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Perioperative Hemotherapy Management in Left Ventricular Assist Device Surgery

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Introduction

Implantation of a left ventricular assist device (LVAD) is 1 of the most complex interventions in cardiovascular surgery. Nevertheless, use of this procedure has increased, with the number of procedures doubling between 2010 and 2019. Left ventricular assist device implantation is performed by select teams at a limited number of facilities. Clinical practice for LVAD support continues to evolve as teams gain experience and devices are improved. This article discusses the interplay of LVAD implantation and the coagulation process—specifically, the optimal blood-device interface and the lack of validated, broadly applicable algorithms for perioperative coagulation management.

Preoperative Coagulation Status

End-stage heart disease necessitating LVAD implantation is accompanied by abnormal end-organ function. For example, congestive hepatopathy is associated with a reduced level of hepatic coagulation factors.[1] Elevation of the international normalized ratio (INR) in patients with congestive hepatopathy is heavily influenced by factor VII, the factor with the shortest half-life.[2] In many patients with chronic liver disease, balanced loss of procoagulant and anticoagulant clotting factors does not reduce their ability to generate thrombin. Viscoelastic testing that is less INR reliant reduces the number of blood components transfused in surgical patients.[3,4] In viscoelastic test systems, the time required to trace movement from baseline (R time thromboelastography and clotting time rotational thromboelastometry) is used as a measure of the enzymatic contribution to clotting, akin to prothrombin time/INR. Although blood use is clearly reduced with viscoelastic testing, its benefit in major clinical outcomes (eg, mortality, intensive care unit length of stay) remains to be determined.[4] Various algorithms have been applied in cardiovascular surgery, but a generally applicable algorithm for LVAD implantation has not been published.

Many patients requiring LVAD implantation are on vitamin K antagonist therapy. The ideal preoperative approach for prompt vitamin K antagonist reversal is to administer intravenous vitamin K because of its earlier correction of prothrombin time/INR in comparison with oral vitamin K. Correction can be anticipated in 6 to 8 hours. When more rapid correction is needed, prothrombin complex concentrate (PCC) infusion is recommended. In the original PCC trial, the dosing schedule was based on the degree of INR elevation; however, a fixed-dose approach has been developed.[5]

Kidney function is also often impaired in LVAD recipients. In patients with more marked azotemia, von Willebrand factor (VWF) multimers and platelet function are altered.[6] These alterations can be treated using any of several interventions, including desmopressin acetate to release VWF for endothelial Weibel-Palade bodies or the use of conjugated estrogens. As a last resort, patients can receive exogenous support using cryoprecipitate and platelets.

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Intraoperative Management

Minimizing cardiopulmonary bypass circuit size and using retrograde perfusion are appropriate strategies in LVAD surgery. Blood salvage is also a mainstay, but the large volume of blood lost during LVAD implantation increases the risk of hemodilution.[3] The rapid assessment of fibrinogen content is a pivotal measure; maintaining levels above 1.5 g/L is important.[7] Platelet counts can be assessed by measuring the count or by using viscoelastic testing as a means of assessing platelet contribution to hemostasis.

Real-time measure of platelet function remains an important goal overlooked by many US sites. Potential assays include thromboelastographic platelet mapping (United States) and Multiplate analysis (European Union). VerifyNow is useful during preoperative assessment, but it has a limited role in intraoperative management because of hematocrit limitations.[8] Maximum amplitude of clot on viscoelastic analysis is a surrogate for measuring platelet contribution to hemostasis.[4,9]

Blood products and systemic hemostatic agents used to improve hemostasis require careful consideration. Increased use of blood components is associated with worse outcomes in patients undergoing LVAD implantation and other procedures.[10] The role of systemic hemostatic agents (eg, fibrinogen concentrates and PCCs) is evolving.[11] Although PCCs theoretically increase thrombotic risk, analyses have shown no evidence of increased thrombotic risk when PCCs are administered at a dose of 30 units/kg. Repeat dosing of factor VIIa perioperatively in patients undergoing LVAD implantation has been associated with increased risk of thrombosis.

