling vascular access devices. Atypical presentation is common in elderly or immunocompromised patients, who often do not have fever.[16] Strong consideration should also be given to IE in patients with fever of unknown origin, unexplained embolic phenomena, or symptoms that raise concern for connective tissue disease or multisystem organ involvement.

Prehospital Care

Prehospital care specific to endocarditis is similar to that of other suspected systemic infections; care remains largely supportive. The authors recommend against prehospital administration of antibiotics in suspected cases of IE. The diagnosis of IE is based significantly on the results of a series of cultures that must be taken over a period of several hours. There are no current evidence-based emergency medical services (EMS) protocols documenting improved patient outcomes with prehospital antibiotics. Additionally, prehospital administration of antibiotics could potentially affect the accuracy of culture results. In order to obtain serial cultures, it is often necessary to delay antimicrobial therapy. Antibiotics should be started once sufficient cultures are obtained.

Emergency Department Evaluation

History

Patients with IE have variable presentations, and the history focuses on distinguishing between subacute and acute forms. The diagnosis of subacute IE is suggested by a history of an indolent process characterized by fever, fatigue, anorexia, back pain, and weight loss. The most common constitutional complaints on presentation of subacute IE are dyspnea, fever, and fatigue.[2,17] Careful attention should be given to patients with prosthetic valves, a history of unrepaired cyanotic congenital heart disease, implanted cardiac devices, or previous IE. Other risk factors include chronic rheumatic heart disease, age-related degenerative valvular lesions, hemodialysis therapy, and coexisting conditions such as diabetes, HIV infection, and intravenous drug use.[18]

IE has a high incidence of embolization, with consequent metastatic infections; therefore, it should be considered in febrile patients with multiple sites of infection.[19] Infection sites may include the central nervous system, gastrointestinal tract, pulmonary system, musculoskeletal system, and the peripheral arteries. Patients with primary cardiac disease in subacute IE may present with signs of congestive heart failure, including dyspnea on exertion, orthopnea, and paroxysmal nocturnal dyspnea caused by valvular insufficiency. Secondary complaints could include focal neurologic complaints due to an embolic stroke or back pain associated with vertebral osteomyelitis. As many as 20% of cases present with focal neurologic complaints and stroke syndromes.[20] Intravenous drug users in subacute IE commonly complain of dyspnea, cough, and pleuritic chest pain due to the predominance of tricuspid valve endocarditis in this group and secondary embolic showering of the pulmonary vasculature. Right-sided disease is associated with a low rate of congestive heart failure and valvular perforation.[21]

Regardless of whether the suspicion is for subacute or acute IE, all patients should be asked about their dental hygiene, invasive dental procedures, and recreational drug use, as any of these may result in bacteremia. A significant portion of subacute disease caused by *S viridans* infection is secondary to gingivitis, so a thorough history must include questions about routine dental hygiene as well as more-invasive procedures. In the majority of patients, symptoms of endocarditis appear within 2 weeks of dental or other procedures, but the average time to diagnosis is 6 weeks. Less than 50% of patients have a history of previously diagnosed underlying valvular disease or murmur.[22]

Patients With Implanted Heart Valves

Patients with recently implanted prosthetic heart valves should be assessed for possible early prosthetic valve endocarditis (PVE) if they have clinical features that resemble those of native valve endocarditis (NVE). Early PVE is defined as infection occurring within 60 days of valve implantation; late PVE occurs after this period. For valvular infection with coagulase-negative staphylococci (CoNS), this cutoff should be extended to 12 months. The rate of embolic stroke is high in the first 3 days of PVE, and congestive heart failure occurs earlier and is more

severe in persons with PVE. Patients may present with symptoms of myocarditis or pericarditis.[23]

Patients With Pacemakers

Patients with pacemakers may have a varied clinical presentation for IE, depending on the site of infection (the generator pocket vs intravascular leads or epicardial leads). The origin of the infection, whether pocket erosion, localized infection of the generator pocket, or bacteremia from a remote site, will dictate clinical symptoms. Infections that occur within a few months of implantation manifest as acute or subacute infections of the pulse generator pocket.[24] Bacteremia can be present even in the absence of clinical signs and symptoms.

Physical Examination

Careful evaluation of vital signs, including fever, is fundamental to the assessment of the patient with suspected IE. A comprehensive physical examination must be done, with a focus on the cardiac, neurologic, and dermatologic evaluation. Congestive heart failure and neurologic complications have the greatest influence on the prognosis of IE and the emergency clinician must look for these findings. **(See Table 1.)**

In approximately one-third of patients with acute IE, murmurs are absent; however, when present, the most common type of murmur is that of aortic regurgitation. Acute-onset IE often progresses rapidly, so the left ventricle does not have a chance to dilate. In this situation, the classic finding of increased pulse pressure in significant valvular insufficiency is absent.[25] Physical examination should focus on cardiac auscultation for signs of a new regurgitant murmur or heart failure. Changes in the characteristics of a previously noted murmur occur in 10% of acute IE patients and increase the likelihood of secondary congestive heart failure. Signs of congestive heart failure are frequently caused by acute left-sided valvular insufficiency.[26]

A neurologic evaluation should be undertaken for evidence of focal neurologic impairment, as up to 65% of embolic events in IE involve the central nervous system.[27] Cranial nerves, cerebellar function, and motor strength should be tested. This is also important as a baseline examination should neurologic deficits develop later.

