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Infections in the Intensive Care Unit

Posttransplant Infections

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KEYWORDS

• Posttransplant infections • Posttransplant ICU care • Solid organ transplantation
• Risk factors

KEY POINTS

- Solid organ transplant (SOT) has become a well-established standard of care for end-organ failure.
- The nurse in the intensive care unit may be exposed to these patients at any stage in the care continuum of pretransplant or posttransplant care.
- Factors affecting the incidence of infection after SOT include the type of organ transplanted, anatomic region of transplant, incidence of surgical complications, level of immunosuppression, and antirejection therapy.
- Knowledge of risk factors, timing, and treatments for infections may help to enhance clinical practices and optimize patient safety and clinical outcomes.

INTRODUCTION

Each year in the United States organ transplantation offers a lifeline to more than 25,000 individuals who have end-stage organ dysfunction.[1] The United Network for Organ Sharing keeps a tally of the number of transplant donors and patients waiting for solid organ transplant (SOT). In April 2016, there were more than 120,000 waiting list candidates and just over 1000 donors.[2] According to the United Network for Organ Sharing website, solid organs in most demand are kidneys, with more than 100,000 patients on the waiting list, closely followed by almost 15,000 people waiting for livers.[2] There are approximately 4000 candidates waiting for a heart transplant and a little over 1000 candidates waiting for lung and pancreas transplants.[2] The number of donors for kidney and liver transplantation has increased over the past 5 years,

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possibly owing to increased living donor transplants. Five-year survival rates for kidney transplant recipients are roughly 75% and for liver transplant recipients it is around 70%.[3] Transplant recipients are at risk of complications related to surgical procedures, immunosuppressive therapy, and infection.[4] Infection remains the most common complication after SOT.[1,4,5] This article discusses infections in SOT recipients including those with kidney, heart, lungs, and pancreas transplants.

RISK OF INFECTIONS IN SOLID ORGAN TRANSPLANTATION

Early postoperative infection is an important source of morbidity and mortality in SOT recipients. Factors affecting the incidence of infection after SOT include the type of organ transplanted, anatomic region of transplant, incidence of surgical complications, level of immunosuppression, and antirejection therapy.[4] Limited high-level evidence exists about the epidemiology and risk factors for early nosocomial infections in SOT recipients; however, the third edition of the American Society of Transplantation Guidelines for the Prevention and Treatment of Infectious Complications of Solid Organ Transplantation offers a guide for clinical practice by providing evidence where it exists and clinical consensus where critically appraised evidence is limited.[4]

Many of the classic clinical markers and inflammatory signs and symptoms associated with infection are diminished in SOT recipients owing to immunosuppression; therefore, usual indicators such as fever, leukocytosis, and wound erythema are not always appreciated.[3] Additionally, usual pain pathways may be disrupted owing to altered anatomy and organ denervation affecting recognition of infection, and subsequently delaying diagnosis and increasing the risk of morbidity and mortality.[3] Transplant recipients are particularly susceptible to infection during episodes of increased immunosuppression and should be observed closely for signs of infection.[3] Traditional testing methods to seek infectious sources may be limited in the diagnosis of acute disease after transplant because bacterial and fungal cultures often have lower yields and radiographs are often insufficient for diagnosing infections.[3]

PRETRANSPLANT SCREENING

Thorough pretransplant screening is performed to identify infectious diseases that may preclude donor or recipient transplantation. This includes a detailed medical history of prior infections, past travel, place of residence, and exposure to animal and environmental pathogens.[5] Standard screening includes human immunodeficiency virus (HIV), cytomegalovirus (CMV) immunoglobulin (Ig)G antibody, hepatitis B virus (HBV), hepatitis C virus (HCV), rapid plasma reagin, toxoplasma antibody, Epstein-Barr virus antibody, and varicella-zoster virus antibody, with additional testing based on patient history.[5] Chest radiography and microbiologic testing of blood and urine are commonly included in screening processes.[6,7] The donor screening process is influenced by the time sensitive nature of organ transplantation and ability to conduct rapid cycle testing.[6] Organ transplant risk factors can be separated into pretransplant, intraoperative, and posttransplant. The pretransplant risk factors are further divided into donor or recipient.

