



IMPACT OF PRE-OPERATIVE DUPLEX MAPPING ON AV FISTULA MATURATION RATES

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ABSTRACT

Background: Arteriovenous (AV) fistula is still considered the access of choice for hemodialysis owing to its better long-term patency rates and associated complications compared to grafts and catheters. Nonetheless, primary non-maturity has remained an important drawback, contributing to, or rather resulting in, delays in starting patients with hemodialysis, along with increased hospital expenditures. Pre-operative duplex ultrasound mapping has been advised for better selection, but its use has been inconsistent, with downstream realities, or evidence, still emerging. **Aims:** Assess the impact that pre-operative duplex ultrasound mapping has on the maturation rates and medium-term patency of AV fistulas for first-time AV fistula patients. **Method:** This present study compared the outcomes among first-time AV fistula patients undergoing pre-operative duplex ultrasound mapping and those who went to fistula creation guided solely by clinical examination at King Hussein Medical Center (KHMC) in the periods between January 2024 and December 2025. The primary outcome was the functional maturation of fistula. Secondary outcomes included access-related revisions early and patency of fistula at 6 and 12 months, respectively. Demographic, clinical, and procedural variables was analyzed for their association with access outcomes. **Results:** Among 608 patients, 324 (53.3%) underwent pre-operative duplex mapping. Functional maturation occurred in 75.3% of mapped versus 71.1% of unmapped fistulas ($P=0.245$). After adjustment, duplex mapping was associated with higher odds of maturation (OR 1.57, 95% CI 1.02–2.40; $P=0.039$) and a lower risk of primary patency loss (HR 0.77, 95% CI 0.60–0.99; $P=0.046$). Mapping was not associated with early or 12-month revision rates. **Conclusion:** Duplex preoperative mapping showed to be beneficial in terms of increasing the rate of AVF maturation, but it might also lead to an increase in patency. However, one should approach these results carefully.

KEYWORDS: vascular surgery, fistula maturation, duplex ultrasound mapping, arteriovenous fistula.

INTRODUCTION

Despite alternative methods being available, arteriovenous fistulas (AVFs) continue to be considered the gold standard of vascular access for hemodialysis due to their improved patency and lower rates of infections compared to grafts or central venous catheters.^[1,12] The difficulty, however, lies in making the fistula work in the first place. It is known that quite a significant number of newly formed arteriovenous fistulas does not mature enough for use in dialysis. Thus, according to the systematic analysis of 37 studies with 7,393 fistulas, the overall primary failure rate is about 23% (95% CI 18–28%)^[1] The failure is especially prevalent among distal

fistulas; the recently conducted meta-analysis of forearms' AVFs demonstrated the primary failure rate of 24.7% (95% CI 20.3–29.1%),^[4] which is similar to the previously published data on higher failure rates of radiocephalic fistulas.^[5]

Therefore, pre-operative vessel mapping by duplex ultrasound has become an essential component of AVF creation. Physical exam may not be sufficient to detect small calibre vessels, presence of stenotic segments, and other anatomical characteristics that can jeopardize the process of maturation. Of these factors, diameter of vein seems to be one of the most crucial ones in early

prediction of fistula success.^[6,7] In the systemic review, fistulas made up of veins smaller than 2 mm showed significantly worse results in terms of functional maturation with the odds ratio of maturation almost five times smaller in smaller vessels (OR 0.19, 95% CI 0.12–0.30).^[7] However, the correlation of these two variables is not enough to establish a certain cut-off point. As such, the 2019 KDOQI guideline regarding vascular access did not recommend any minimal vessel diameter and suggested individual evaluation for arteries and veins smaller than 2 mm.^[9]

The issue of whether duplex mapping should be done in every patient is not very clear. There is conflicting evidence from randomised and observational studies. In a Cochrane review of four randomised controlled trials, there was no statistical significance between pre-operative ultrasonography mapping and fistula maturation success rate after six months (RR 1.11, 95% CI 0.98-1.25) and successful fistula for haemodialysis (RR 1.12, 95% CI 0.99-1.28).^[3] In some other randomised controlled trials, the results were negative especially in patients where the vessels seemed suitable based on physical examinations.^[10] On the contrary, there are other studies that suggest that ultrasound helps.