IE may result in metastatic infections, and clinical findings depend on the organ involved. In right-sided endocarditis, septic pulmonary emboli may be seen.[8]

In the West, IE is often identified at an earlier stage now than in the past. For this reason, the historical or classic textbook stigmata associated with endocarditis (such as Osler nodes and Janeway lesions) are uncommon. Nonetheless, the identification of these lesions is worth mentioning, and a vigorous search should be undertaken for the classical clinical stigmata of endocarditis including evidence of small and large emboli, with special attention to the fundi, conjunctivae, skin, and digits. Peripheral cutaneous or mucocutaneous lesions of IE include petechiae, splinter hemorrhages, Osler nodes, Janeway lesions, and Roth spots. Embolic phenomena may be present in over 30% of patients, often as the presenting feature.[28]

Petechiae

Petechiae are, generally, the most common skin manifestation of IE. They are comprised of small red spots on the skin caused by capillary hemorrhage from microemboli from vegetations.[29] These lesions do not blanch with pressure, and they may coalesce into larger areas of discoloration or ecchymosis. Petechiae can be found anywhere on the skin, including mucous membranes.[30] Special attention should be paid to identifying these lesions in patients with suspicion for IE, and presence of petechiae in a patient with nonspecific complaints should prompt the search for IE.

Table 1. Criteria That Should Raise Suspicion Of Infective Endocarditis

- High clinical suspicion (urgent indication for echocardiographic screening and possibly hospital admission)
  - New valve lesion/(regurgitant) murmur
  - Embolic event(s) of unknown origin (especially cerebral and renal infarction)
  - Sepsis of unknown origin
  - Hematuria, glomerulonephritis, and suspected renal infarction
  - "Fever," plus
    - Prosthetic material inside the heart
    - Other high predispositions for IE
    - Newly developed ventricular arrhythmias or conduction disturbances
    - First manifestation of congestive heart failure
    - Positive blood counts (if the organism identified is typical for native valve endocarditis/prosthetic valve endocarditis)
    - Cutaneous (Osler, Janeway) or ophthalmic (Roth) manifestations
    - Multifocal/rapid changing pulmonic infiltrations (right-heart IE)
    - Peripheral abscesses (renal, splenic, spinal) of unknown origin
    - Predisposition and recent diagnostic/therapeutic interventions known to result in significant bacteremia
- Low clinical suspicion
  - Fever, plus none of the above

Abbreviations: IE, infective endocarditis.

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Splinter Hemorrhages

These thin, red lines of blood running under the nails in the direction of nail growth look like splinters, and they are usually caused by trauma to the hands or feet. However, hemorrhages that do not extend for the entire length of the nail are more likely the result of IE than trauma. They may be caused by vasculitis (swelling of the blood vessels) or microemboli (tiny clots in the capillaries).[28] **(See Figure 1.)**

Osler Nodes

Osler nodes are small, tender nodules that range from red to purple and are located in the pulp spaces of the terminal phalanges of the fingers and toes, the soles of the feet, and the thenar and hypothenar eminences of the hands. Their appearance is preceded by neuropathic pain lasting hours to days. They remain tender for a maximum of 2 days. The underlying mechanism is probably the circulating immunocomplexes of IE. Osler nodes in a patient with IE suggest a left-sided infection.[31] **(See Figure 2.)**

Janeway Lesions

Janeway lesions are painless macules located on the thenar and hypothenar eminences of the hands and feet. Pathologically, these lesions are microabscesses of the dermis caused by septic emboli.[32] They usually represent an infectious vasculitis of acute IE resulting from *S aureus* infection.[33]

Roth Spots

Roth spots are oval-shaped hemorrhages with white centers present on the retina of some patients with IE. The Litten sign represents cotton-wool exudates seen with this process.[34,35] Endocarditis should also be considered in patients presenting with vasculitis.[36]

Pacemaker Concerns

Fever is the most common finding in early infection in patients with pacemakers, and it may be the only finding in approximately 33% of patients. Late infections of the pocket may be caused by erosion of the overlying skin, without systemic involvement. Such erosions always indicate infection of the underlying device and warrant removal.[37] The most significant late infections involve the transvenous or epicardial leads.[38] Epicardial lead infection leads to pericarditis or mediastinitis, along with bacteremia. Infection of the transvenous electrode produces signs and symptoms of right-sided endocarditis. Endocarditis that occurs early after implantation of a pacemaker (33% of cases) shows prominent systemic signs of infection, often with obvious localization to the pacemaker pocket. Late infections have much more subtle manifestations, may occur up to several years after implantation or reimplantation, and almost universally present with fever. Signs of right-sided endocarditis (such as pneumonia and septic emboli) are observed in up to 50% of patients.[39]

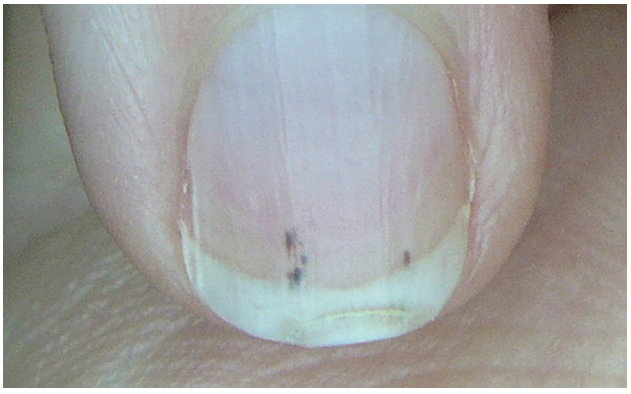
Diagnostic Studies

Laboratory Studies

Most laboratory studies obtained in patients with suspected IE will feature nonspecific findings. At a minimum, the authors recommend a renal function panel (RFP) and complete blood count (CBC). Anemia is present in the majority of cases but is more common in subacute presentations. Hematuria and proteinuria may be present. Erythrocyte sedimentation rate and C-reactive protein (CRP) measurements are often abnormal but nonspecific, as with most inflammatory processes.

