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Ventricular Assist Device-Specific Infections

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1. Introduction

Ventricular assist devices (VADs) have been shown to offer a significant survival benefit over medical therapy in patients with advanced heart failure. Despite significant advances in device technology and surgical technique, VAD-specific infections still remain among the most common causes of morbidity and mortality in patients with VADs. VAD-specific infections may involve the driveline exit site, the VAD pocket, or the device pump/cannula. The incidence of infection after VAD implantation depends on the type of device implanted, the location of the device, pre-operative patient characteristics, and post-operative driveline/device management.
This chapter provides a summary of the various characteristics that may contribute to a patient's risk of VAD-specific infection and describes pre-, peri-, and postoperative management to aid in limiting the risk of VAD-specific infection. The chapter also includes definitions of the various types of VAD-specific infections and outlines a general guideline for the treatment of these different infections. This guide builds upon current literature available on VAD-specific infection (Chinn et al., 2005; Slaughter et al., 2010).

2. Definition and types of VAD infection

In 2010 the International Society for Heart and Lung Transplantation (ISHLT) drafted an expert opinion paper regarding the standardization of definitions of infection in patients with VADs (ISHLT, 2010). This document outlines a classification system to organize and delineate different types of VAD-related infections. The first level of classification calls for the differentiation of VAD-*specific* infections, VAD-*related* infections, and Non VAD-related infections. The VAD-specific infection category contains three distinct subcategories of infection, percutaneous driveline infections, pocket infections, and pump and/or cannula infections.
VAD-related infections refer to infections not directly involving the VAD itself but possibly occurring as a result of VAD placement. These include infective endocarditis (IE), bloodstream infections (BSIs) and mediastinitis. Further details regarding these infections can be found in the ISHLT document.

2.1 Types of VAD-specific infection

2.1.1 Driveline infection

Infection of the percutaneous driveline can be divided into three clinical situations, minor exit site erythema, superficial infection or cellulitis, and deep infection.

Minor erythema is defined as involving only the superficial layer of skin and should involve an area of less than 2cm radius around the margin of the incision/exit site. The patient should have no evidence of purulent discharge coming from the exit site and should not have any systemic symptoms or increase in temperature around the driveline site. Erythema at the exit site may represent irritation from mobility of the driveline or it could signal the early stages of cellulitis.

A superficial infection involves tissues superficial to the fascia and muscle layers of the incision. The patient should have either purulent drainage from the incision site or cellulitis spreading from around the exit site in a greater than 1cm radius from the margin of incision with erythema and increased local temperature. Fever, drainage, warmth, tenderness at the site, and leukocytosis would all suggest cellulitis over minor erythema.

Deep infection of the driveline involves the deep soft issues such as the fascial and muscle layers of the incision. The patient should have purulent discharge from the site, spontaneous dehiscence along the driveline, and/or an abscess or other evidence of infection involving the deep incision.

Defining the characteristics of any particular percutaneous driveline infection is crucial as each clinical situation demands a different therapeutic strategy.

2.1.2 Pocket Infection

In VADS where the device is kept inside the body cavity, pocket infections refer to infections that occur in the space that holds the pump device. In most cases the pocket is either intra-abdominal or intra-thoracic. In order to diagnose a pocket infection there must either be positive cultures obtained from the pocket space, either surgically or by needle sampling, or radiographic evidence of infection in the pocket area. There should also be systemic signs of infection including fever, nausea, vomiting, or pain at the site of the pocket.

