Bugs &

The intensive care unit is particularly vulnerable to secondary infections.

By Kate J. Morse, RN, APRN, CCRN, MSN,
and
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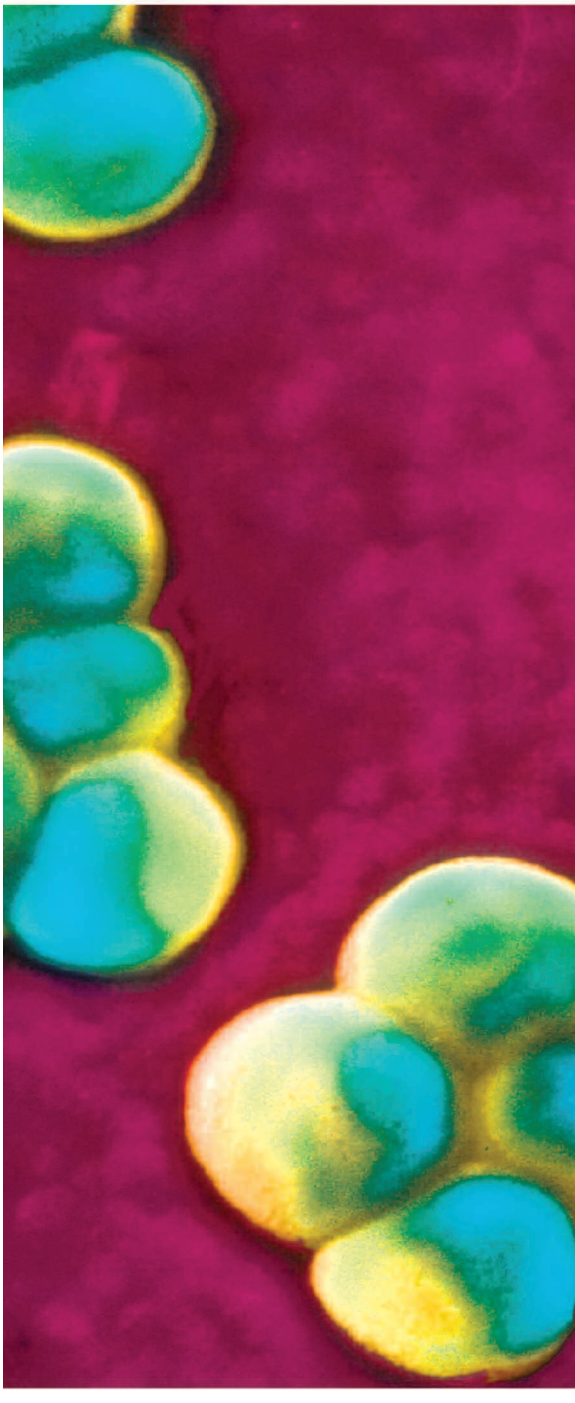

Infections in critical care can lead to a devastating outcome. The patient in the intensive care unit (ICU) is particularly vulnerable to secondary infections when compared with non-ICU areas. Patients in the ICU are exposed to a broader spectrum of antibiotics and have a higher incidence of indwelling catheters (urinary and intravascular). Consequently, they're predisposed to greater risk, not just for infection, but also for multidrug-resistant (MDR) pathogens.

An overview of the types of pathogens commonly seen in the ICU, as well as a framework for interpreting cultures, benefits the bedside nurse. Additionally, consider a brief review of the more common critical care infections.

Early identification

The cost of infections in dollars and lives is significant. The National Nosocomial Infections Surveillance (NNIS) was established in 1970, when selected hospitals began reporting infection data for the development of a national database. Currently, nearly 300 hospitals are participating in data collection, all of which are collected using standardized definitions and protocols. In addition to rates and types of infection, the NNIS reports on the type of organisms and the development of resistant organisms. In the most recent report of data, compiled from January 2002 through June 2004 for a combined medical/surgical ICU (nonteaching), the urinary-catheter-associated urinary tract infection (UTI) 50% percentile rate was 3.1%.[1] This means that 50% of hospitals had a lower rate of infection and 50% of hospitals had a higher rate of infection. The pooled mean rate of UTI was 3.1%.