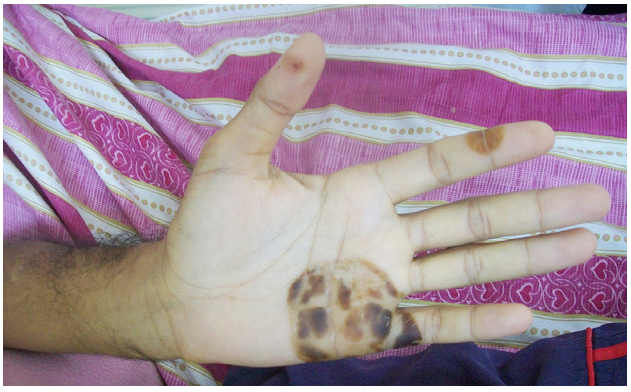
A 2006 study sought to determine the usefulness of ESR, rheumatoid factor, CRP, and tumor necrosis factor (TNF) for the diagnosis of IE in 270 cases of suspected endocarditis. The suspected cases were ultimately categorized as definite IE (vs rejected IE) after the evaluation was complete. No statistically significant differences were found in the positive versus normal CRP, ESR, and TNF measurements between the positive and negative cases. Rheuma-

Figure 1. Appearance Of Splinter Hemorrhages



Source: Splarka. Public domain, via Wikimedia Commons from Wikimedia Commons.

Figure 2. Appearance Of Osler Nodes



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toid factor was elevated in more rejected cases.[40] A 1997 prospective study of 89 cases specifically sought to compare CRP to ESR, and it found the CRP more sensitive for IE, with a normal level in only 4% of cases, versus 28% of cases with ESR.[41] Based on current available evidence, there is no combination of laboratory tests that is sensitive and specific enough to rely on for diagnosis of IE.

Laboratory studies are likely more useful in prognostication of patients subsequently diagnosed. One study found that abnormal creatinine, low serum albumin, abnormal white blood cell count, and elevated ESR were strongly associated with in-hospital death. CRP, while often abnormal, was not associated with inhospital death.[42]

Blood Cultures

The most widely used criteria for the diagnosis of IE are the Duke Clinical Criteria for the Diagnosis of Infective Endocarditis.[43,44] The Duke criteria have a sensitivity of about 80% and are outlined in **Table 2**. **Table 3** reviews the definitions of terminology of the Duke criteria.[45] The hallmark of the ED evaluation is obtaining appropriate cultures for suspected infectious species. Validation studies of the Duke criteria have found a specificity of 99% and a negative predictive value of 92%, giving the criteria excellent diagnostic power.[46,47]

Blood cultures are positive in 95% of IE cases.

Table 2. Duke Criteria for the Diagnosis of Infective Endocarditis

Definite IE	Pathologic criteria • Micro-organisms demonstrated by culture or histology in a vegetation, or in a vegetation that has embolized, or an intracardiac abscess, or • Pathologic lesions, ie, vegetation or intracardiac abscess present, confirmed by histology showing active endocarditis Clinical criteria, using the definitions outlined in **Table 3** • 2 major criteria, or • 1 major and 3 minor criteria, or • 5 minor criteria
Possible IE	Findings consistent with IE that fall short of "definite" but are not "rejected"
Rejected IE	• Firm alternate diagnosis for manifestations of endocarditis, or • Resolution of manifestations of endocarditis, with antibiotic therapy for 4 days or less, or • No pathologic evidence of IE at surgery or autopsy, after antibiotic therapy for ≤ 4 days

Abbreviation: IE, infective endocarditis.

Table 3. Definitions Of Terminology In The Duke Criteria

Major Criteria	
Positive blood culture for IE	• Typical micro-organism for IE from 2 separate blood cultures: ◦ Viridans group streptococci, *Streptococcus bovis*, HACEK group, or ◦ Community-acquired *Staphylococcus* or enterococci in the absence of a primary focus, or • Persistently positive blood culture, defined as recovery of micro-organism consistent with IE from: ◦ Blood cultures drawn > 12 h apart, or ◦ All of 3 or a majority of 4 or more separate blood cultures, with first and last drawn at least 1 h apart
Evidence of endocardial involvement	• Positive echocardiogram for IE: ◦ Oscillating intracardiac mass on valve or supporting structures, in the path of regurgitant jets, or on implanted material, in the absence of an alternative anatomic explanation, or ◦ Abscess, or ◦ New partial dehiscence of prosthetic valve, or ◦ New valvular regurgitation (increase or change in pre-existing murmur not sufficient)
Minor Criteria	
Predisposition	• Predisposing heart condition • Intravenous drug use
Fever	• ≥ 38°C (100.4°F)
Vascular phenomena	• Major arterial emboli, septic pulmonary infarcts, mycotic aneurysms, intracranial hemorrhage, conjunctival hemorrhages, Janeway lesions
Immunological phenomena	• Glomerulonephritis, Osler nodes, Roth spots, rheumatoid factor
Microbiologic evidence	• Positive blood culture not meeting major criterion as noted previously or • Serologic evidence of active infection with organism consistent with IE
Echocardiogram	• Consistent with IE but not meeting major criterion as noted previously

Abbreviations: IE: infective endocarditis; HACEK: *Haemophilus* species, *Aggregatibacter* species, *Cardiobacterium hominis*, *Eikenella corrodens*, and *Kingella* species.

Culture-negative IE is generally a result of improper culture technique or partial pretreatment with antibiotics. For patients with suspected IE, 3 to 5 sets of blood cultures should be obtained from different sites 1 to 2 hours apart. Each set consists of 1 aerobic plus 1 anaerobic bottle. If the patient is not critically ill, it is preferred to delay antibiotic therapy in order to obtain proper cultures. If the patient is critically ill, obtain cultures at least 30 to 60 minutes apart before starting antibiotics.[43]

Echocardiography And Bedside Ultrasound

Since transesophageal echocardiography (TEE) has become more widely available, modifications to the Duke criteria have been proposed that would incorporate TEE into the evaluation of patients with suspected IE and negative transthoracic echocardiogram (TTE) findings.[48] **Table 4** outlines these changes. This is likely outside the scope of most ED management, since TEE is not readily available at most facilities.

When IE is suspected, the 2014 ACC and AHA guidelines recommend that TTE be the initial study of choice in almost all cases. The full ACC/AHA recommendations regarding the use of TTE in suspected IE are available at http://content.onlinejacc.org/article.aspx?articleid=1137806.