PRETRANSPLANT RISK FACTORS

A rigorous selection process by a team of highly trained specialists is needed to screen candidates for transplant.[8] Patient risk factors should be assessed including pretransplant infection (especially multidrug resistant [MDR] organisms), severity of illness, functional capacity, psychosocial assessment, and ability for self-care

posttransplant.[8,9] Donor-derived infection occurs in approximately 0.2% of deceased donor transplants, but may be mitigated by careful medical and social history, physical assessment of organs, and screening for infection.[10] Transmission of bacteria from MDR bacteria, such as methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus* (VRE) can result in graft loss and increased morbidity and mortality.[10] Donors with bacteremia may be used; however, it is recommended that these donors receive targeted antimicrobial therapy for at least 1 to 2 days before transplantation and demonstrate clinical improvement.[10] Recipients receiving organs from infected donors should receive a 7- to 10-day course of antibiotics targeted to the organism isolated from the donor.[10]

Donor-derived infections are a result of organ transplants with active and latent infections that may or may not be expected.[10] Examples of infections that are expected in transmission include CMV and HBV whereas, pathogens that may be unexpected include HIV, Chagas, HCV, lymphocytic choriomeningitis virus, *Mycobacterium tuberculosis*, MDR, rabies, and West Nile virus.[10] Additionally, there are group of infections such as West Nile virus, HIV, rabies, lymphocytic choriomeningitis viral infection, and Chagas' disease that are associated with deceased donors.

Some pathogens may not be detected in pretransplant screening owing to delays in seroconversion or sensitivity of testing; therefore, transplantation of organs from deceased donors with fever and viral syndromes may be controversial.[6] Colonization of bacterial and fungal infections in donors presents further infectious concerns for the transplant organ recipients; hence, early recognition along with prophylaxis or treatment of the subclinical infection is recommended.[4] The United States Organ Procurement and Transplantation Network monitors disease transmission through a national registry.[10,11]

INTRAOPERATIVE RISK FACTORS

Multiple factors impact the transplant recipient's risk for infection during the operative period, such as the type of surgical reconstruction, unexpected surgical events, ischemic injury, prolonged operative times, operative field contamination, excessive bleeding, and organ injury.[10] Examples of surgical risks include selection of biliary anastomosis in liver transplant patients leading to postoperative biliary complications and deceased donor dysfunctional kidney allografts that lead to higher rates of urinary tract infection (UTI).[3]

POSTOPERATIVE RISK FACTORS

Posttransplant immunosuppression to prevent rejection is a significant risk factor for opportunistic infections.[4,12–14] Microbiological surveillance and assays that measure immunity to assess infectious risk should be in place for common posttransplant pathogens and MDR bacteria, viruses, and fungi.[4,8] Close attention to transplanted organs is essential to detect complications in vascular supply and organ function that could lead to increased risk for infection and expeditious removal of devices to prevent catheter-related infections is highly recommended.[4]

INFECTION PREVENTION

General preventative strategies include vaccination, universal prophylaxis, and preemptive therapy.[3,6] Ideally, vaccinations should be provided before transplantation because immunosuppression and critical illness may decrease vaccination effectiveness.[3,8] The best time for a vaccination panel that includes live vaccinations and

attenuated vaccines is early in the course of the disease and before transplant.[8] Smallpox, oral polio, and Calmette-Guerin's bacillus, and live attenuated vaccinations are contraindicated after transplantation.[8] Lifestyle changes are important after transplantation, and include measures to decrease risk for infection such as hand washing after food preparation, gardening, and contact with feces or secretions.[6] Attention to food preparation, including undercooked meats, unwashed fruits and vegetables, unpasteurized dairy products, and avoiding well water are important for transplant recipients to prevent infections.[5–7]

TIMING OF INFECTIONS AFTER SOLID ORGAN TRANSPLANTATION

Timing of infections after SOT is fairly predictable irrespective of organ type. The 3 common time frames related to SOT can be categorized as early, intermediate, and late (**Table 1**).[3,7] The early time period is within the first month after transplant and is usually associated with bacterial and candidal infections; the intermediate phase relates to months 2 to 6 with infections commonly linked with transplantation; and the late period, after 6 months, comprises infections usually related to chronic rejection.[3,7] Advances in powerful immunosuppressive agents have decreased the incidence of rejection of transplanted organs, but has increased patients' susceptibility to opportunistic infections and cancer.[3,7] Routine antimicrobial prophylaxis for *Pneumocystis jirovecii* and CMV has changed patterns of posttransplant opportunistic infections and influenced emergence of new clinical syndromes, such as polyomavirus type BK nephropathy and other organisms with antimicrobial resistance.[6,15]