Central-line-associated bloodstream infections (CBSIs) for a combined medical/surgical ICU (nonteaching) 50% median percentile rate

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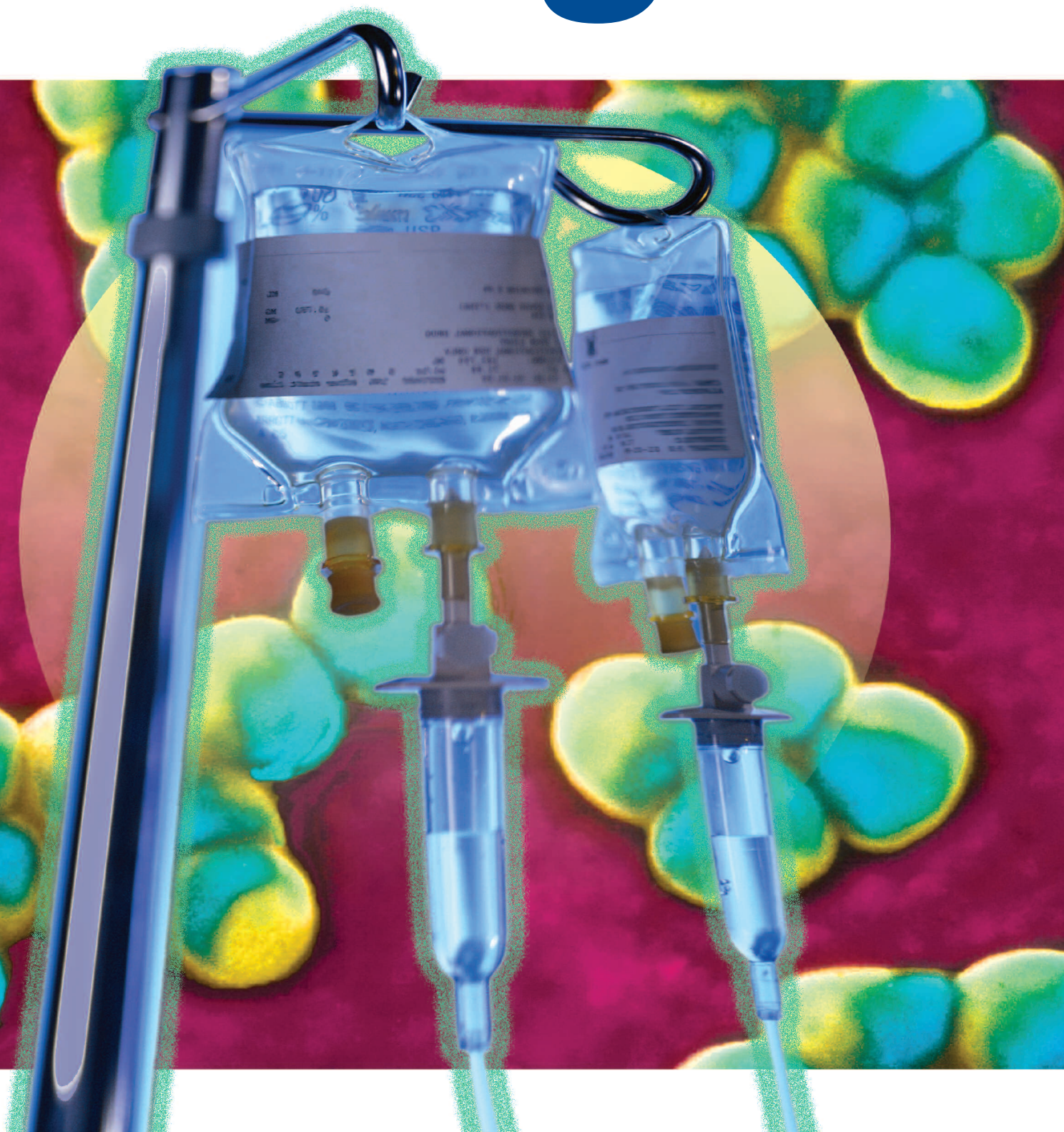


was 3.1%, and the pooled mean rate for CBSI was 3.2%.[1] For the same patient population, the 50% median percentile rate for ventilator-associated pneumonia (VAP) was 5.1%, with a pooled mean rate of 5.1%.[1] It's important for nurses to know the rates of these infections in their institution, as nursing plays an important role in prevention.

Common infections

Ventilator-associated pneumonia is the leading cause of hospital-acquired infection deaths, exceeding the rate of death from CBSIs, severe sepsis, and respiratory tract infections in the nonintubated patient.[2] The hospital mortality rate of mechanically ventilated patients who develop VAP is 46%, as compared with 32% for mechanically ventilated patients who don't develop VAP.[2] The estimated increased cost with each episode of VAP is $40,000 for that patient's hospital stay.[3]

The rate of CBSIs is higher in ICU patients than non-ICU patients. Intravenous (I.V.) catheters in the ICU are manipulated more frequently, remain in place longer, and may have been placed under urgent circumstances during which providers may not have adhered to aseptic techniques.