TTE has reported sensitivity of 50% to 90%, with high specificity (> 90%) for NVE. TTE has poorer test characteristics for PVE, with reported sensitivity of 36% to 69%.[49] The range of sensitivity for TTE is wide because earlier studies reported much higher sensitivities, likely due to significant selection bias. The accuracy of TTE is also limited by several factors, including operator skill in image acquisition and interpretation, the type of probe used, and the frequency of probe.

Despite the less desirable test characteristics, the authors recommend bedside echocardiogram in suspected cases of IE, given the high specificity, but it should not be used to rule out the diagnosis. See **Figures 3 and 4** for the appearance of vegetations on echocardiogram.

Table 4. Proposed Modifications To The Duke Criteria For The Diagnosis Of Infective Endocarditis

- Eliminate the minor criterion, "echocardiogram consistent with IE but not meeting major criteria"
- Possible IE:
  - 1 major criterion and 1 minor criterion, or
  - 3 minor criteria
- Blood culture positive for IE: single positive culture for *Coxiella burnetii* or antiphase I IgG antibody titer > 1:800
- Echocardiogram positive for IE: TEE recommended in patients with prosthetic valves, rated at least "possible IE" by clinical criteria, or complicated by IE (paravalvular abscess); TTE as first test in other patients

Abbreviations: IE, infective endocarditis; IgG, immunoglobulin; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography.

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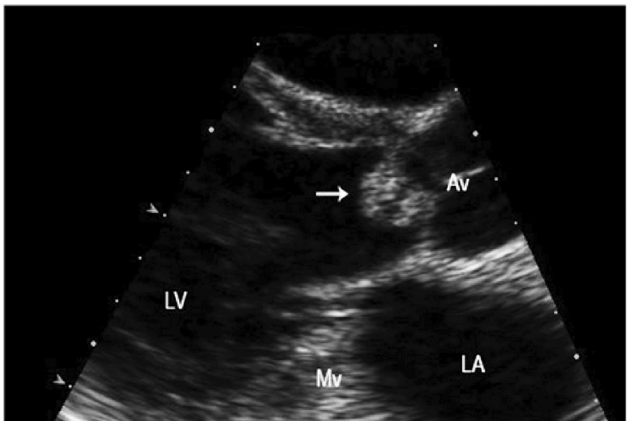
Radiographic Studies

Most radiographic studies in the ED are of very limited value for the diagnosis of IE but they may

Figure 3. Transthoracic Echocardiogram Of Aortic Valve, With Vegetation



Arrow points to vegetation on the aortic valve.

Abbreviations: AV, aortic valve; LA, left atrium; LV, left ventricle; MV, mitral valve.

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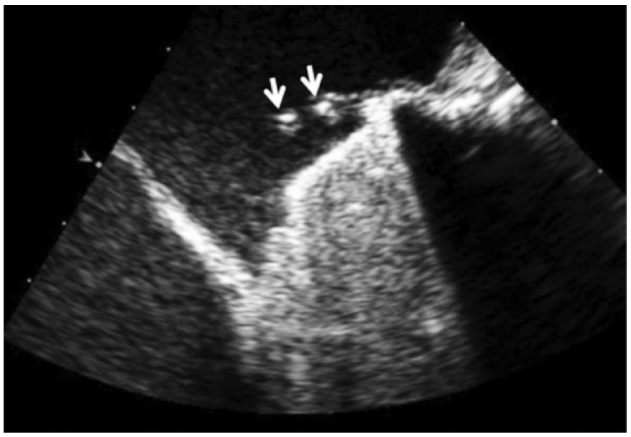
Figure 4. Transesophageal Echocardiogram Of Prosthetic Mitral Valve, With Vegetation



Arrows point out vegetations on the prosthetic mitral valve strut.

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be useful for evaluation of secondary complications related to infection. The primary role of chest radiographs in the setting of suspected endocarditis is to evaluate for possible alternative diagnoses as well as secondary complications such as pulmonary abscesses, cardiac enlargement, and heart failure.

Computed tomography (CT) and magnetic resonance imaging (MRI) of the brain are useful when evaluating for brain abscesses and bleeding from emboli. Patients with skin manifestations should undergo cerebral imaging, as these patients have a higher rate of IE-related extracardiac complications (particularly cerebral emboli) than patients without skin manifestations.[50] Almost one-third of patients will experience neurologic complications at some point during the course of their treatment.[51] Patients with suspected IE and new onset of neurologic symptoms should also undergo imaging of the brain.[43] Although occult cerebral complications are relatively common, the clinical implications of these asymptomatic findings are unclear at this time. A 2013 prospective study of 109 patients with probable endocarditis without neurologic symptoms underwent MRI of the brain; 72% were found to have abnormalities, 37% had acute ischemic changes, and 57% had cerebral microbleeds.[52] Another case control study found similar results.[53] The workup for various secondary complications is outside the scope of this review.

Radionuclide scanning techniques have been studied over the past several decades. While the technology has proven useful in various areas of medicine, its use is not common in the detection of endocarditis due to the availability and accuracy of echocardiography.[54] Various techniques have been evaluated, including tagged white blood cell and platelet scans. Evidence supporting these techniques is very limited, consisting of mostly animal studies and case series.[55-59] Radionuclide scanning techniques have proven more useful in the detection of complications such as mycotic aneurysms, osteomyelitis, and microabscesses.

Cardiac CT scanning has been studied in the evaluation of valvular lesions. One small study noted a sensitivity of 97%, specificity of 88%, positive predictive value (PPV) of 97%, and negative predictive value (NPV) of 88%, when compared to TEE. CT correctly identified 96% of valvular lesions and 100% of abscesses and pseudoaneurysms.[60] However, larger studies are lacking at this time, and it is premature to recommend the routine use of CT for this indication. ECG-gated CT scanning is becoming more widely available with the spreading use of coronary computed tomography angiography (CCTA). Evidence in favor of this technique is currently limited, but as the technology improves, it will likely become more widely used. A 2012 prospective study of 27 patients, with TEE used as the gold standard, demonstrated that ECG-CT was able to find 93% of lesions.[61]

Photoemission tomography computed tomography (PET-CT) and single photo emission computed tomography (SPECT) also show promise for the diagnosis of IE.[62] However, these studies play an extremely limited role, if any, in the ED evaluation.