According to the ISHLT document on infections in VAD patients pocket infections must meet at least one of the following criteria: 1) The patient must have organisms cultured from the pocket space obtained during a surgical operation or needle sampling, 2) Isolation of indistinguishable organisms from either 2 exterior aspects of the VAD, or 1 exterior aspect and one pocket space culture, 3) Abscess or other evidence of infection seen in the pocket during a surgical operation or histopathologic examination, or 4) At least two of the following signs or symptoms with no other recognized cause: fever, nausea, vomiting, pain in the pocket area, or jaundice and organisms seen or cultured from aspirated fluid or pocket area. (ISHLT, 2010)

2.1.3 Pump and/or Cannula infections

The portion of the VAD referred to as the 'pump' is the part of the device involved in the propulsion of blood and includes both continuous and/or pulsatile flow devices either intra- or para-corporeal. The cannula is the part of the VAD connecting the pump device to the patient's cardiovascular system. According to the ISHLT, a pump and/or cannula infection may either be diagnosed by microbiological, histopathological, or clinical criteria. Although some of these require exploration or explantation of the device itself, a diagnostic criterion based on the modified Duke's criteria has been used to clinically diagnose pump and/or cannula infection.

If the VAD is not actively explanted, a set of criteria adapted from the modified Duke's criteria have been formulated to diagnose pump and/or cannula infection. Within this

system a clinical diagnosis requires either 2 major criteria, 1 major and 3 minor criteria, or 4 minor criteria. Major criteria include 1) The recovery of an indistinguishable organism recovered from 2 or more sets of peripheral blood cultures obtained over a 4-week period, with no other focus of infection, 2) Blood cultures from a central venous catheter (CVC) turning positive ≤2 hours after blood cultures drawn from peripheral blood, and 3) positive echocardiogram showing oscillating mass that is adherent to the VAD. Minor criteria include 1) Fever ≥ 38^{o}Celsius, 2) Vascular phenomena such as major arterial emboli, septic pulmonary infarcts, mycotic aneurysm, intracranial hemorrhage, conjunctival hemorrhage, or Janeway's lesions, 3) Immunological phenomena such as glomerulonephritis, Osler's nodes, or Roth spots, or 4) Microbiological evidence such as positive blood cultures that do not meet criteria as noted above.

3. Epidemiology of VAD-specific infection

Infection is a relatively common complication after mechanical circulatory support (MCS). The exact incidence of infection in mechanical device patients has varied over time mostly due to a lack of uniformity in the definition of VAD-specific infection. In 2003, Holman et al. published an article reviewing the prevalence/incidence of VAD infection in 15 prior studies from 1998 to 2001 (Holman et al., 2003). The prevalence of infection in this series ranged from 21% to 89% depending on the type of infection and the VAD used. The original REMATCH study from 2001 demonstrated an incidence of 0.6 infectious events per patient year with sepsis accounting for 41% of deaths in the mechanical support arm (Rose et al.,2001). The follow-up 2007 HeartMate II bridge-to-transplant pivotal trial demonstrated that 14% of the 133 study patients developed percutaneous lead infections however a total of 20% of the total population developed sepsis (Miller et al., 2007). In the 2009 HeartMate II destination therapy pivotal trial, 35% of patients undergoing HeartMate II continuous flow left ventricular assist device (LVAD) implantation developed LVAD-related infections versus 36% in the pulsatile HeartMate XVE group (Slaughter et al. 2009). The incidence of LVAD-related infection in these two groups was .48 infectious events per patient year in the continuous flow group versus .90 infectious events per patient year in the pulsatile flow group.

Although there is some variation among incidence and prevalence of infection depending on the type of infection and the type of mechanical circulatory support being employed it is clear that infection is a major cause of morbidity and mortality in patients supported by MCS. In a recent series reviewing 81 patients receiving continuous-flow LVADs, patients who had an infection on VAD had a significantly prolonged hospital stay with a trend toward increased mortality in comparison with patients who did not have infection (Topkara et al., 2010). Sepsis has also been shown to significantly decrease survival in VAD patients with both continuous and pulsatile-flow devices (Topkara et al., 2010; Holman et al., 2004). Prevention, diagnosis and treatment of these infections is therefore paramount in proper VAD management.

4. Common organisms

While VAD infection could theoretically involve any organism there are particular organisms that are more common than others. Bio-film producing organisms, especially gram positive bacteria and fungi such as staphylococcus species (sp.) and candida are

among the most common organisms causing VAD-specific infections. Gram negative bacteria such as pseudomonas and enterococcus are also bio-film producing organisms commonly implicated in VAD-specific infection (Holman et al., 2003). Pre-operative prophylactic antibiotics are therefore tailored against these organisms. Likewise, empiric therapy for VAD patients presenting with fever or other signs or symptoms of infection usually include antimicrobial therapy directed against these organisms.