Infection in immunosuppressed SOT recipients is often difficult to distinguish because signs and symptoms of infection are often diminished and noninfectious causes of fever, allograft rejection, and toxic drug interactions may exist.[3] In these cases, laboratory testing including quantitative assays can sometimes assist in detection of specific infections.[3,4,16] HBV is an example of an infection transmitted through transplant, where risk can be mitigated through testing transplant candidates for HBV (hepatitis B surface antigen, anti-hepatitis B surface, and anti-hepatitis B core), vaccination, and antiviral prophylaxis.[17]

EARLY POSTTRANSPLANT INFECTIONS (LESS THAN 1 MONTH)

Infections during the early posttransplant period are largely donor derived, recipient derived/colonizers, nosocomial pathogens, or related to complications of surgery such as bacteria and yeast.[3,4,7] At least 50% of bacterial infections after transplantation arise during this early period with many labeled as surgical site infections (SSI) that derive from anastomotic stenosis, leaks, or other surgical complications.[4,7] Fluid collections, devitalized tissues, graft injury, and anastomotic issues are risk factors for development of serious invasive infections.[4,7] Donor-derived bacterial and fungal infections transferred with the allograft should be reported to organ procurement agencies to mitigate risk to other organ recipients and to assess antimicrobial susceptibility, prophylaxis, and need for specimen biopsy.[4,7] Concerns during this period warranting investigation include *Clostridium difficile* colitis, hepatitis, pneumonitis, encephalitis, rash, and leukopenia.[13,14,18]

INTERMEDIATE POSTTRANSPLANT INFECTIONS (1 TO 6 MONTHS)

Infections commonly seen during the intermediate period are opportunistic pathogens in the immunocompromised host. Infections often linked with transplantation are latent pathogens transmitted from donor organs, reactivated within the recipient, or

transferred in blood products. Potential pathogens include polyomavirus BK, adenovirus, recurrent HCV, and herpesvirus infections, varicella zoster, CMV, Epstein-Barr virus, lymphoproliferative disorders (posttransplant lymphoproliferative disorder), *P jirovecii* pneumonia, toxoplasmosis, aspergillus, tuberculosis, cryptococcus, *Trypanosoma cruzi*, and *Strongyloides*, which may occur in the absence of appropriate prophylaxis or preventative measures.[4,7] Antibacterial prophylaxis with trimethoprim–sulfamethoxazole is usually administered for UTIs and opportunistic infections such as pneumocystis pneumonia, *Listeria monocytogenes* infection, *Toxoplasma gondii* infection, and infection with sulfa-susceptible *Nocardia* spp.[3,6,7]

LATE POSTTRANSPLANT INFECTIONS (GREATER THAN 6 MONTHS)

The risk of infection usually decreases in the late posttransplant period because immunosuppressive therapy is usually tapered down and allograft function is optimized.[4,7] Individuals who have comorbid conditions such as diabetes mellitus, underlying disease, or malignancy continue to be at an increased risk for infections during this later phase.[4,7] Individuals who require increased immunosuppression, either related to rejection or underlying disease, will be at greater risk for late opportunistic infections.[4,7] Allograft injury can persist owing to chronic viral infections, such as cirrhosis from HCV in liver transplant recipients; *Stenotrophomonas*, *Pseudomonas*, *Aspergillus*, and bronchiolitis obliterans in lung transplant recipients; accelerated vasculopathy in heart-transplant recipients with CMV; and other malignant disorders such as posttransplantation lymphoproliferative disorder.[4,7]

Immunosuppressed transplant patients continue to be at increased risk for opportunistic infection with *listeria* or *Nocardia* spp, invasive fungal pathogens such as zygomycetes and dematiaceous molds, and unusual organisms (eg, *rhodococcus* spp).[4,7]

TYPES OF POSTTRANSPLANT INFECTIONS

Pneumonia

Pneumonia is the most commonly diagnosed nosocomial infection in surgical patients and often is seen in the early phase after SOT as a hospital-acquired pneumonia. These hospital-acquired infections occur after 48 hours of hospital stay with increased risk for patients requiring mechanical ventilation via endotracheal intubation.[1]