This is far from all of the evidence, however, as more recent studies have made the story even more complex. For example, an updated systematic review and meta-analysis which included 18 studies involving 3,655 patients found pre-operative ultrasound mapping was associated with a marked decrease in primary AVF failure (RR 0.56, 95% CI 0.37–0.84) and improved one-year primary patency (RR 1.33, 95% CI 1.19–1.47).^[2] This difference is of clinical significance. The benefit seen in these later analyses is largely due to observational studies in which the decision for the use of ultrasound can be driven by factors such as the nature of the patient themselves, the physical examination and surgeon preference and difficulty of the procedure.^[2,8]

On the basis of this background information, the current research evaluates whether preoperative duplex ultrasound mapping has any role in the improvement of maturation and patency in patients with first-time creation of an AVF in a tertiary care center. In this study, by comparing patients who had undergone ultrasound mapping and those who had been examined clinically only, the role of ultrasound in improving outcomes of AVF would be assessed.

METHODS

Study design and setting

The present retrospective cohort study was conducted in King Hussein Medical Centre (KHMC), which is a tertiary referral hospital in Jordan. The study sample consisted of patients who underwent their first attempt at autogenous arteriovenous fistula (AVF) formation from January 2024 to December 2025. Patients were grouped

based on whether they had pre-surgical vessel mapping via duplex ultrasound or not.

Study population

Patients included in the study were adults with stage 5 chronic kidney disease undergoing first-time autogenous upper-limb AVF creation. Those with past history of AV access creation in any of the two upper limbs, prosthetic graft placement, and insufficient information in surgical or follow-up notes were excluded from the study. Patients with insufficient follow-up duration to fulfill the criterion for the desired outcomes were excluded from the analysis of that outcome.

Data collection

The retrospective analysis of the patients' medical records, operative notes, vascular access files, dialysis files, and follow-up files was done through the use of a data collection form. Some of the variables that were collected included age, gender, body mass index, diabetes mellitus, hypertension, ischaemic heart disease, peripheral arterial disease, smoking habit, catheter dependency at the time of AVF creation, dialysis vintage, serum albumin, size of the veins and arteries, fistula configuration and site, and operator's experience level.

Statistical analysis

Continuous variables were reported as mean (SD) or median (IQR), and categorical variables were expressed as frequencies and percentages. Differences between groups were compared by performing suitable parametric or non-parametric test as per suitability. Logistic regression was employed for determining associations of AVF maturation, and Firth penalized logistic regression was utilized for early revision analysis. Revision numbers were assessed by employing Poisson regression, and primary patency was determined using Kaplan Meier analysis and Cox regression. Analysis was conducted using R software (version 4.3.3).

RESULTS

From 720 selected procedures, 608 patients were selected with pre-operative duplex mapping done in 324 (53.3%) of them. In the mapping group, patients had higher risk characteristics including being older, diabetic, with peripheral arterial disease, catheter-dependent, small vein sizes, and fewer radiocephalic fistulas. In total, 446 (73.4%) fistulas matured. Unadjusted maturation rate in those with mapping was 75.3%, compared with 71.1% in those without mapping ($P=0.245$); however, after controlling for clinical and anatomical factors, maturation was positively correlated with mapping (OR 1.57, 95% CI 1.02–2.40; $P=0.039$).

Large diameters of veins and arteries were among the most important positive predictors of maturation, while brachiocephalic and brachio basilic fistulas outperformed radiocephalic fistulas in terms of their maturation rates. Old age was negatively correlated with maturation, while

high levels of albumin were positively correlated with good results. The median duration to maturation was also shorter for the mapping technique (67.5 days compared to 72.5 days; $P = 0.009$). Mapping did not correlate with revision procedures within 90 days and 12-months revision rate. However, the primary patency rate was higher among patients undergoing the mapping technique both at six months (69.1% compared to 65.1%) and twelve months (62.6% vs 56.7%) after the procedure, with lower adjusted hazards of patency loss (HR 0.77, 95% CI 0.60–0.99; $P = 0.046$). Sensitivity analysis yielded similar estimates, confirming the robustness of the major results, and the primary model showed moderate discriminative power.

