Transplantation 2017 Scientific Meeting, April 5-8, 2017, San Diego, Calif), and the FDA approved this application.

MANAGEMENT OF POSTOPERATIVE BLEEDING

Perioperative bleeding, defined as receiving >4 U packed red blood cells within 7 days of surgery or requiring a reoperation, is the most common complication after LVAD implantation, with reported rates between 20% and 81%.[104-106] The high incidence following LVAD implantation is a result of preoperative heart failure that contributes to nutritional deficiency, thrombocytopenia, renal insufficiency, and hepatic dysfunction; nonphysiological sheer stress imparted by CF LVADs, with resultant von Willebrand factor deficiency; anticoagulation and antiplatelet medications; pre-existing RV dysfunction; and VAD-specific surgical techniques.[107,108] The additional morbidity of bleeding is related to increased incidence of infection, respiratory failure due to transfusion associated lung injury, right heart failure, proinflammatory cytokine release leading to pulmonary hypertension, increased chance of allosensitization, and risk of transmission of emerging pathogens not tested for routinely.[109-112]

Preoperative strategies to prevent bleeding include optimizing nutrition and coagulation parameters.[113] Anticoagulant and antiplatelet medication should be discontinued and any pre-existing coagulopathy corrected before surgery. This might require administration of vitamin K or fresh frozen plasma or even platelet transfusions.[114] Optimizing hemodynamic parameters with inotropes or an IABP can help reverse hepatic and renal dysfunction and their related coagulopathies.

Intraoperative management is the most important aspect of prevention of bleeding. The primary class of agents shown to decrease bleeding are antifibrinolytic agents.[115] Two drugs that can be used are epsilon-aminocaproic acid and transexamic acid. Although not specifically studied in patients with an LVAD, these 2 drugs can decrease bleeding and transfusion requirements after cardiopulmonary bypass. Appropriate dose-dependent reversal of heparin with protamine sulfate is important.

Other important strategies used to decrease bleeding during routine heart surgery that can be applied to LVAD surgery include removal of whole blood before cardiopulmonary bypass to permit return of platelet- and factor-rich autologous blood after protamine reversal, retrograde autologous priming after cannulation to decrease hemodilution, and normothermia during cardiopulmonary bypass.[116-118]

Standard approaches to achieving hemostasis after cardiac surgery should be applied to patients with an LVAD. A thoracotomy approach has also been shown to decrease bleeding compared with standard sternotomy approach to LVAD implantation.[119,120]

There are also additional potential sites of bleeding with LVAD surgery. One is the preperitoneal pocket, especially in the HeartMate II. The pump pocket should be created before heparinization with liberal use of cautery. Intrapericardial devices such as the HVAD, Jarvik 2000 (Jarvik Heart, New York, NY), and HeartMate 3 generally have less bleeding than those requiring extrapericardial placement. Care is required during tunneling of the driveline. Engorged veins or rectus muscle arterial vessels can be injured and lead to significant bleeding. The other 2 LVAD-specific bleeding sites are the apical inflow cannula and the outflow graft-aortic anastomosis. The LV apex can be fragile, especially in elderly patients or patients with prior acute myocardial infarctions. Once the heart is placed back in the pericardium, visualizing and repairing any bleeding is challenging. Many techniques have been described to ensure optimal hemostasis, and they all involve reinforcement with additional prosthetic material. The most common site of bleeding other than the sternum is probably the outflow anastomosis. Multiple suturing techniques have been used, including running, interrupted, and interrupted mattress with pledgets. Sternal management requires particular attention, because most of these patients have some degree of cachexia leading to fragile and osteoporotic bones. In the event of uncontrollable coagulopathy, packing the mediastinum, placing a vacuum dressing, and returning to the operating room later for irrigation and delayed closure have been successfully employed.[121]

Prohemostatic agents are required if measures outlined above are unsuccessful in preventing bleeding and coagulopathy. Guidelines recommend use of fresh frozen plasma when there is a reduction in coagulation factor levels (PT or activated PTT >1.5 times the reference level).[122] Cryoprecipitate is administered for a fibrinogen deficiency (<100 mg/dL). Platelets can be administered for active bleeding with thrombocytopenia (<50,000 platelets per microliter of blood), when abnormal platelet function is contributing to bleeding, or for prophylaxis with a platelet count <20,000 platelets per microliter of blood. Although laboratory-based or point-of-care methods (eg, PT, activated PTT, platelet count, and thromboelastography) cannot predict which patients will bleed, they can identify patients who likely have a factor deficiency state and who may benefit from factor replenishment in the face of excessive bleeding.[122-125]

Intractable, life-threatening bleeding can be treated with factor concentrates. Recombinant activated clotting factor VII (NovoSeven; Novo Nordisk, Copenhagen, Denmark) is approved for patients with hemophilia but used off-label for life-threatening hemorrhage. Although activated recombinant factor VII administration seemed helpful in controlling life-threatening hemorrhage, patients requiring higher doses (eg, 30 to 70 μg/kg) had a dramatically higher incidence of serious thromboembolic events in patients with an LVAD.[126,127] A randomized clinical