The American College of Radiology has developed appropriate use criteria to help guide clinicians on the use of imaging in suspected endocarditis.[63]

Electrocardiography

Electrocardiographic studies are of little value in the acute setting to diagnose IE. However, a baseline electrocardiogram (ECG) should be obtained, as changes in conduction have prognostic value. Progression to heart blocks or worsening of baseline conduction abnormalities are often indicative of extension of the infective lesion.[64] Acute myocardial infarction as a result of IE is rare, with only scattered case reports. One study noted new onset of sinus tachycardia (53%), low voltage (44%), various heart blocks (9%), ST-segment changes (8%), atrial fibrillation (4%), ventricular tachycardia (3%), and supraventricular tachycardia (1%). Only autopsy-proven IE was included in this study, so there may be some selection bias.[65]

Treatment

Antibiotics

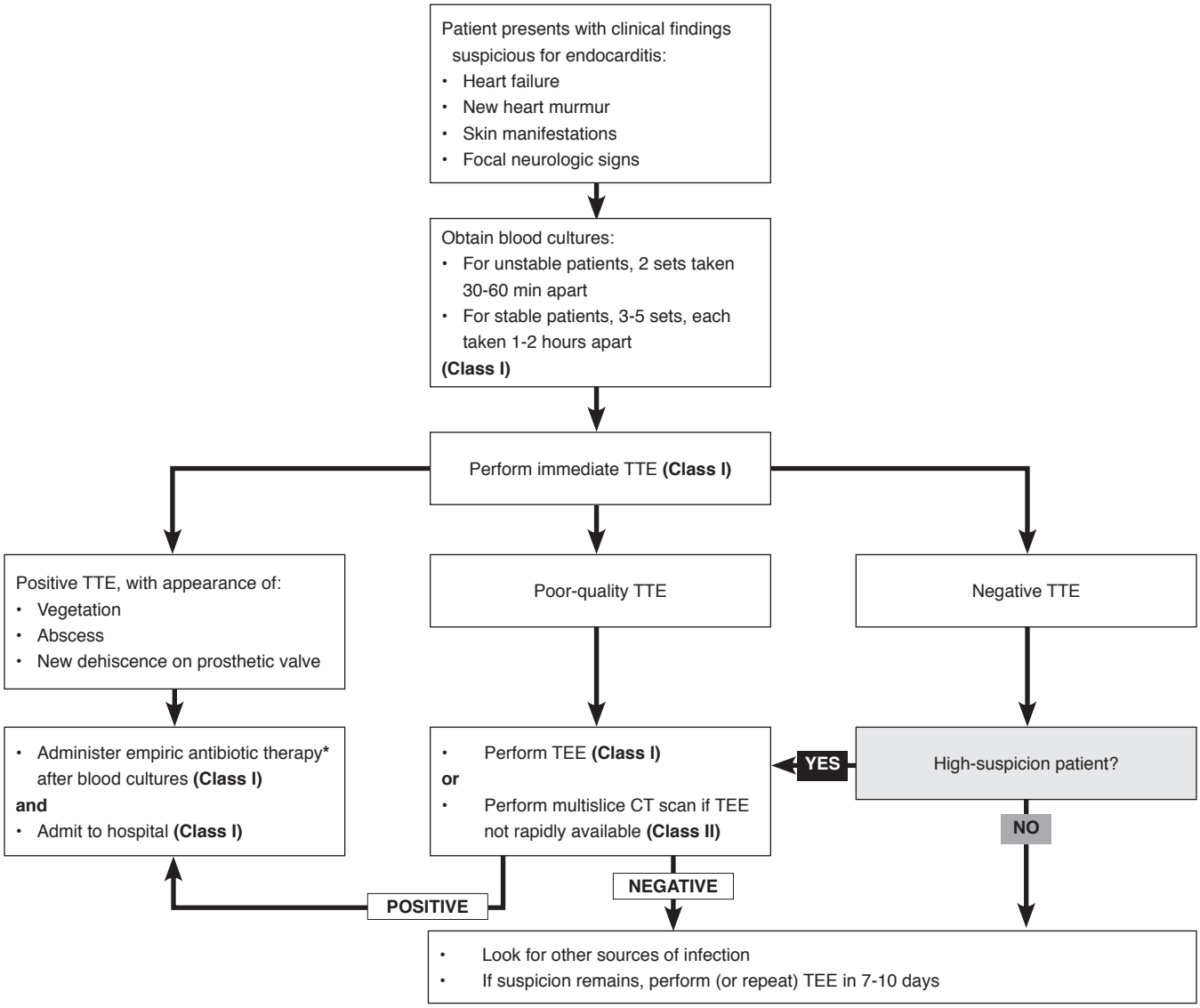
In the ED, culture results are rarely available to help guide therapy; thus, treatment is primarily based on risk factors for various micro-organisms, along with local resistance patterns.[66] **Table 5, page 11,** outlines initial treatment for suspected endocarditis when culture results have not yet been obtained.[67]

When a probable etiology is not discernible based on risk factors, antibiotic therapy should be geared towards staphylococcal and streptococcal species. The authors recommend a third- or fourth-generation cephalosporin and an aminoglycoside for empiric therapy; the preferred regimen includes ceftriaxone and vancomycin. Antimicrobials should be administered as soon as sufficient cultures are obtained; most courses of treatment will continue for 2 to 4 weeks, depending on the agent used and the organism identified.

Surgical Intervention

Surgical consultation for patients with IE helps to identify patients who may benefit from early valve surgery. Both the AHA and ACC recommend surgery in patients with heart failure, perivalvular abscess, difficult-to-treat pathogens, large vegetations, and septic emboli.[68]

Clinical Pathway For Imaging Approaches To Suspected Infective Endocarditis



*See **Table 5, page 11.**

Abbreviations: CT, computed tomography; ED, emergency department; TEE, transesophageal echocardiogram; TTE, transthoracic echocardiogram.