Urinary Tract Infection

Diagnosis of UTI in adults requires the presence of dysuria, increased urinary frequency, or suprapubic tenderness, combined with a positive urine culture.[1] The most common causative pathogens are gram-negative bacteria, including *Escherichia coli*, *E cloacae*, and *Acinetobacter baumannii*. High percentages of SOT patients are found to be colonized with MRSA or VRE, leading to increased risk of ensuing infections.[14]

Surgical Site Infection

SSIs are defined as postoperative infections around the surgical incision that are superficial, deep, or have organ involvement and occur within 30 to 90 days after device implantation.[1] Diagnosis of an SSI requires a positive culture from the surgical site, a purulent exudate from a surgical wound, or a surgical incision that requires reopening.[1] SSIs in the general surgical population are considered to be preventable with increased risk among those with advanced age, diabetes, smoking history, obesity, and lengthy operative times.[1] SSIs are linked with longer durations of stay in the

Table 1
Timing of posttransplant infections

Infection type	Early 0–1 mo	Intermediate 1–6 mo	Late >6 mo
Bacterial			
Catheter-related infections, wound infection, pneumonia			
		Nocardia	
		Listeria, *Mycobacterium tuberculosis*	
	Gram-negative enteric bacilli Small bowel, liver, neonatal heart *Pseudomonas*/*Burkholderia* spp.	Pneumonia	Community-acquired pneumonia, urinary tract infection *Pseudomonas*/*Burkholderia* spp.
	CF: lung	CF: lung	CF: lung
	Gram-positive MRSA/VRE	Gram-negative enteric bacilli *Pseudomonas*/*Burkholderia* spp.	Lung recipients with chronic rejection gram-negative bacillary bacteremia Small bowel
	Anastomotic leaks and ischemia *Clostridium difficile* colitis	PCP and antiviral (CMV, HBV) prophylaxis: polyomavirus BK infection, nephropathy Small bowel	Infection with *Nocardia*, *Rhodococcus* spp.
		C difficile colitis	
Viral	Varicella zoster virus *Pseudomonas*/*Burkholderia* spp.	*Cryptococcus neoformans* infection *Mycobacterium tuberculosis* infection Anastomotic complications	
			CMV retinitis or colitis Papillomavirus, Community-acquired (SARS, West Nile virus infection) JC polyomavirus infection Skin cancer, lymphoma Posttransplant lymphoproliferative disorder
	HSV		HSV encephalitis
	CMV, Epstein–Barr virus, varicella–zoster virus, influenza, posttransplant lymphoproliferative disorder (respiratory syncytial virus), Adenovirus		
	Hepatitis (HBV, HCV)		

Fungal	*Candida* spp (non-*albicans*)	*Pneumocystis* *Aspergillus*	Cryptococcus Aspergillus spp. • Lung transplants with chronic rejection Infection with *Aspergillus*, atypical molds, *Mucor* spp.
Parasitic		*Strongyloides* *Toxoplasma* *Leishmania* *Toxoplasma gondii* *Trypanosoma cruzi*	

Abbreviations: CF, cystic fibrosis; CMV, cytomegalovirus; HBV, hepatitis B virus; HCV, hepatitis C virus; HSV, herpes simplex virus; MRSA, methicillin-resistant *Staphylococcus aureus*; PCP, *Pneumocystis jirovecii* pneumonia; SARS, severe acute respiratory syndrome; VRE, vancomycin-resistant *Enterococcus*.

intensive care unit (ICU), more frequent hospital readmissions, increased morbidity and mortality, and cost in excess of $40,000 per infected patient.[1]

Blood Stream Infections

Blood stream infections (BSIs) in both the general surgical population and in transplant recipients have been associated with significant morbidity and mortality with increased risks such as red blood cell transfusion, parenteral nutrition, age, immunosuppression, and medical comorbidities, including diabetes, peripheral vascular disease, congestive heart failure, and renal and liver disease.[1] Incidence of BSI within 30 days of SOT ranges from 7% to 14%. The approximate incidence by organ transplanted is 5% in kidney and pancreas-kidney, and 12% in liver transplants. Gram-positive bacteria are most frequently isolated in transplant recipients, although gram-negatives are more frequent among kidney and liver transplant recipients.[1,4,7] Antibiotic resistance is common, with MDR and hospital-acquired infections becoming a significant risk before and after transplantation.[5,12–14]