The nurse may access the catheter frequently during the care of the patient for blood draws or blood, drug, and fluid administration. Coupled with the fact that the patient may be exposed to drug-resistant pathogens, these patients are placed at a higher risk. Studies of catheter-related bloodstream infections (CR-BSIs) that control for the underlying illness severity indicate that the mortality rate for these infections is between 4% and 20%.[4] Costs per CR-BSI are estimated to be between $3,700 and $29,000.[5]

A fever in the ICU doesn't always herald an infection, but can instead warn of acute inflammation. A febrile response is brought on by inflammatory cytokines, which can be stimulated by a number of events other than infection. Approximately 50% of fevers are not infections.[6] Part of the nurse's role is to monitor the patient with the most accurate means available and to communicate with the team caring for the patients any pertinent changes in condition.

Early identification of a bacterial infection is crucial, so effective antibiotic therapy can be started immediately to reduce patient morbidity and mortality. When a patient develops a fever in the ICU, the nurse expects to collect appropriate cultures. Frequently, he is the first caregiver to receive the preliminary Gram stain and cultures results. Therefore, nurses should understand the nature of the Gram stain and its implications concerning empiric antibiotic therapy.

Gram stain basics

Developed in the 1880s, the Gram stain continues to be an important test performed on a specimen to identify a bacterial pathogen. It can be applied to body fluids like blood, urine, and joint and cerebrospinal fluid (CSF); secretions such as sputum; and aspirates or swabs of tissues. Usually performed immediately after the specimen is collected, it can provide valuable information on the possible cause of the infection.[7]

The specimen to be stained is applied in a thin layer to a glass slide and allowed to dry. The Gram stain procedure is done in three steps, as follows:

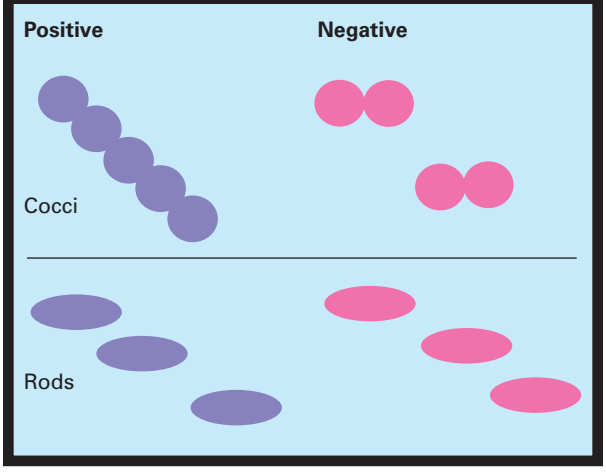
1. Cover the slide with crystal violet, then iodine, which stains everything a deep blue-purple color.
2. Quickly decolorize the slide with an alcohol-acetone solution and rinse with water.
3. Counterstain the slide with fuchsin, which stains everything pink.

Gram-positive organisms retain the blue-purple stain, whereas in Gram-negative organisms the blue stain is washed out and the organisms stain pink like the background material.[7]

Bacteria can then be divided into four main groups based on their Gram stain characteristic and morphology. (See "Gram stain result.") The Gram stain result can help direct the initial choice of antibiotics and give confidence that the empiric therapy will be adequate.

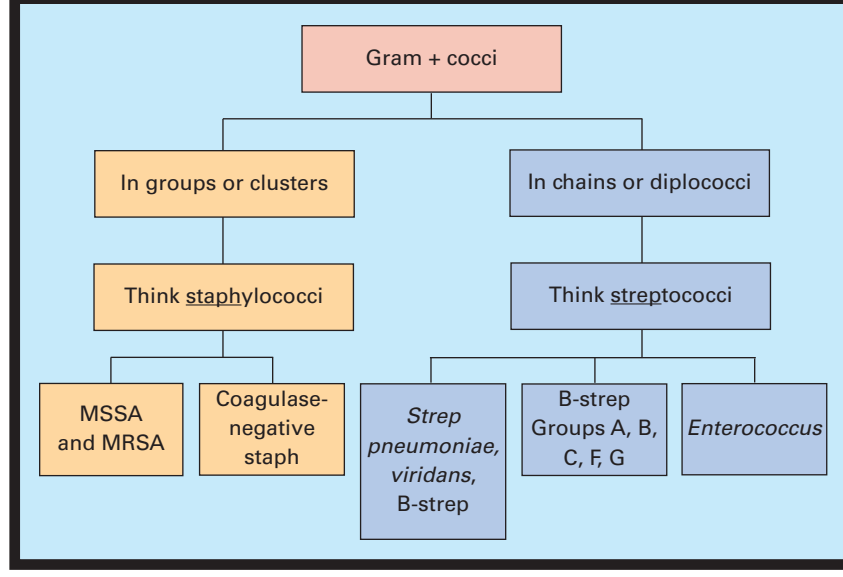
Consider a description of different Gram stain possibilities, some of the more common pathogens associated with each Gram stain, and a generalization of what may