DISCUSSION

The major discovery in this cohort study is the disparity in the unadjusted and adjusted findings. There was a slight increase in the maturation rate in the mapped group compared with unmapped patients (75.3% vs. 71.1%) and yet the unadjusted difference was insignificant ($P = 0.245$). However, when adjusted, preoperative mapping increased the odds of maturation (OR 1.57). This is a clinically rather than statistically valid change. The patients selected for mapping were elderly and had diabetes, peripheral arterial disease, catheter dependence, and small veins, all of which are linked to lower fistula maturation rates. In other words, the surgeon was more predisposed to request mapping from risky patients.

The same trend can be considered consistent with confounding by indication and could be the reason for inconsistencies observed in the literature. While the Cochrane review of randomized studies demonstrated no significant improvement in maturation at six months (RR 1.11, 95% CI 0.98–1.25), a more recent meta-analysis that included a higher number of observational studies indicated significantly lower rates of primary failure among the group where preoperative mapping was performed (RR 0.56, 95% CI 0.37–0.84).^[2,3] Results from randomized trials have been conflicting in assessing the impact of routine mapping on the outcome of fistulas as well.^[10,11] However, the observations are not mutually exclusive because the influence of mapping in clinical practice heavily depends on patient selection criteria.

Our results were generally similar to what has been found previously. The overall non-maturation was 26.6%, in line with the pooled value of approximately 23% and the 24.7% seen for forearm fistulas.^[1,4] Non-maturation in radiocephalic fistulas was 23.8%, somewhat higher than the 15.3% observed in an earlier meta-analysis of radiocephalic fistulas.^[5] One-year primary patency was between 56.7% and 62.6%, in line with the pooled estimate of 60%.^[1,12] This implies that the cohort can be regarded as representative of contemporary practice in fistulas.

Vein diameter was one of the variables that was most associated with maturation, with an OR of 2.86 per 1-mm increase. This finding is consistent with the poorer outcomes in fistulas that were formed using veins that were smaller than 2 mm.^[7] In addition, it offers a rationale behind the effect of mapping, since ultrasound can have an effect on outcomes largely because it can prevent surgeons from selecting marginal vessels and choosing the best access configuration. Since mapped patients had significantly lower rates of radiocephalic fistulas, which also had the worst maturation rate, it is possible that the choice of configuration is on the causal pathway linking mapping to maturation. As anticipated, the exclusion of this factor from the analysis led to a slight rise in the mapping estimate from 1.57 to 1.61.

Female gender and diabetes, previously shown to predict early fistula failure, were not important in this population.^[6,8] Female gender was found to have the expected effect, although the confidence intervals were wide; diabetes was not significantly associated with the outcome, even with adjustment. These results do not suggest that these risk factors are insignificant in predicting fistula maturation. The sample size may have limited precision for weaker associations and secondary outcomes.

The secondary outcomes proved to be inconsistent. There was no relation between mapping and early revision (OR 0.86) or frequency of revisions within 12 months (IRR 0.94). Lower loss of primary patency was observed (HR 0.77, 95% CI 0.60–0.99), consistent with previous findings on improved patency after mapping.^[2] Nevertheless, since the primary patency endpoint includes cases of non-maturation as well, some part of this effect should be explained by the result regarding maturation. In the analysis excluding patients with non-maturation, the estimates remained almost the same but were more imprecise (HR 0.77, 95% CI 0.47–1.27).

In the context of a clinical setting, such outcomes do not indicate that every patient will require routine mapping by means of ultrasound. Individualized assessment of the patient's condition is the main feature of the current guidelines on vascular access, and there is still no randomized proof of the effectiveness of universal mapping.^[3,9–11] At the same time, our data prove that selective mapping of high-risk patients can be underestimated with the use of crude comparisons with unmapped patients.

Both the crude and adjusted estimates along with sensitivity analyses are provided in this study. Nevertheless, due to the observational nature of the study and its implementation at a single centre, there is a possibility that confounding was present. In particular, the decision to map was based on unmeasured surgeon's judgment.