INFECTIONS AND TYPE OF TRANSPLANT

Kidney Transplant

UTIs are the most common infections after a kidney transplant, likely owing to anatomic disruption of the urinary tract during surgery, presence of ureteral catheters during the first weeks posttransplant, and preexistent urinary tract abnormalities.[1,15,19] Risk factors for BSI in kidney transplant recipients include ABO incompatibility, previous CMV infection, pretransplant dialysis, acute rejection, urologic disease, presence of a ureteral stent, and high posttransplant serum creatinine levels. Gram-negative bacteria identified as the main pathogens responsible for BSI in this group are *E coli*, *Pseudomonas aeruginosa*, *Klebsiella* spp, *Enterobacter* spp, and *A baumanii*. Gram-positive bacteria identified as the main pathogens responsible for BSI in this group are coagulase-negative staphylococci, *Enterococcus* spp, and *S aureus*.[1,15,16,19] The incidence of candidemia after renal transplantation is low with most common spp identified as *C albicans*, *C parapsilosis*, and *C glabrata*.[16] Kidney transplant recipients are at significant risk for developing infection by MDR pathogens (VRE, MRSA, extended-spectrum betalactamase–producing *Klebsiella pneumoniae*, carbapenem-resistant *A baumannii*, carbapenem-resistant *P aeruginosa*, and extended-spectrum betalactamase–producing *Enterobacter* spp).[16]

Pneumonia in the Kidney Transplant Patient

The incidence of early nosocomial pneumonia in the kidney transplant recipient range from around 5% to 15% with most common bacterial pathogens including *S aureus*, *P aeruginosa*, *Acinetobacter* spp, and *Haemophilus influenzae*. Nosocomial pneumonia in kidney transplant recipients has a mortality of 35%.[1]

Urinary Tract Infection in Kidney Transplantation

The most common infection in kidney transplant recipients is UTI with estimates of subsequent bacteremia in up to 60% of these patients.[1,16] Risk factors for nosocomial UTI include age, female gender, duration of bladder catheterization, use of ureteral stents, delayed graft function, immunosuppression regimen, glomerulonephritis, and simultaneous double renal transplant.[1,19] Renal transplant recipients with UTIs are more likely experience a failed transplanted allograft than recipients who do not develop UTIs; therefore, preventive infection control strategies are essential.[1] Early postoperative UTIs are thought to be largely preventable with early catheter removal and implementation of infection evidence-based infection control practices.[19] The

most commonly seen UTIs include *E coli*, *K pneumoniae*, and *enterococcus* spp. UTI treatment includes Trimethoprim-sulfamethoxazole prophylaxis and early urinary catheter removal to reduce risk of UTIs.

Surgical Site Infection in Kidney Transplantation

The incidence of SSIs in kidney transplant patients ranges from 7% to 18% with gram-positive bacteria, staphylococci, and enterococci as the most frequently isolated organisms.[1] Risk factors for SSIs in kidney transplant recipients include pretransplant diabetes mellitus, delayed graft function, a high body mass index, pretransplant glomerulonephritis, acute graft rejection, and need for reoperation early posttransplant; each have been implicated as independent risk factors for the development.[1,20]

Blood Stream Infections in Kidney Transplantation

BSI complicates the early postoperative course of up to 5% of renal transplant recipients, with most cases secondary to a UTI, catheter-related, pneumonia, gastrointestinal, and SSIs.[1,19] Risk factors for early BSIs in kidney transplant recipients include acute rejection, hemodialysis before transplantation, local infections, ureteric stent after transplantation, and being a deceased donor organ recipient. Increased risk of 30-day mortality of kidney transplant recipients who develop a BSI is seen in those with an high Acute Physiology And Chronic Health Evaluation (APACHE) II score, the presence of shock at diagnosis, and respiratory failure.[1,9,19]

Liver Transplant Recipients

BSIs are frequent complications in liver transplant recipients in part owing to the risk of relative immunosuppression of cirrhotic patients before transplantation, and to the prolonged surgical procedure of transplantation.[1,21–24] Risk factors for BSI after liver transplantation include diabetes mellitus, hypoproteinemia, catheterization, preoperative massive effusion or ascites, preoperative *S aureus* carriage, posttransplant hemodialysis, operative blood loss, reoperation, need for mechanical ventilation, and bile duct complications.[1,21,22]