Gram stain result



be appropriate initial antibiotic therapy. The list of pathogens is by no means complete, and the choice of antibiotic therapy is complex, influenced by the site of infection, patient allergies, prehospital setting, and patient comorbidities such as renal and hepatic insufficiencies. But an ICU nurse knowing these basic tenets will be better able to communicate with the physicians involved in the case. For instance, if a nurse was caring for a patient receiving vancomycin for I.V. line sepsis and the patient then developed a productive cough with purulent sputum, and that patient's Gram stain of the expectorated sputum showed many Gram-negative rods, the nurse would recognize the inadequacy of vancomycin and would subsequently alert the treating physician.

Figure 1. Gram-positive cocci



Administering antibiotics

Figure 1 demonstrates the possibilities if the initial Gram stain is Gram-positive cocci. The nurse can follow the algorithm to determine the most likely possibilities. The next step would be to ensure that the patient was currently on the appropriate antibiotics, and if not, contact would need to be made with the physician to change therapy. Vancomycin provides broad-spectrum coverage of both streptococci and staphylococci with the exception of vancomycin-resistant enterococci. The addition of ceftriaxone (Rocephin) should be considered in suspected pneumococcal meningitis. Try to change to a non-vancomycin and more narrow-spectrum antibiotic once culture data is known.

If the Gram stain preliminary report yields Gram-positive rods, Figure 2 demonstrates the potential pathogens. The antibiotic therapy depends on the clinical situation. Metronidazole (Flagyl) should treat most *Clostridium* infections. *Bacillus* and *Corynebacterium* isolates are usually contaminants (skin flora), but can be pathogens in the right setting. *Listeria* CSF infections are treated with ampicillin and gentamicin (Garamycin). Each patient needs to be carefully evaluated.

Gram-negative cocci are outlined in Figure 3. Remember that preliminary cultures can have mixed pathogens and each one needs to be evaluated against the current antibiotic regimen. In the case of Gram-negative cocci the use of a third-generation cephalosporin such as ceftriaxone covers all the above pathogens. Chloramphenicol has been used in penicillin-allergic patients with *Neisseria meningitidis* meningitis. A variety of regimens have been used to treat *Neisseria gonorrhoeae* and pelvic inflammatory disease.

The identification of Gram-negative rods in a Gram stain depends on whether the organism is aerobic or anaerobic as demonstrated in Figure 4. The empiric broad-spectrum therapy of aerobic Gram-negative rods can be provided with piperacillin-tazobactam (Zosyn) or imipenem-cilastatin (Primaxin). Metronidazole or ampicillin-sulbactam (Unasyn) is used to treat known *Bacteroides fragilis* infections. An aminoglycoside plus a fluoroquinolone combination can be used in penicillin-allergic patients. Therapy should be simplified once culture data is known.[8]

As stated above, in the choice of empiric antibiotic therapy there are many considerations, including the site of the infection, setting in which the infection occurs, allergies of the patient, possible conflicting medications, and patient comorbidities. If all of these are considered, the Gram stain is not necessary for the choice of broad-spectrum antibiotic coverage. But once the Gram stain and preliminary culture information is known, the clinician should make sure the chosen antibiotic regimen covers the possible pathogens. After receiving final culture data, with antibiotic sensitivities to the isolated pathogens, the clinician hopefully can simplify antibiotic therapy to make it more

narrow spectrum in coverage, in an effort to minimize the risk of developing MDR bacteria. If the patient has been on coverage and has grown potential pathogens despite adequate coverage, the physician may decide to broaden or double-cover the most likely culprit.

Disease-specific infections

Neisseria meningitidis, a Gram-negative diplococci, is currently the leading cause of bacterial meningitis in the United States. This is secondary to the decrease in *Streptococcus pneumoniae and Haemophilus* as a result of increased vaccines.[9] The incidence of disease is 1,400 to 2,800 cases/year in the United States (according to data from the Centers for Disease Control and Prevention). It's more common in children than adults.

