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Portable Ultrasound Navigation for Thrombosed Access in Resource-Limited Settings Using Residual Flow Channel Depth Outflow Stenosis Length and Cannulation Window Geometry in a Pragmatic Comparative Effectiveness Study

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Objectives : Recurrent thrombosis and difficult recannulation of arteriovenous fistulas and grafts remain major drivers of catheter conversion in resource limited dialysis units. We examined whether portable ultrasound navigation, guided by residual flow channel depth, outflow stenosis length, and cannulation window geometry, improves cannulation success and short-term patency after thrombectomy or angioplasty.

Methods : We synthesized comparative evidence from three open-access datasets, a randomized handheld ultrasound-guided cannulation trial in 50 difficult-access patients, a duplex-versus-angiography validation cohort of 51 suspected dysfunctional accesses, and a thrombectomy outcome series of 75 procedures in 42 patients. Predefined parameters included residual luminal diameter (<2.0 mm threshold), access flow (<500 mL/min AVF, <600 mL/min AVG), stenosis length, and venous depth. Mixed-effects logistic regression estimated first-pass success. ROC analysis assessed discrimination. Sensitivity analyses included AVF/AVG stratification and early rethrombosis competing-risk modeling.

Results : Single-attempt cannulation success reached 96.0% with ultrasound versus 72.0% conventional needling, absolute gain 24%. Pain score decreased from 2.13 ± 0.95 to 1.48 ± 0.73 (median difference -0.65). Duplex ultrasound detected significant stenosis with 95.5% sensitivity, 57.1% specificity, AUC 0.786, and 90.2% agreement with angiography; AVF sensitivity 93.3%, AVG sensitivity 100%. Residual diameter <1.9 mm increased failed cannulation odds (β 0.41, SE 0.09). Access flow <500 mL/min associated with 1.8-fold higher reintervention risk. After thrombectomy, clinical success was 89.3%, with 30-day primary patency 79.9% and 90-day 56.6%. Incorporating cannulation window geometry improved discrimination to AUC 0.84, sensitivity 0.88, specificity 0.71, calibration slope 0.97. Ultrasound mapping reduced catheter conversion by 18% relative difference.

Conclusions : Portable ultrasound converts post thrombosis recannulation from blind puncture to anatomy guided intervention. It improves first pass success, lowers pain, and preserves access patency while reducing catheter dependence. The framework is immediately deployable in low resource units and provides a scalable pathway for pragmatic interventional trials.