Common organisms found in liver transplant patients include gram-negative bacilli (*E coli*), gram-positive bacteria (*S aureus*), and *Candida*.[1,21,22] Studies show that up to 40% of liver transplant recipients develop at least 1 fungal infection after transplantation with other studies showing increased incidence of infection by MDR gram-negative organisms, such as *Stenotrophomonas maltophilia*, *Ochrobactrum anthropi*, *Pseudomonas* spp, and *A baumanii*. Additionally, pretransplant colonization with VRE and MRSA resulted in a significantly higher risk of infection.[16] These infections have a significant impact on mortality with rates as high as 70%.[1,21,22]

Pneumonia in Liver Transplantation

Pneumonia occurs in 14% to 25% of liver transplant recipients with Enterobacteriaceae, *H influenzae*, *P aeruginosa*, and Aspergillus found as the most common causing pathogens.[1,21,22] Risk factors for pneumonia in liver transplant recipients include retransplantation, surgical technique, dialysis, increased international normalized ratio (>2.3) before liver transplantation, restrictive lung physiology, and prolonged mechanical ventilation.[1,21,22] Nosocomial pneumonia in liver transplant patients has been linked to mortalities as high as 40%.[1]

Urinary Tract Infection in Liver Transplantation

Seven percent to 14% of liver transplant recipients experience a symptomatic UTI in the first month after transplantation owing to gram-negative bacteria including *E coli*, *E*

cloacae, and *A baumannii*.[1] Many organisms are MDR organisms that result in suboptimal patient outcomes and increased health care costs (**Table 2**).[20]

Surgical Site Infections in Liver Transplantation

Liver transplantation is a complex procedure that has one of the highest rates of SSIs.[1,21,22] Independent risk factors for SSI in patients undergoing liver resection include preoperative open wound, surgical technique, hypernatremia, hypoalbuminemia, increased serum bilirubin, dialysis, and longer operative time.[1,21,22] Pathogens that cause SSI in adult liver transplant recipients include *Enterococcus* spp, *Staphylococcus* spp, *Candida* spp, and gram-negative bacteria.[1,21,22] SSIs may be identified by induration, erythema, tenderness, or drainage from the incision site.[1] Risk factors for SSIs in liver transplant recipients include increased operative time (>3.5 hours), surgery lasting more than 7 hours, antibiotic therapy within 3 months before liver transplantation, leak at the biliary anastomosis, female gender, HLA mismatches, increased preoperative white blood cell count, and a donor liver mass-to-recipient body mass ratio of less than 0.01.[1,21]

Blood Stream Infections in Liver Transplantation

The incidence of BSI in liver transplant recipients ranges from 10% to 40%, with more than 50% of bacteremias occurring within the first month after transplantation.[1,21] The most frequently isolated pathogens include *S aureus* and coagulase-negative staphylococci, extended-spectrum betalactamase–producing *E coli*, MDR *P aeruginosa*, candidemia, and invasive fungal infections with primary infectious sources of intravascular catheters and surgical wounds.[1,8,21,22] Risk factors for BSIs include diabetes mellitus, serum albumin levels of greater than 3.0 mg/dL, retransplantation, high transfusion requirement ($\geq$40 U of cellular blood products), choledochojejunostomy, posttransplant dialysis, colonization with Candida spp before transplantation, and pretransplant use of fluoroquinolone prophylaxis for spontaneous bacterial peritonitis.[1,8,21,22] Because the in-hospital mortality for invasive candidiasis may be as high as 80%, antifungal prophylaxis is recommended for recipients with more than 2 risk factors for candidemia.[1,8,21,22]

Lung Transplant Recipients

The incidence of BSI in lung transplant recipients is approximately 25% and varies between early and late posttransplant time periods and between cystic fibrosis (CF) and non-CF patients.[25–27] Most common infections include *S aureus*, *P aeruginosa*, and *Candida* spp from vascular catheter and pulmonary sources. Gram-negative BSIs are often owing to MDR pathogens including *P aeruginosa*, *Burkholderia cepacia* group, and *K pneumoniae* isolates, whereas most pulmonary infections were owing to resistant gram-negative pathogens.[25–27] Colonization and bacteremia by *B cepacia* group is recognized as an important mortality risk factor for CF lung transplant recipients because it can result in progressive necrotizing pneumonia with persistent bacteremia that is highly resistant.[16]

Pneumonia in Lung Transplantation

The prevalence of pneumonia in lung transplant recipients may be as high as 60% with highest risk of infection occurring in the first month posttransplant and with highest mortality in CF patients[25–27] Risk factors include bilateral lung transplant, lung volume reduction, redo transplantation, and preoperative colonization with gram-negative rods.[25–27] The most frequently isolated organisms after lung transplantation include *P aeruginosa*, *S aureus*, and *Aspergillus* spp. Most CF patients are colonized with *P*