Neisseria meningitidis (a Gram-negative cocci) is colonized on nasopharyngeal surfaces and transmitted via large respiratory droplets through direct contact from the patients or asymptomatic carriers. Patient groups that are at higher risk for contracting the disease are the very young and persons with deficiencies in the terminal complement pathway, anatomic or functional asplenia, antecedent infections, household crowding, chronic underlying disease, and both active and passive smoking.[9] College students living in dorms are also at high risk.

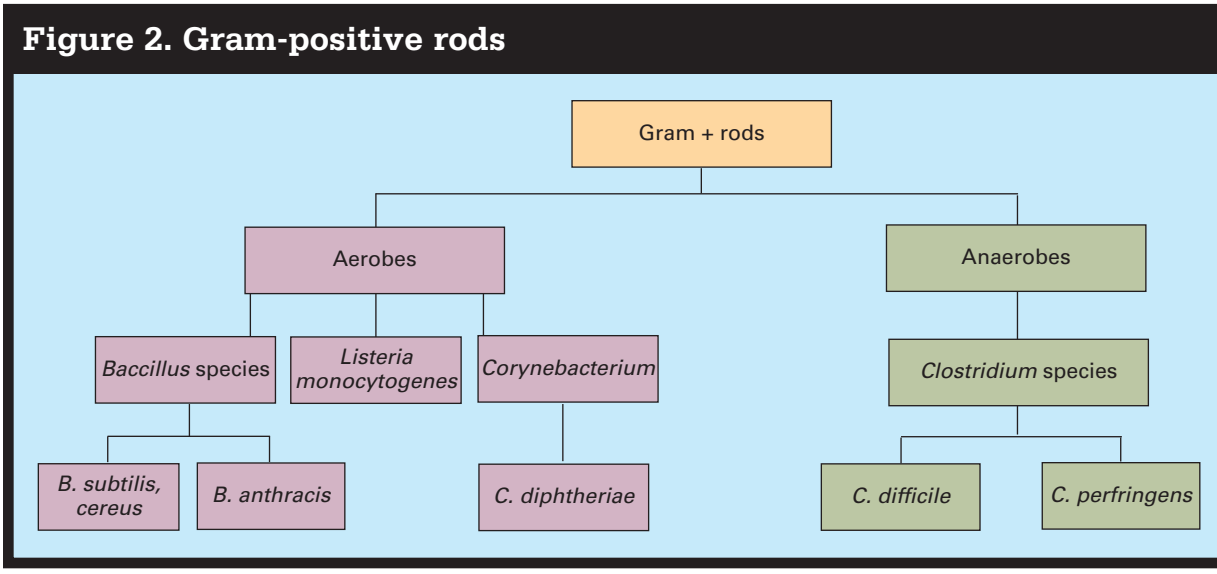
The clinical presentation can be varied. After a few days of a seemingly innocent upper respiratory infection, the patient can develop a sudden fever and chills. Other associated presenting symptoms can include malaise, weakness, myalgia, headache, nausea, vomiting, and arthralgia. The classic skin rash, which is essential for identifying meningococcemia, may be a few ill-defined lesions to a widespread petechial eruption within a few hours.[10]

The most serious form of the disease is fulminant meningococcemia and occurs in approximately 5% to 15% of cases of meningococcal disease. This clinical presentation is abrupt with high fever, chills, myalgia, weakness, nausea, vomiting, and headache. Within the next few hours, apprehension, restlessness, and, frequently, delirium occur. The petechial rash appears suddenly and is widespread; as meningococcemia progresses, purpuric and ecchymotic lesions may form.[10] The classic signs and symptoms in adults include head ache and nuccal rigidity. The patient will have positive Kernig's and Brudzinski's signs. (See "Assessment for meningeal irritation.")

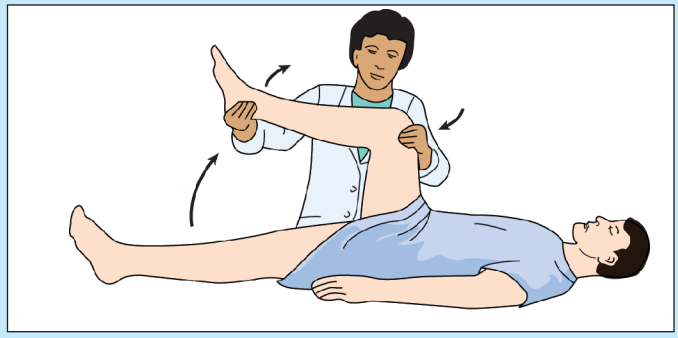
Treatment depends on early recognition. Nurses should expect to receive orders for blood cultures, complete blood cell count, electrolyte studies, and possibly coagulation studies and a disseminated intravascular coagulation panel. Other diagnostics would include a computed tomography scan of the head prior to performing a lumbar puncture (LP) to rule out signs of increased intracranial pressure. If the diagnosis is strongly suspected, antibiotics can be started prior to the LP. The treatment of choice is a third-generation cephalosporin such as ceftriaxone or cefotaxime (Claforan). Other alternative therapies are penicillin G, ampicillin, chloramphenicol, a fluoroquinolone, such as ciprofloxacin (Cipro), and aztreonam (Azactam).[11]