5. Pre-operative considerations

Prevention of VAD-specific infection begins even before surgical implantation of the device. To this end, patient selection plays an important role in successful surgical outcomes. At the center of this issue is the immune status of the patient. While it is well accepted that heart failure itself causes some amount of immunodeficiency, one must ensure that a VAD candidate's immune status is not so compromised as to negatively affect outcome after VAD. Although VAD implantation has been carried out even in a patient with human immunodeficiency virus, immunodeficiency could increase risk of infection after surgery (Fieno et al, 2009). Patients on immunosuppression for comorbid conditions (i.e. rheumatology or transplant patients) should also be thoroughly evaluated prior to proceeding for VAD. Comorbid conditions that may themselves alter a patient's immune status such as hyperglycemia in diabetes should also be optimized prior to surgery. Nutritional status also contributes to a patient's overall immune status and a thorough nutritional evaluation should be undertaken in any patient being considered for VAD.

In addition to intrinsic patient characteristics, a thorough evaluation for active or occult infection should also be undertaken in every candidate. Any elevation in the white blood cell (WBC) count should be investigated and possibly treated pre-operatively. Any known active infection should also be treated to completion to ensure a sterile surgical implantation and to prevent hematogenous seeding of the device by any active infection. Dental hygiene should be evaluated by an oral surgeon/dentist and x-rays of the teeth should be obtained to rule out occult dental infections. Each patient should be screened for decubitus ulcers as these may also be a source of infection. Immediately prior to surgery, central venous catheters (CVCs), urinary catheters, peripherally inserted central catheters (PICC lines) and any other non-implanted devices should be removed and if necessary replaced peri-operatively.

From a provider standpoint, CVC implantation peri-operatively should be carried out in sterile fashion according to the general principles for prevention of catheter-specific bloodstream infection (CRBSI) from the Centers for Disease Control and Prevention (CDC) (O'Grady et al., 2002).

6. Preoperative management

The night before surgery the patient should be bathed in an antiseptic agent such as chlorhexidine. Pre- and perioperative prophylactic antibiotic strategies are commonly employed in cardiovascular surgery as well as surgeries involving implantation of hardware (i.e. orthopedic surgery) (Raymond et al., 2002; Martorell et al., 2004). While there is no VAD-specific data that clearly favors a particular perioperative antibiotic strategy, data from the cardiovascular and orthopedic literature has been extrapolated to guide therapy during VAD implantation.

The primary pathogens of concern are gram-positive organisms, specifically staphylococcal sp. since this is the most common group of organisms causing device infections (Holman et al., 2003). Vancomycin, 15mg/kg, intravenously (IV) 1 hour preoperatively, then every 12 hours for 48 hours along with Rifampin, 600mg IV 1-2 hours preoperatively, then daily for 48 hours, is usually an acceptable strategy for perioperative antibiotic coverage. Some studies have also suggested that nasal colonization by staphylococcus aureus (S. aureus) may predict S. aureus bacteremia and surgical site infection after cardiac surgery and that treatment of this colonization might actually help prevent infection (Raymond et al., 2002; Martorell et al., 2004). The evidence to support this strategy is not entirely confirmatory however for those with a nasal culture positive for S. aureus preoperatively, it may be beneficial to treat with mupirocin 2% nasal ointment the evening before surgery and then twice daily for 5 days afterward.(Perl et al., 2003;Bratzler et al., 2004).

Gram negative coverage should be tailored to the patient and/or the institutional patterns of colonization and susceptibility. There is no definitive recommended agent for prophylaxis against gram negative organisms, however at some centers fluoroquinolones such as ciprofloxacin are also used peri-operatively. Although doses should be adjusted for renal clearance, Ciprofloxacin 400mg IV before surgery and every 12 hours for 48 hours after surgery is a generally acceptable strategy.