Class Of Evidence Definitions

Each action in the clinical pathways section of *Emergency Medicine Practice* receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

Special Circumstances

Prosthetic Valves

The distinction between NVE and PVE is clinically important. PVE can be classified as early (< 60 days after valvular surgery), intermediate (60 days to 1 year postsurgery), or late (> 1 year postsurgery). Early PVE is usually caused by intraoperative contamination or postoperative bacterial contamination (usually nosocomial). Micro-organisms damage the valve prosthesis by either direct intraoperative contamination or hematogenous spread during the initial days and weeks after surgery. These bacteria have direct access to the prosthesis-annulus interface and to perivalvular tissue along suture pathways because the valve sewing ring, cardiac annulus, and anchoring sutures are not endothelialized early after valve implantation. These structures are covered with host proteins (such as fibronectin and fibrinogen) to which organisms can adhere and initiate infection.[69] As the sewing ring, sutures, and heart tissues become endothelialized over 2 to 12 months after valve replacement, sites for adherence of micro-organisms and access to host tissues adjacent to the prosthesis are altered. The pathogenesis of late PVE then begins to resemble NVE. Late PVE is usually caused by community-acquired micro-organisms.[70,71]

Heart failure often occurs in patients with PVE and increases the risk of inhospital mortality by threefold. Persistent infection, aortic involvement, abscess, and diabetes mellitus are the independent risk factors associated with mortality in patients with PVE and heart failure.[72]

Indwelling Lines

Endocarditis is encountered with increasing frequency as a serious complication of central venous catheter bloodstream infection. These complications more often involve right-sided cardiac structures, with catheter tips in or near the right atrium, frequently require TEE for diagnosis, and have significant inpatient mortality.[73]

Infections related to totally implanted access ports are also responsible for morbidity and mortality. Main risk factors for infections include total parenteral nutrition, young age, difficulties during insertion, poor general status, and neutropenia. Catheter removal is mandatory in the case of local complication (tunnel infection or port pocket abscess), septic thrombosis, IE, osteomyelitis, septic shock, or infection related to specific pathogens (*S aureus, Candida* spp., and *P aeruginosa*). Otherwise, retention of the catheter (including antibiotic lock therapy) might be proposed, given results from recent studies. One study noted a rate of 4.6 infections per 10,000 catheter-days.[74] While this number may seem low, it must be considered that this study involved the use of long-term indwelling lines for home use, so centers with a high volume of such patients are likely to see this type of infection. Based on a large meta-analysis, antiseptic-impregnated catheters have lower rates of infections.[75] However, when the catheter is the likely source of infection, removal should be considered, depending on the clinical circumstances.

Intravenous Drug Use

Intravenous drug use clearly plays a role in the risk for developing IE, with some specific differences in pathophysiology. Most endocarditis occurs on the left side (mitral and aortic valves), likely because of the higher pressures and a large, turbulent volume of flow. Right-sided endocarditis accounts for approximately 5% to 10% of cases in the general population, mostly involving the tricuspid valve. Among intravenous drug users, however, IE is more likely to occur on the right side, compared with the general population (76% vs 9%, respectively). The incidence of infection reportedly ranges from 1.5 to 2 cases per 1000 addict-years.[76]

Pediatric Congenital Heart Disease

Rheumatic heart disease used to be the overwhelming risk factor for the development of IE in the pediatric population. With rheumatic heart disease nearing extinction in the United States, the risks have shifted to those with congenital heart disease. Almost all pediatric patients with IE have an identifiable risk factor and, in patients with congenital heart disease, IE must be on the differential. An Oregon-based cohort study evaluated the risk of IE development up to 25 years after repair of congenital heart disease lesions. They found that patients with the following deficits were at elevated risk of IE (in descending order): tetralogy of Fallot, isolated ventricular septal defect, coarctation, valvular aortic stenosis, primum atrial septal defect, dextrotranspo-

Table 5. Empiric Therapy For Suspected Endocarditis[67]

Disease	Recommended Empiric Therapy*
Suspected native valve endocarditis	Vancomycin 15-20 mg/kg/dose IV every 8-12h† **or** Daptomycin‡ 6 mg/kg/dose IV daily
Suspected prosthetic valve endocarditis	Rifampin 300 mg PO/IV every 8h **plus** Gentamicin 1 mg/kg/dose IV every 8h **plus** Vancomycin 15-20 mg/kg/dose IV every 8-12h†

*Local resistance patterns must be taken into account.

†Maximum dose 2 g.

‡The authors do not recommend the use of daptomycin in the emergency department.

Abbreviations: IM, intramuscular; IV, intravenous; PO, by mouth.

sition of the great arteries, complete atrioventricular septal defect, pulmonary atresia with an intact ventricular septum, and pulmonary atresia with ventricular septal defect. No children with secundum atrial septal defect, patent ductus arteriosus, or isolated pulmonic stenosis developed IE after repair.[77]

Antibiotic Prophylaxis

Prophylaxis for the prevention of IE in at-risk patients is based largely around the AHA clinical guidelines. Recommendations have been modified over the years based on clinical evidence. It appears that IE is more likely to occur from frequent random exposure to bacteremias encountered with daily living than from medical procedures. There is little quality evidence supporting prophylaxis, and benefit is likely outweighed by antibiotic-associated adverse events.[78] A 2012 study showed no change in IE rates after the 2007 guideline changes.[3] A 2011 United Kingdom study found a 79% reduction in prophylactic antibiotic use under the new guidelines but no change in IE rates.[79] **Table 6** outlines the pathologies at highest risk for endocarditis. Patients with conditions that are not noted in the table should not receive prophylaxis. **Table 7** describes recommended antibiotic regimens for these patients for dental procedures. Currently, prophylaxis prior to dental procedures is recommended when the procedure involves manipulation of gingival tissue or periapex, or perforation of the oral mucosa. Additionally, only patients with the conditions outlined in **Table 6** should receive an antibiotic prophylaxis regimen similar to that for dental procedures for any procedure on the respiratory tract, infected skin (ie, abscess, cellulitis), or musculoskeletal tissues. Administration of antibiotics solely for prevention of IE is not recommended for any patients undergoing genitourinary or gastrointestinal tract procedures.