Vaccination is the best method of disease prevention. The recommendations are not to vaccinate the general public, but to vaccinate children and, if not previously

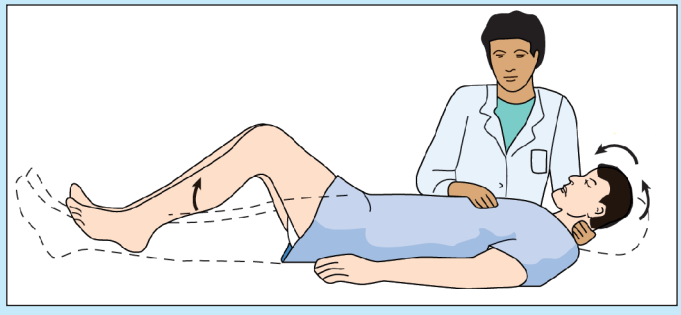
Figure 2. Gram-positive rods



Assessment for meningeal irritation[12]



Kernig's sign:
With the patient supine, flex his or her leg at both the hip and knee, then extend the leg. Mild discomfort behind the knee is normal. A positive Kernig's sign is indicated by pain and increased resistance. When present bilaterally, it suggests meningeal irritation.



Brudzinski's sign:
While supine, flex the patient's neck and observe both the hips and knees. A positive Brudzinski's sign is indicated by flexion of the hips and knees and suggests meningeal inflammation.

immunized, college students, military recruits, certain travelers, persons in an area of high outbreaks, and those at high risk (such as splenectomy patients).[9]

Zapping VAP and HAP

Pulmonary infections account for a large percentage of patients admitted to ICUs. The infection is defined based on when it's identified and risk factors. It's classified as community-acquired pneumonia when the patient has become exposed to pathogens outside the hospital and is admitted with the illness.

Hospital-acquired pneumonia (HAP) and VAP are serious infections. In critical care, VAP is a pneumonia that develops (and was not present or brewing at the time of intubation) 48 to 72 hours after intubation.[13] Hospital-acquired pneumonia is defined as pneumonia that occurs 48 hours or more after admission to the hospital that was not present at the time of admission.[13] Healthcare-associated pneumonia (HCAP) includes any patient who has been in a healthcare environment and exposed to pathogens. This includes any patient who has been hospitalized for 2 or more days in the preceding 90 days or who resides in a nursing home or long-term-care facility; has received antibiotic therapy, chemotherapy, or chronic wound care in the last 30 days; or has attended a hospital or renal dialysis clinic.[13]

It's important for the nurse caring for these patients to be familiar with these definitions to accurately identify patients and assist with appropriate therapy. In particular, critical care nurses should be aware of their unit's VAP rate and the importance of the role of the bedside nurse in the prevention of the infection. The American Thoracic Society has developed guidelines for the care of this complex patient population. The microbiology of VAP and HAP in the critical care unit often involves MDR organisms. The most common are *Pseudomonas aeruginosa, Acinetobacter* species, and methicillin-resistant *Staphylococcus aureus*.[13]

It's imperative for bedside nurses to be aware of the most common infections in their specific ICU, as well as the resistance patterns of the microbes. The microbiology department, in conjunction with the infection control committee, typically publishes this information yearly. This documentation, which should be available to all practitioners, describes the types of infections that have been documented in the past year and the resistances and sensitivities to antibiotics.

If HAP, HCAP, or VAP are suspected, the nurse should expect to obtain a fresh sputum specimen, chest X-ray, blood cultures, and a complete blood cell count with differential. After the blood cultures and sputum are collected, the nurse should start antibiotics immediately.

The goal is to cover at least 90% of the possibly offending organisms from the beginning. Therefore, the physician will take into account the patient's comorbidities and medical history, the timing of the infection (early or late after intubation for VAP), and the unit's pattern of infections and antibiotic resistances. Particularly if MDR pathogens or late-developing VAP is suspected, expect to see triple antibiotic coverage ordered. The patient's clinical course is followed closely, and once the cultures are back antibiotics are adjusted appropriately.