Another virulent infection that may cause significant device related infection are fungal organisms (Bagdasarian et al., 2009). Fungal VAD infections are associated with high morbidity and mortality and prophylactic agents should be employed to prevent their development. The most commonly employed agent is Fluconazole, 400mg IV preoperatively, then every 24 hours for 48 hours afterward.

The use of prophylactic antibiotics beyond 48 hours after surgery does not seem to be beneficial and may actually be harmful in that it may increase antimicrobial resistance patterns. The practice of continuing prophylactic antibiotics beyond 48 hours is therefore not recommended.

7. Intraoperative management

An elevated level of precaution in the operating room (OR) can also help prevent VAD-related infection. As with any sterile procedure proper hand and arm washing with an antimicrobial agent for a minimum of 3 minutes is essential (Mangram et al., 1999). Caps, masks, gloves, and sterile gowns should be worn by all OR staff and OR traffic should be limited. The patient should be prepared using a solution of broad spectrum antimicrobials, alcohol and iodophor such as DuraPrep (3M Corporation) and sterile drapes. The device itself should also be opened under sterile conditions and only immediately before use.

7.1 The Percutaneous Driveline/Tube

The percutaneous driveline/tubing is among the most important channels for infection with VADs. Proper tunneling and positioning are therefore imperative for infection prevention.

When positioning the percutaneous driveline one should consider body habitus, angle between costal margins, and thickness of subcutaneous tissue. The driveline should begin at the VAD and tunnel to the right upper quadrant where it should exit near the midclavicular line, 4-6cm below the costal margin. The distance between the exit site and pump pocket should be maximized so as to prevent the transmission of infection from the exit site to the

pocket itself. The length of the percutaneous pathway should be maximized (10-12cm) and should enter the muscle within 4-8cm of the VAD. The velour portion of the percutaneous driveline should not extend more than 1-2cm outside the body (Chinn et al., 2005; Slaughter et al., 2010). Some centers have even begun fully implanting the velour portion however this has not yet been supported with any large-scale studies.

7.2 Hemostasis and drainage

Fluid and blood collections within the patient can potentially become infected and should therefore be avoided. It is often helpful to place bilateral chest tubes and mediastinal or pocket drains to prevent fluid from accumulating. Likewise, patients should be monitored for bleeding post-operatively and potentially re-explored if there is evidence of excessive or persistent fluid or blood output from any of a patient's drains or tubes.

8. Postoperative management

The post-operative period is the most important time for infection prevention with VADs. Prophylactic systemic antibiotics are usually discontinued after 48 hours postoperatively. After discontinuation of post-operative antibiotics prevention of infection depends primarily on proper exit site management and nutritional support.

8.1 Driveline exit site management

The percutaneous driveline exit site should be carefully managed post-operatively in order to prevent the introduction of pathogens. Dressings should be changed starting 24-48 hours after surgery and earlier if the dressing becomes saturated with blood or drainage. Dressings should be changed under sterile conditions using sterile technique with a sterile drape, and sterile gown and gloves as well as cap and mask. Using sterile gloves, the old dressing should be removed and discarded. At this point a new set of sterile gloves should be put on and the exit site should be inspected for signs of infection, tissue breakdown, and drainage. Deep probing should generally be avoided. Any drainage should be swabbed and sent for culture. The wound should then be cleaned with an antiseptic agent such as 1% chlorhexidine and rinsed with 0.9% normal saline solution. The area should then be dried to completion using sterile gauze and then dressed with sterile gauze with enough gauze placed to cover and protect the entire exit site. After completion of all these steps the abdominal binder should be reapplied.

Over time there should be incorporation of the driveline at the site of the exit site with good tissue in-growth around the driveline itself. This may take weeks to months to occur and need not fully occur prior to discharge, however it is imperative that good hygiene and sterile technique be exercised at all times. It is generally advised that patients avoid showering until after adequate tissue in-growth into the velour has occurred and until there is no drainage or signs of infection at the exit site. Even when sponge bathing, the exit site should be kept dry. Ultimately it will be the responsibility of the patient's caregiver to maintain and change driveline dressings therefore, the caregiver should be carefully and thoroughly educated in proper sterile technique and should demonstrate competency in this task prior to discharge.