Table 6. Cardiac Conditions For Which Antibiotic Prophylaxis May Be Reasonable[78]

- Placement of a prosthetic cardiac valve or a prosthetic material for repair of cardiac valves
- Prior incidence of infective endocarditis
- Any of the following congenital heart disease conditions:
  - Cyanotic congenital heart disease that is unrepaired
  - Congenital heart defect that has been completely repaired in the previous 6 months with prosthetic material or device
  - Congenital heart defect that has been repaired with prosthetic device, but has residual defects
- Cardiac valvulopathy in patients who have had heart transplant

Disposition

Given the high mortality rate associated with IE, patients with suspected IE will almost universally be admitted to the hospital. Rare circumstances may allow for discharge of subacute or chronic presentations and patients who are hemodynamically stable and have very close follow-up. However, this should be considered with caution.

Controversies And Cutting Edge

Anticoagulation

In patients with NVE, anticoagulation is not recommended. Patients with prosthetic valves are generally already taking anticoagulation medication and no change in their therapy is indicated.[80]

Daptomycin

A recent randomized controlled trial demonstrated noninferiority of daptomycin at 6 mg/kg daily, compared with standard therapy for right-sided IE.[81] However, the authors of this review caution against this practice. This study was not designed specifically for endocarditis (as it included septic patients), and all of the IE patients included had left-sided disease only. Given that the location of infection is likely not known in the ED, daptomycin should not be widely applied.

Table 7. Antibiotic Prophylaxis For Dental Procedures[78]

Route of Administration/Allergy Status	Agent	Adults*	Children*
Oral	Amoxicillin	2 g	50 mg/kg
Unable to take oral medication	Ampicillin	2 g IM or IV	50 mg/kg IM or IV
	Cefazolin/ceftriaxone	1 g IM or IV	50 mg/kg IM or IV
Allergic to penicillins or ampicillin (oral)	Cephalexin	2 g	50 mg/kg
	Clindamycin	600 mg	20 mg/kg
	Azithromycin/clarithromycin	500 mg	15 mg/kg
Allergic to penicillins or ampicillin (and unable to take oral)	Cefazolin/ceftriaxone	1 g IM or IV	50 mg/kg IM or IV
	Clindamycin	600 mg IM or IV	20 mg/kg IM or IV

*Doses of oral medication should be taken one hour prior to procedure. Parenteral medications should be given 30 minutes prior to procedure.
Abbreviations: IM, intramuscular; IV, intravenous.

Early Surgical Intervention

A 2012 randomized controlled trial sought to determine the effect of early surgery on IE patient outcomes. In this trial, patients who had left-sided endocarditis with severe valve disease and large vegetations were randomized to early surgery within 48 hours or conventional therapy. The composite end point of all-cause mortality, embolic events, or recurrence at 6 months was 3% in the early-surgery group versus 28% in the conventional group.[82] Previous prospective nonrandomized trials have shown similar benefit.[83]

Summary

IE remains a challenging disease to diagnose in the ED. This disease requires that emergency clinicians maintain vigilance for risk factors and, when suspected, additional history will help guide the workup and treatment. Mortality remains high for this disease, and most patients with suspected IE will require admission. Cultures are of the utmost priority, along with appropriate antibiotics. TTE is usually available in the ED, but it does not rule out the disease and, thus, TEE should be considered in high-risk patients.

Case Conclusions

The 28-year-old man who presented to the ED with 1 week of progressively worsening back pain was ultimately diagnosed with a spinal epidural abscess. You obtained a history of significant dental work done in the month preceding the onset of the back pain. He was admitted for surgical decompression after the diagnosis was made via MRI. He was later diagnosed with IE caused by infective emboli.

For the 77-year-old woman who presented tachycardic, tachypneic, and febrile with a petechial rash, you drew a total of 5 sets of blood cultures from different sites, 1 hour apart prior to antibiotic administration. Her cardiologist was consulted and she was admitted to the hospital. Her pacemaker was removed and cultured and found to be culture-positive with the same bacteria noted in the blood cultures that you drew in the ED. TEE revealed a vegetation on the tricuspid valve. Her symptoms improved with antimicrobials and she was discharged with a PICC line and 6 weeks of intravenous antimicrobials.

For the 46-year-old man who presented to the ED with symptoms that were suggestive of pneumonia, you decided to hold antibiotics and work the patient up for his recurrent infections. An echocardiogram was performed, which demonstrated a mitral valve vegetation. His condition worsened in the ED and he was admitted to the hospital, where he was found to have a cardiac abscess. He was taken in for surgical repair and ultimately required a valve replacement.

Abbreviation List

ACC	American College of Cardiology
AHA	American Heart Association
CBC	Complete blood count
CRP	C-reactive protein
CT	Computed tomography
ECG	Electrocardiogram
ESC	European Society of Cardiology
ESR	Erythrocyte sedimentation rate
HACEK	*Haemophilus* species, *Aggregatibacter* species, *Cardiobacterium hominis, Eikenella corrodens,* and *Kingella* species
IDSA	Infectious Diseases Society of America
IE	Infective endocarditis
MRI	Magnetic resonance imaging
MRSA	Methicillin-resistant *Staphylococcus aureus*
NVE	Native valve endocarditis
RFP	Renal function panel
PVE	Prosthetic valve endocarditis
P aeruginosa	*Pseudomonas aeruginosa*
PICC	Peripherally inserted central catheter
S aureus	*Staphylococcus aureus*
TEE	Transesophageal echocardiography
TNF	Tumor necrosis factor
TTE	Transthoracic echocardiography

Risk Management Pitfalls for Infective Endocarditis

1. **"All the laboratory tests were normal; she couldn't have endocarditis."**
   There are no laboratory tests that are sensitive or specific enough to diagnose or rule out endocarditis. While a CBC, ESR, and blood cultures are helpful, all have limitations.