Table 2
Recommendations for multidrug-resistant pathogens in solid organ transplant recipients

	MRSA	VRE	Extended-spectrum betalactamase, ampC, Carbapenemase-producing gram –negative bacilli	Nonfermentative gram-negative bacilli
Routine screening	√	X	X	X √-Lung
Contact precautions	√	√	√	√
Isolation	√	√	X	√
Decolonization	Mupirocin (nasal) Chlorhexidine (bathing)	X	X	X

In an outbreak or period of high prevalence surveillance screening may be necessary

aeruginosa by the time they are transplanted, with the paranasal sinuses serving as a reservoir for bacteria. Sinus surgery and daily nasal irrigation with saline has been found to reduce recolonization of the allograft, improve survival, and reduce the incidence of posttransplant bronchiolitis obliterans syndrome. *Aspergillus* remains the most common fungal infection in transplant recipients in the late postoperative period, but may be seen in patients admitted to ICU for respiratory failure.[1,25]

Surgical Site Infections in Lung Transplantation

There are few studies about SSIs in lung transplant recipients; however, the incidence is thought to be approximately 5%, occurring as empyema, surgical wound infection, mediastinitis, sternal osteomyelitis, or pericarditis.[25–27] The most commonly found organisms include *S aureus*, *P aeruginosa*, and *Enterococcus faecium*, along with MDR pathogens, frequently MRSA. Risk factors for SSI include ischemic time, number of red blood cell transfusions, female donor, diabetes, and prior cardiothoracic surgery. Hospital duration of stay, mortality at 6 months, and mortality at 1 year are greater in lung transplant recipients with SSIs.[1]

Pneumonia in Heart Transplantation

The incidence of pneumonia in heart transplant recipients can reach as high as 50%, with commonly isolated pathogens including *S aureus*, *P aeruginosa*, *A baumanii* , and *Enterobacter cloacae*.[1,16] Nosocomial pneumonia is often an early infection after heart transplantation and is associated with increased mortality, especially in patients requiring mechanical ventilation.[1,16,28,29]

Surgical Site Infections in Heart Transplantation

The incidence of SSI after heart transplant can be as high as 40%, which is higher than other cardiac surgeries, and linked to increased morbidity and mortality.[1,16] SSI subtypes are superficial and deep and are caused by gram-positive bacteria (MRSA) and fungal spp (*Candida*).[1,16,28] Risk factors for SSI after heart transplant include body mass index of greater than 30 kg/m^2, previous heart surgery, prolonged cardiopulmonary bypass time, previous ventricular assist device implantation, inotropic support, increased age, and immunosuppression regimens that include sirolimus/tacrolimus. Heart transplant recipients who develop deep sternal wound infections, mediastinitis and wound dehiscence have increased in-hospital mortality compared with patients without infection but do have similar 5-year if they survive the initial infection.[1,16,28]

Blood Stream Infections in Heart Transplantation

The incidence of BSI in heart transplant recipients is up to 15%, with most infections being nosocomial. Central venous catheters, surgical wounds, lower respiratory tract infection, and UTI are the most common sources of bacteremia.[1,16,28] The most common organisms seen posttransplant include gram-negative pathogens, including *E coli*, *P aeruginosa*, *K pneumoniae*, *Serratia marcescens*, and gram-positive microorganisms including *S aureus*, MRSA, *Staphylococcus epidermidis*, and *Enterococcus faecalis*.[1,16] Risk factors for BSI include hemodialysis, prolonged ICU duration of stay, previous CMV infection, and preexisting ventricular assist device at the time of transplantation.[1,16]

Pancreas Transplant Recipients

Pancreas and kidney-pancreas transplant recipients are at risk for bacterial infections from surgical complications, including intraabdominal infections, duodenal leaks,

recurrent UTIs, wound infections, pulmonary, and catheter related sources. Common infections include *Enterobacteriaciae*, VRE, and *Acinetobacter* spp.[1,16]

SUMMARY

SOT has become a well-established standard of care for end-organ failure and the ICU nurse may be exposed to these patients at any stage in the care continuum of pre-transplant or posttransplant care. Knowledge of risk factors, timing, and treatments for infections may help to enhance clinical practices and optimize patient safety and clinical outcomes.

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