8.2 Nutrition

Post-operative nutritional status is critical to patient success and is known to influence morbidity and mortality in surgical patients (Holdy et al., 2005). Nutritional

supplementation, either oral or parenteral, should be instituted as soon as possible after surgery. Oral or nasogastric supplementation is preferable given the increased risk of infection with parenteral feeding. Supplementation should be done under the supervision of a clinical dietician/nutritional specialist to ensure that the patient receives appropriate protein and caloric intake to ensure proper recovery and wound healing. This will also help prevent infection. Blood sugar control is also imperative post-operatively and endocrine consultation may be of assistance in maintaining a blood sugar as close to 110mg/dl as possible (Van Den Berghe et al. 2001)

9. Diagnosis of VAD-specific infection

VAD-specific infections include infections occurring at the cutaneous exit site, in the device pocket, or infections of the internal surface of the device or valves. VAD specific infections are commenced in many ways: a) inoculation at the time of surgery b) from percutaneous driveline exit site onto the device; or c) hematogenous spread from a blood stream infection. Post-operative VAD infections can result from hematogenous spread from line related blood stream infections or bacteremia from open wound infection, urinary tract infection or pneumonia.

9.1 Driveline Infection

Driveline exit site infections should be diagnosed by thorough physical examination at the driveline exit site. Erythema and poor wound healing can be suggestive of driveline infection. Associated signs of systemic infection such as fever, tachycardia and leukocytosis may or may not be present with driveline exit site infection. In the case of a suspected driveline infection, cultures and gram stain of the driveline exit site should be obtained without deep probing. This may not be always helpful because of skin colonization by variety of microorganisms and may be positive in absence of true infection. Ultrasonography, computed tomography, or localizing abscess scan (gallium, indium) may also be helpful in detecting the driveline infection. Findings suggestive of infection include inflammation or fluid collection along the driveline pathway.

9.2 Pump pocket Infection

Pump pocket infections present with local inflammation and can be associated with signs of sepsis. It may present as a local abscess which can be diagnosed by palpation and by the imaging studies. If the suspicion of abscess is high on imaging, incision and drainage should be performed. Persistent drainage from the driveline exit site can be another presentation of underlying pocket infection. In patients with signs of systemic infection complete blood count and multiple blood cultures should be obtained.

9.3 Device Infection

Intravascular device infections occur during the implantation procedure or by hematogenous spread when a biofilm forming bacteria is introduced onto the external and/or internal surfaces of the device. The most common pathogens causing blood stream infection in patients with VAD related infection are coagulase negative staphylococci, staphylococcus aureus, Candida spp., and gram negative infections like Pseudomonas aeruginosa. Infections with multidrug-resistant pathogens result from prolonged hospitalization and increased antibiotic exposure.

A VAD related blood stream infection is difficult to differentiate from a non-VAD-related blood stream infection. Diagnosis of VAD related blood stream infection is typically made when: 1) the same organism is isolated from drainage around the exit site or obtained through a percutaneous aspiration of a fluid collection; 2) no other source of bacteremia is identified 3) the bacteremia is sustained despite appropriate antibiotic therapy or despite adequate drainage of an identified source. Positive cultures of the device (valves, internal pump surface, pump pocket) in presence of bacteremia is the gold standard but it is rare for patients with permanently implanted VAD to undergo explantation of the device. Clinical manifestations of infected intravascular devices are fever, leukocytosis, new incompetence of the pump inflow or outflow valves, and septic embolization in absence of vegetation on the native cardiac valves. For the diagnosis of device infections, exclude other device infection from pacemakers and automatic implantable cardiac defibrillators and line related infections. Multiple blood cultures from peripheral line and central venous catheter should be obtained in suspected line related infection. Intradevice echocardiography can be very helpful to evaluate device valves and function.