2. **"I know the patient had altered mental status. I just didn't think endocarditis was the cause."**
   Cast a broad net in a patient with fever and altered mental status. If no other cause is immediately noticeable, consider endocarditis as a possibility.

3. **"I forgot to check the blood cultures. I'm not sure why the nurses drew them."**
   Any test that is ordered needs to be checked. Failure to do so places the provider at significant medicolegal risk in the event of a bad outcome. There should be a system in place to check all cultures and laboratory tests ordered in the ED.

4. **"I know the patient had back pain and fever. I never considered endocarditis and an epidural abscess."**
   Endocarditis can be a source of many atypical and rare infectious disease entities. Patients with midline back pain, fever, and no evidence of a source should be investigated and endocarditis considered as a possible cause.

5. **"I recognized the skin lesions, but the patient looked good, so I didn't think they were important."**
   Maintain a broad differential diagnosis for cutaneous lesions. Any lesions associated with fever could potentially have been caused by cardiac emboli.

6. **"I thought the AHA guidelines got rid of the need for all prophylaxis measures."**
   Not all. Patients with heart valve replacements, previous IE, or some forms of congenital heart disease still require medications.

7. **"I thought he had the flu. I didn't ask if he had any indwelling devices."**
   There are a number of risk factors that predispose patients to IE. The presence of intravascular devices is one of these. Maintain a high index of suspicion in these patients.

8. **"I just thought she had a recurrent infection. I didn't even think about endocarditis."**
   If someone is treated for an infection and either doesn't improve or worsens, complete a comprehensive history and physical examination. There may be new findings, such as a murmur, that could lead to the differential/diagnosis of IE.

9. **"I know they just had a pacemaker/automated external defibrillator placed. What are the odds the fever was related to that?"**
   Cardiac device infection is a serious emerging disease, with a 210% increase in incidence from 1993 to 2008.[84] These patients also have a higher rate of complications including valve infections, heart failure, and persistent bacteremia.

10. **"I didn't ask about recent dental visits."**
    Consider endocarditis in anyone with a fever after recent dental surgery. Get in the habit of asking whether patients have had any recent dental visits or procedures.

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study will be included in bold type following the reference, where available. In addition, the most informative references cited in this paper, as determined by the authors, will be noted by an asterisk (*) next to the number of the reference.

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1. Which of the following statements is TRUE?
- a. The number of patients with infected intracardiac devices has risen in recent years.
- b. Mortality rates secondary to IE have decreased in recent years.
- c. Hospitalization related to IE has decreased in recent years.
- d. The rate of IE related to intravenous drug use and HIV has increased in recent years.

2. Which organism most commonly causes IE?
- a. Streptococci of the viridans group
- b. *S aureus*
- c. Enterococci
- d. *P aeruginosa*

3. Which of the following statements is FALSE?
- a. IE secondary to *P aeruginosa* has a high rate of neurological involvement.
- b. IE secondary to *P aeruginosa* is associated with mycotic aneurysms with a higher-than-average rate of rupture.
- c. IE secondary to *P aeruginosa* is associated with panophthalmitis.
- d. The course of IE with *P aeruginosa* is much faster than that of *S aureus.*

4. Which of the following statements is TRUE?
- a. Leukocytosis is sensitive and specific for IE.
- b. Abnormal creatinine, low albumin, and elevated ESR are associated with decreased inhospital mortality in IE.
- c. The ECG is sensitive and specific for diagnosing IE
- d. Progression to heart blocks or worsening of baseline conduction abnormalities on ECG often indicates extension of IE.

5. **Which of the following statements is FALSE?**
   a. In suspected cases of IE, ED workup centers on obtaining blood cultures.
   b. TEE is needed to confirm the diagnosis of IE.
   c. Blood cultures are positive in 50% of IE cases.
   d. The primary causes of culture-negative IE are improper culture techniques and partial pretreatment with antibiotics.

6. **Which of the following statements is TRUE?**
   a. TTE should be the initial study of choice due to its wide availability and high specificity.
   b. TTE is more sensitive for IE than TTE.
   c. CT chest is an alternative to echocardiography for diagnosing IE.

7. **The primary role of chest radiographs in the setting of suspected endocarditis is to evaluate for:**
   a. Possible alternative diagnoses
   b. Secondary complications
   c. A and B
   d. None of the above

8. **Which of the following regarding antibiotic use in suspected infective endocarditis is TRUE?**
   a. The suggested empiric regimen for NVE is vancomycin.
   b. The suggested empiric regimen for NVE is nafcillin or rifampin plus vancomycin and gentamicin.
   c. Antibiotic administration should be delayed until culture results are available.

9. **Which of the following statements is TRUE?**
   a. Administration of antibiotics for IE prevention is recommended for at-risk patients undergoing dental procedures.
   b. Administration of antibiotics for IE prevention is recommended for at-risk patients undergoing genitourinary procedures.
   c. Administration of antibiotics for IE prevention is recommended for at-risk patients undergoing gastrointestinal tract procedures.
   d. Decreasing the use of antibiotic prophylaxis has led to increased incidence of streptococcal endocarditis.

10. **Patients with left-sided endocarditis with severe valve disease and large vegetations have lower mortality and embolic events with early surgery (within 48 hours), compared with conventional therapy.**
    a. True
    b. False

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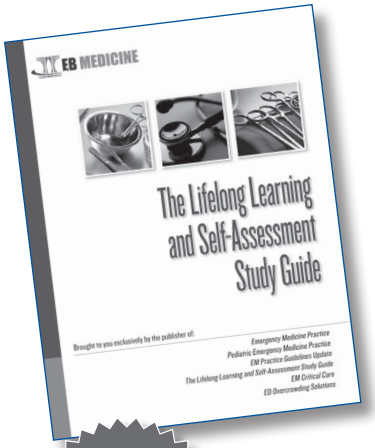

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