Shear-based perturbations of coagulation caused by platelet activation and the physical effect of VWF are known to occur but cannot be measured easily in either intraoperative or postoperative clinical settings because of the complexity of the assays.[12] Recently, a means of assessing VWF alteration by using a ratio of glycosylphosphatidylinositol binding to VWF content was reported.[13] Although loss of large VWF multimers is well documented, the effect of this finding on bleeding is a subject of debate. More work in this important area is needed as the contribution of abnormally small cohorts of VWF since shear-based exposure of cleavage sites leads to the development of an acquired von Willebrand disease state. Activation of platelets with an eventual depletion of response was noted in a study in which P-selectin and microparticle formation were assessed. The investigators proposed that platelet dysfunction may contribute to perioperative bleeding.

Abbreviations and Acronyms

INR	international normalized ratio
LVAD	left ventricular assist device
PCC	prothrombin complex concentrate
VWF	Von Willebrand factor

Postoperative Management

In LVAD implantation, differentiating coagulopathy from surgical bleeding during the early postoperative state is essential. Viscoelastic systems offer a quicker assessment. Once the effect of hemodilution, residual heparin effect, and platelet dysfunction are eliminated, the role of device-related shear on VWF multimers becomes a major consideration. An algorithm that can be used to sort out the coagulation status is shown in Figure 1. In addition, protocols need to be adopted for the careful titration of systemic anticoagulation (see Table I for key steps). In the absence of fully biocompatible LVADs that negate the need for chronic antithrombotic therapy, the surgical team must work closely with the intensive care unit team in selecting an appropriate time to start anticoagulant treatment.

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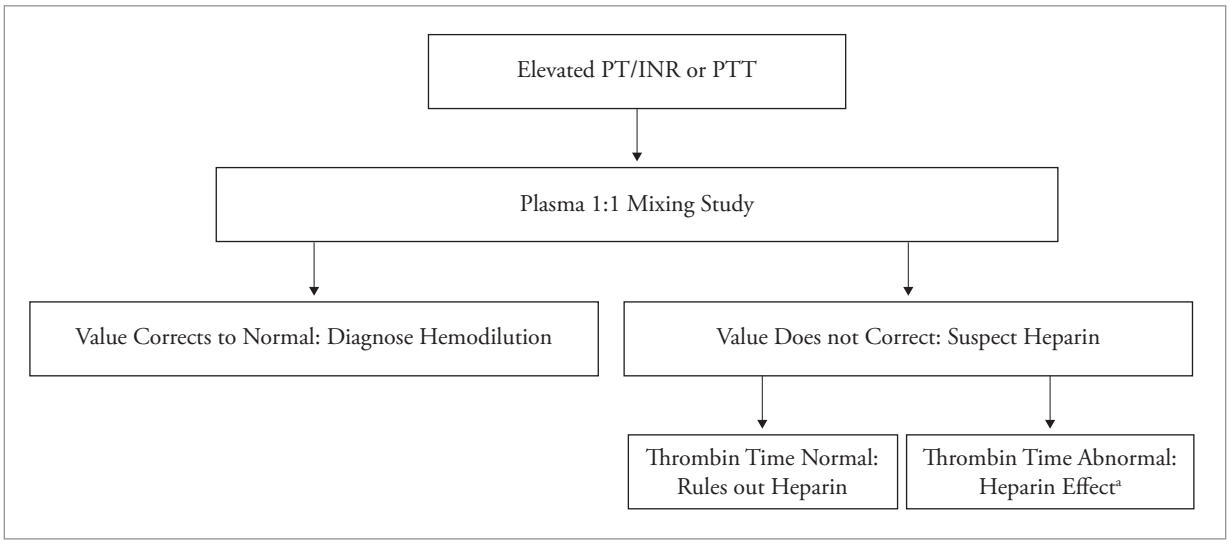

Fig. 1 An algorithm for determining coagulation status.

[a]Protamine inhibition or reptilase time can be used to confirm heparin effect.

TABLE I. Key Steps in Initiating Anticoagulation After Left Ventricular Assist Device Placement

1. Do not use a bolus dose to start anticoagulation.
2. Initiate anticoagulation at a lower dose (eg, 5-10 U/kg heparin).
3. Titrate the anticoagulant upward using partial thromboplastin time and viscoelastic testing. To start, aim for twice the baseline value.
4. The anti–factor Xa assay can be used but may be too specific, given hepatic dysfunction.
5. As the patient's condition stabilizes and hepatic function improves, transition to routine target values.

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