around the LCA orifice (Fig. 2, *middle*). This atheromatous material was removed very carefully, creating a wide orifice. Then a saphenous vein patch (15×10 mm) was sutured with 7-0 Prolene sutures from the inferior border of the LMT incision up to the junction of the aortic wall, terminating 5 mm below the end of the aortotomy. After the saphenous vein patch was secured, the entire course of the LMT was carefully examined. The transected aorta was reconstructed with a continuous 4-0 Prolene suture (Fig. 2, *bottom*).

The patient was weaned from the pump without difficulty and transferred to the intensive care unit in good condition. There were no postoperative changes in the electrocardiogram. The recovery was uneventful, and the patient was discharged in good condition. Postoperative catheterization revealed a large LCA orifice and LMT (Fig. 1).

Surgical angioplasty of the LMT provides physiologic coronary perfusion and good late results without the difficulties associated with graft occlusion.⁴ Impaired LMT flow, however, may result in significant damage to the myocardium.⁵ Physiologic reconstruction after exposure of the entire LMT is necessary to provide the best flow through this vessel. The "superior approach" de-

scribed here is an effective way to gain wide exposure of the LMT for surgical manipulation.

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WHOLE BLOOD HEPARIN CONCENTRATION MEASUREMENTS BY AUTOMATED PROTAMINE TITRATION AGREE WITH PLASMA ANTI-XA MEASUREMENTS

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Findings recently reported by our group indicated that point-of-care monitoring of heparin concentration by an automated protamine sulfate titration (PST) method (Hepcon HMS, Medtronic Hemotec, Inc., Englewood, Colo.) can reduce excessive microvascular bleeding and blood component transfusion.¹ That study was preceded by another evaluation in which we found a high degree of correlation between heparin concentration determined by

plasma anti-Xa and whole blood automated PST.² Hardy and colleagues³ recently published a comparison of heparin measurements by Hepcon automated PST and a laboratory-based anti-Xa chromogenic assay in a relatively small number of patients undergoing cardiac operation with the use of cardiopulmonary bypass (CPB). In contrast to our observations of a strong linear relationship between whole blood PST and plasma anti-Xa measurements,² these investigators found unacceptably high variability between the two heparin concentration measurements. In explaining this discrepancy, Hardy and colleagues³ suggested that our data analysis was limited and potentially misleading because we did not use bias analysis. We therefore reanalyzed our data with a bias analysis method as used by that group.

Plasma anti-Xa and whole blood PST measurements (duplicate) on blood specimens obtained at sequential operative times (4 to 6 per patient) from 62 patients undergoing cardiac operations were reanalyzed.² Whole blood (WB) PST heparin values were converted to plasma equivalent values (PE) using concurrently measured hematocrit (Hct) values with the following formula: $PE\ WB\ PST = (WB\ PST \times 100 / [100 - Hct])$. The mean difference or bias between plasma anti-Xa

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Fig. 1. Bias analysis of plasma anti-Xa versus plasma-equivalent whole blood heparin concentration measurements. Heparin concentration in plasma was measured with use of an anti-Xa chromogenic assay and whole blood heparin concentration values were measured with an automated PST method with use of the Hepcon instrument. Whole blood heparin concentration values were converted to plasma equivalent values (*PE*) with the following formula: $PE\ PST = (PST \times 100 / [100 - \text{hematocrit}])$. The differences between anti-Xa and whole blood heparin concentration measurements are plotted on the y axis and the averages of the two heparin concentration values are plotted on the x axis. The mean (bias) and plus or minus two standard deviations of the differences are represented by the *horizontal lines*. $n = 310$.

and corrected whole blood PST measurements was 0.002 ± 0.53 U/ml. Fig. 1 shows the results of the bias analysis with means and two standard deviation confidence intervals for the 310 measurement pairs. The mean difference obtained using duplicate measurements was similar to those obtained with each of the two individual measurements (measurement 1: 0.008 ± 0.56 ; measurement 2: -0.004 ± 0.56).

The findings of this further analysis of our previously published data indicate that measurements of heparin concentration derived from the Hepcon HMS automated protamine titration method agree well with laboratory-based anti-Xa measurements of heparin concentration when the sensitivity limit of 0.7 U/ml for the Hepcon HMS method is applied as suggested by Hardy and colleagues.³ Several factors may account for the discrepancy between our findings and those of Hardy and colleagues.³ Most important, in their study, hematocrit values used for the conversion of whole blood heparin concentration into plasma equivalent values were obtained from arterial blood gas analysis determined at 30-minute intervals during CPB and not from a conventional hemocytometer with blood specimens obtained simultaneously with those used for measurement of heparin concentration (as was done in our study), and this may have led to miscalculation of plasma-equivalent whole blood heparin concentrations

as acknowledged by the authors.³ Differences in standardization and performance of laboratory-based anti-Xa chromogenic assays may have also contributed to the different results obtained by Hardy and colleagues.³ The wide variability in anti-Xa measurement values between various institutions with low-molecular-weight heparin⁴ or the inconsistency between laboratory-based anti-Xa and protamine titration methods,⁵ or both of these reasons, may also in part account for the discrepancy between our studies.

Maintenance of adequate, patient-specific heparin concentrations with the use of the Hepcon instrument has been shown to reduce excessive hemostatic system activation and preserve coagulation factors during CPB,⁶ which may in part account for the significant reduction in blood component transfusion requirements seen with this approach.¹ In an attempt to explain the benefits found in our previous studies, Hardy and colleagues³ suggested that administration of higher heparin and lower protamine doses may have accounted for the improved outcomes. Although these findings may be the result of administration of greater overall heparin doses, the relative importance of administering heparin on the basis of patient-specific requirements cannot be overlooked. In our previous evaluation,¹ the total heparin dose was directly related to the concentration of heparin maintained during CPB that was designated for each patient on the basis of

the patient's anticoagulant response to heparin before CPB by use of a standard assay (activated clotting time). Finally, we have recently evaluated the use of continuous infusions of heparin during CPB to maintain stable, adequate heparin concentrations. Unpublished data from this study confirm the reliability and usefulness of on-site, whole blood heparin concentration measurements by the Hepcon HMS system.

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