10. Treatment of VAD infection

Prior to initiating treatment for a VAD infection blood cultures, drainage culture, and if possible, aspirates should be obtained in order to identify the offending pathogen. Broad-spectrum antibiotics may be initiated early but therapy should be tailored to the particular organism once speciation and susceptibilities have been completed. Infectious disease consultation should be obtained for antibiotic selection as well as dosing and timing of therapy.

Therapy for VAD-specific infection is based on the type of VAD infection (Driveline, Pocket, or Device) as well as the patient's infection history. A more invasive infection or a history of recurrent or resistant infection may prompt a more aggressive therapeutic approach.

10.1 Driveline infection

Therapy for driveline exit site infections typically begins with oral antibiotics targeted against gram-positive organisms. Blood and drainage cultures should be drawn and evaluated for possible organism identification and susceptibility. If an organism is identified therapy can be targeted toward that organism; if not, empiric therapy directed toward cutaneous flora such as staphylococcus aureus should be initiated. Aggressive wound care is also important. The driveline exit site and dressing should be kept clean and should be immobilized to prevent disruption of the area surrounding the driveline itself.

If the infection appears to be more extensive or invasive, surgical incision and debridement may be necessary. This should be done in the OR under sterile conditions.

Over time, driveline infections have a tendency to become recurrent (Vilchez et al., 2001). In the case of recurrent driveline infections intravenous antibiotics may become necessary. Infectious disease consultation can be helpful to guide such therapy. Ultimately long-term antibiotic therapy may be helpful to suppress and prevent recurrence of infection. The need for this type of therapy must be weighed against the risk of developing resistant organisms and antibiotic side effects (Tayama et al., 2006)

10.2 Pocket Infection

The initial steps in treating a pocket infection are similar to those with a driveline infection. After cultures have been obtained, broad spectrum antibiotics should be initiated with narrowing of therapy once species and susceptibilities have been identified.

If an abscess or fluid collection is identified either on exam or radiologically it should be aggressively drained, either percutaneously or by surgical incision and drainage. Any fluid obtained from a pocket should be sent immediately for culture.

If antibiotics and percutaneous or surgical drainage are unsuccessful and the patient continues to exhibit signs and symptoms of an active infection, a device pocket revision may be necessary. This approach may also be indicated if cultures grow particularly virulent organisms such as gram negative bacilli or yeast.

Another approach to pocket infections that is still under investigation is the implantation of polymethylmethacrylate (PMMA) beads that are impregnated with vancomycin, tobramycin, and possibly other antibiotic agents. These can be surgically placed to coat the external surface of the VAD. These beads are currently approved for use with chronic osteomyelitis and infected orthopedic implants and their use with VADs is still experimental and requires further research as to optimum size, shape, and positioning of the beads. A potential risk of using these beads is that they may breed more resistant organisms (Chinn et al., 2005; Slaughter et al., 2010).

After either percutaneous or surgical incision and drainage, aggressive wound care is critical to successful treatment of an infected VAD pocket. Patients should undergo sterile daily dressing changes and monitoring for signs of continued infection. Antibiotics should be used and patients may be discharged home on intravenous treatment via a PICC line for prolonged antibiotic therapy. This should be done under the supervision of an infectious disease specialist.

Vacuum assisted closure (V.A.C., KCI USA, Inc. San Antonio, TX, USA) of a pocket wound may assist with wound healing after surgical incision and drainage and should be considered (Baradarian et al., 2006).

10.3 Pump and/or Cannula infection

Infection of the actual pump or device cannulae is a very serious complication of VAD therapy. Although difficult to establish a concrete diagnosis there are a number of factors that may make pump or cannulae infection more likely. These are described in more detail in the definition and diagnosis sections of this chapter but include persistent bacteremia or fungemia, especially in the case of gram negative bacilli or yeast. Also suggestive of a pump or cannula infection is the presence of a vegetation or interruption in the flow through the VAD cannulae on echocardiogram. Alterations in pump parameters such as low flow states, spikes in power or in the rotations per minute demonstrated by the VAD may also suggest infection.