Infective endocarditis

When a microbial infection invades the endothelial surface of the heart, it's called infective endocarditis (IE). The subsequent lesion that develops, most often in the valvular structures, is vegetation composed of platelets and fibrin, which is rich with microorganisms and inflammatory cells.[14] The infection can also occur at the site of a septal defect, on the chordae tendineae or mural endocardium. Indwelling intravascular lines can also be a source of seeding.

The clinical presentation of IE includes fever, chills, sweats, anorexia, and dyspnea. In addition to the constitutional signs of infection, other signs and symptoms can depend on the degree of location destruction of the infection (for example, severe mitral regurgitation), if and where there's distal embolization of the vegetation to distant sites (for example, the development of acute renal failure), the seeding of remote sites during bacteremia, and the antibody response to the infecting organism.[15]

Nurses should expect a complete infectious workup, including blood cultures, complete blood cell count with differential, erythrocyte sedimentation rate, metabolic panel, urine and sputum cultures, and if the patient has an indwelling intravascular line at least one of the blood cultures should be obtained via that port. An initial transthoracic echocardiogram should be done, followed by a transesophageal echocardiogram, if indicated. If the diagnosis of IE is suspected, antibiotics should be started promptly.

Although many organisms can be responsible for the development of IE, the most common organisms are streptococci, staphylococci, and enterococci.[15] Patients at higher risk for developing IE include those with mitral valve prolapse, I.V. drug abusers, those with prosthetic valves, adults with congenital heart defects, and those with indwelling catheters.[14-15]

The goal with antibiotic therapy is to kill the offending organism; therefore, the antibiotics chosen need to be able to provide bactericidal action as opposed to bacteriostatic. The regimen chosen is based on the patient's history and presence of a prosthetic valve. In general, expect to see aqueous penicillin G, ceftriaxone, or aqueous pencillin G plus gentamicin or vancomycin ordered. This regimen covers the most common organisms. The patients are followed closely with repeat blood cultures and echocardiograms.

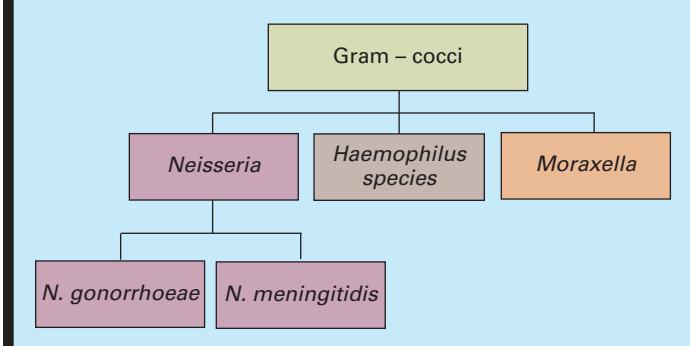
Urinary tract infections

The presence of urinary catheters is commonplace in the hospital and more so in the ICU. However benign these catheters may seem compared with other invasive monitoring options, they're the most common source of healthcare-associated infection. The nurse is often the first practitioner to notice a change in the quality of the urine and suspect a UTI. The most common causative organisms of catheter-associated UTIs are caused by a variety of pathogens, including *Escherichia coli, Klebsiella, Proteus*, *Enterococcus*, *Pseudomonas, Enterobacter, Serratia*, and *Candida.*

Nosocomial UTIs may be caused by MDR pathogens or multiple pathogens. In the ICU, determining the origination of the infection can be complicated. The most common pathogens are enteric Gram-negative aerobic bacilli with the most common being *E. coli*.[6] The nurse should expect to send a urine sample for urinalysis, culture and sensitivity, a complete blood cell count, and blood cultures if urosepsis is suspected.