If a pump or cannula infection is suspected then device replacement should be considered. The natural history of this type of infection portends a poor prognosis and early rather than late replacement is preferable. If VAD replacement is not an option then aggressive intravenous antibiotic therapy should be pursued and continued for a prolonged period of time. This should be guided by an infectious disease specialist based on the organism involved and the history of the infection. Many patients with persistent pump or cannula infection will ultimately require lifelong oral suppressive therapy.

11. Additional considerations in VAD patients

11.1 Immune function after VAD

Immune function in VAD patients is an area of active research and early studies have shown an alteration in immune function in comparison to heart failure controls. This is an important finding as it suggests that patients with VADs may inherently be at increased risk for infection. Temporary alterations in T-cell function and quantity have been observed early after VAD implantation (Deng et al., 1999; Itescu et al., 2000; Clark et al., 2001; Itescu et al., 2003; Rothenberger et al., 2001; Ankersmit et al., 1999). Cellular immunity has also been shown to remain impaired at 6 months after VAD implantation (Kimball et al., 2008). Among the indices found to be altered at 6 months were a decrease in proliferative response to an immune challenge, a decrease in expression of interleukin 2 and tumor necrosis factor-α, an increase in interleukin 10, and an increased prevalence of suppressive T-regulatory cells. These all suggest a compromise in cellular immunity among long-term VAD recipients secondary to a downregulatory cytokine imbalance and an increase in suppressive T-regulatory cells.

11.2 VAD Infection and transplantation

Given that VADs are commonly used as a bridge to transplantation it is important to understand the effect of VAD-related infections on post-transplant outcomes. A retrospective review from Columbia University in 2009 reported that pre-transplant device-related infection of any kind had no effect on post-transplant 1-year survival rates, but was associated with an increased rate of post-transplant infection. In particular, a driveline infection during VAD support predisposed to infection of the former VAD pocket and driveline site after cardiac transplantation (Schulman et al,. 2009). No other VAD-related infections including pocket infection, wound infection, or sepsis were associated with post-transplant infection.

The primary concern with VAD-related infection in patient's awaiting transplantation is that these infections can have a significant effect on survival to transplantation. For this reason, VAD-related infection can actually be used as a reason to upgrade a patient's priority on the transplant list in order to expedite the course to transplantation.

12. Future implications

VAD implantation represents a major development in the treatment of advanced heart failure. Despite major advances in the size, durability and portability of VADs, infection remains a significant cause of morbidity and mortality after VAD implantation. Improving outcomes in the future will require better infection prevention through developments in device and driveline technology. Among the ultimate goals is total implantability of the VAD which would eliminate the need for a driveline and thereby eliminate one of the most important pathways for infection . The clinical utility baseline study (CUBS) trial from 2007 compared the totally implantable LionHeart to the REMATCH data and demonstrated decreased incidence of infection with the totally implantable device suggesting that total implantability may improve infectious outcomes after VAD (Pae et al., 2007)

13. Conclusion

At the present time infection prevention depends upon thorough pre-operative evaluation and treatment to improve modifiable risk factors such as nutrition, glycemic control, and

infectious and immune status. Peri-operatively, attention to sterile technique and appropriate prophylactic antibiotics can help prevent infection around the time of implantation. After surgery, immobilization of the driveline along with sterile driveline wound care and patient education are key to long-term success with VADs.

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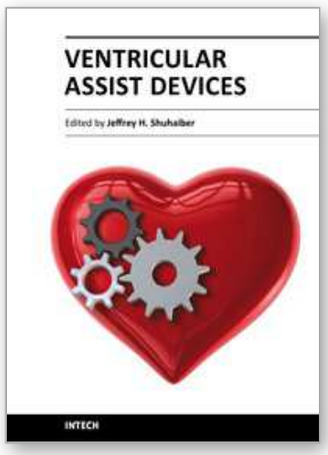

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The assist devices will continue adding a large number of years of life to humans globally and empower the medical society to optimize heart failure therapy. While expensive and cumbersome task, the foundation provided in this book reflects a contemporary product of original research from a multitude of different experts in the field. We hope this cumulative international effort provides the necessary tools for both the novice as well as the active practitioner aiming to change the outcome of these complex patients.

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