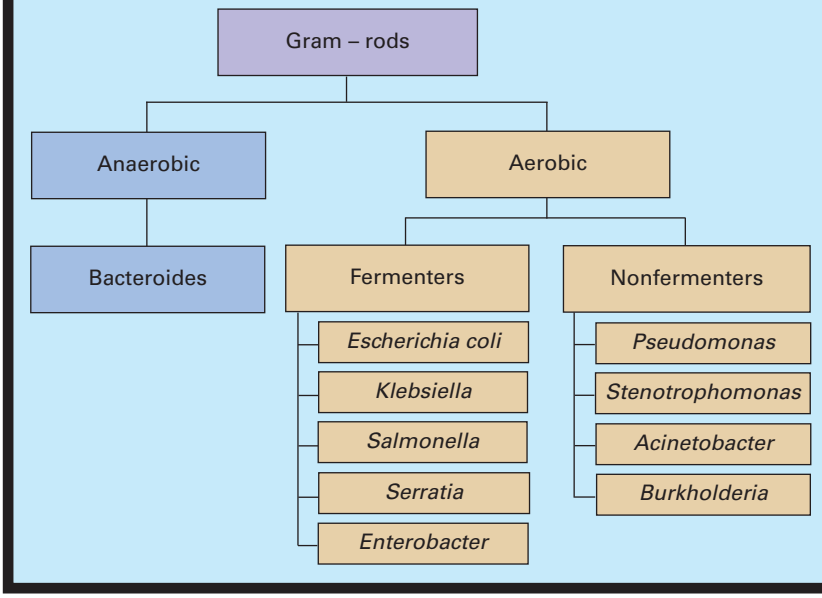
The clinical picture can be difficult to see in the ICU, depending on the acuity of illness that required the patient to be admitted. A new fever is always a concern that may indicate a developing UTI. Additionally, confusion in older adult patients may be the only sign of a UTI. The empiric antibiotic regimen for a nosocomi-

Figure 3. Gram-negative cocci



al UTI is based on covering the most common pathogens. To provide Gram-negative bacilli coverage, a third-generation cephalosporin, an aminoglycoside, aztreonam, or imipenem-cilastatin should be given. If a Gram-positive cocci infection is suspected, *Enterococcus* is the most common causative organism and a fluoroquinolone such as ciprofloxacin (Cipro) is indicated. Fungal UTIs require antifungal agents such as Amphotericin B.[6]

Figure 4. Gram-negative rods



Anaerobic organisms

The development of *Clostridium difficile* is almost always related to previous antibiotic use. The presence of diarrhea in a critically ill patient can be multifactorial, but this pathogen must always be kept in mind. *Clostridium difficile* is a Gram-positive, spore-forming anaerobic organism that's associated with the development of gastrointestinal infections, ranging from asymptomatic colonization to severe diarrhea and the development of pseudomembranous colitis, toxic megacolon, intestinal perforation, and death.[6, 16–17] *Clostridium difficile* is not an invasive pathogen, but the endotoxins released cause inflammation in the bowel mucosa.

The ICU nurse is the first-line caregiver that notes this change in patient condition. Communicating the change to the other team members is an important part of preventing the infection's progression. Patients who are at greatest risk for developing *C. difficile* include those with the following criteria:

- receiving broad-spectrum antibiotics
- being older than 65 years of age
- undergoing nasogastric suction
- experiencing prolonged hospital stays.[16]

The administration of antiulcer medications such as proton pump inhibitors may also be a risk factor, but conflicting evidence exists.[16] Expect to obtain stool samples and to start antibiotics once the samples are collected. The standard therapy is oral vancomycin or oral/I.V. metronidazole.[6]

Catheter-related bloodstream infections

Critically ill patients frequently have multiple I.V. lines to provide appropriate monitoring and allow for the administration of therapy. These patients are at risk for developing infections related to these devices. The risks and benefits for each line or device must be carefully considered.

The types of organisms that cause CR-BSIs have evolved over time. According to the NNIS database, coagulase-negative staphylococci, followed by enterococci, are the most frequent isolates, but *S. aureus* is on the increase.[1] An unexplained fever in a patient with invasive lines must be suspect for CR-BSI, and of course the development of purulent discharge at the insertion site is potentially diagnostic.

Nurses should expect to draw blood cultures both peripherally and through the line. If at all possible, the line in question should be removed. The empiric antibiotic therapy depends on the degree of illness and the presence of neutropenia or a prosthetic heart valve. For the presence of purulent discharge at the insertion site, vancomycin is the drug of choice because the staphylococci may be resistant to cephalosporins. If the patient has a prosthetic heart valve, in addition to vancomycin, gentamicin is added as a second agent.[6] If the patient is neutropenic, the recommended therapy includes vancomycin, gentamicin, and ceftazidime (Fortaz).[6]

Nursing's role

The ICU nurse cares for an increasingly vulnerable and complex patient population. The development of new infections can be costly and deadly. The nurse is often

the first caregiver to identify a new infection and to receive the results from the microbiology lab. Therefore, it's imperative to be armed with basic knowledge of ICU pathogens and to communicate with the physician in a timely manner. The nurse has a very important role in recognition of potential infections, prompt notification of results, and, above all, prevention. M

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