Moreover, the study was underpowered for its secondary outcomes, and vessel measurement may not be equally available or measured among those who went through mapping compared with those who did not. The missing

values were primarily handled using complete case analysis, while the shortened follow up time in patients recruited later decreased the number of the risk set at 12 months.

Table 1: Baseline characteristics of the analytic cohort (n=608).

Characteristic	Whole cohort
Age, years, mean (SD)	57.3 (13.2)
Female sex	243 (40.0%)
Body-mass index, kg/m ² , mean (SD)	27.8 (4.9)
Diabetes mellitus	269 (44.2%)
Hypertension	491 (80.8%)
Ischaemic heart disease	124 (20.4%)
Peripheral arterial disease	69 (11.3%)
Current smoker	136 (22.4%)
Dialysing via CVC at creation	301 (49.5%)
Dialysis vintage, months, median (IQR)	0.0 (0.0-6.2)
Serum albumin, g/dL, mean (SD)	3.6 (0.5)
Vein diameter, mm, mean (SD)	2.6 (0.7)
Vein diameter <2.0 mm	116 (19.1%)
Artery diameter, mm, mean (SD)	2.3 (0.4)
Radiocephalic configuration	286 (47.0%)
Brachiocephalic configuration	263 (43.3%)
Brachio basilic configuration	59 (9.7%)
Left-sided access	535 (88.0%)
Consultant operator	362 (59.5%)
Pre-operative duplex mapping	324 (53.3%)

Values are mean (SD), median (IQR) or n (%).

Percentages are of non-missing observations.

Table 2: Characteristics and outcomes by pre-operative mapping strategy.

Characteristic	Clinical examination only (n=284)	Duplex mapping (n=324)	P value
Age, years, mean (SD)	55.4 (13.2)	59.0 (13.1)	<0.001
Female sex	113 (39.8%)	130 (40.1%)	0.933
Body-mass index, kg/m ² , mean (SD)	27.6 (4.8)	27.9 (5.0)	0.459
Diabetes mellitus	103 (36.3%)	166 (51.2%)	<0.001
Peripheral arterial disease	21 (7.4%)	48 (14.8%)	0.004
Current smoker	66 (23.2%)	70 (21.6%)	0.629
Dialysing via CVC at creation	116 (40.8%)	185 (57.1%)	<0.001
Serum albumin, g/dL, mean (SD)	3.6 (0.4)	3.6 (0.5)	0.079
Vein diameter, mm, mean (SD)	2.7 (0.7)	2.5 (0.6)	0.004
Artery diameter, mm, mean (SD)	2.3 (0.4)	2.3 (0.4)	0.352
Radiocephalic configuration	150 (52.8%)	136 (42.0%)	0.008
Consultant operator	165 (58.1%)	197 (60.8%)	0.498
--- Outcomes ---			
Functional maturation at 6 months	202 (71.1%)	244 (75.3%)	0.245
Access-related revision ≤90 days	38 (13.4%)	42 (13.0%)	0.879
Revisions in 12 months, median (IQR)	0.0 (0.0-1.0)	0.0 (0.0-1.0)	0.803
Days to maturation, median (IQR)	72.5 (58.2-96.0)	67.5 (53.0-86.0)	0.009

P values from Welch t-test, Wilcoxon rank-sum test, chi-square or Fisher exact test as appropriate. Days to maturation are among fistulas that matured.

Table 3: Multivariable logistic regression for functional maturation within six months.

Term	Adjusted OR (95% CI)	P value
Pre-operative duplex mapping (vs clinical examination)	1.57 (1.02 to 2.40)	0.039
Vein diameter, per 1 mm larger	2.86 (1.83 to 4.46)	<0.001
Artery diameter, per 1 SD larger	2.04 (1.57 to 2.66)	<0.001

Female sex (vs male)	0.81 (0.53 to 1.23)	0.328
Diabetes mellitus	1.00 (0.65 to 1.53)	0.982
Brachiocephalic (vs radiocephalic)	2.34 (1.40 to 3.91)	0.001
Brachiobasilic (vs radiocephalic)	3.14 (1.42 to 6.98)	0.005
Dialysing via CVC at creation	0.85 (0.56 to 1.30)	0.452
Age, per 10 years older	0.82 (0.69 to 0.96)	0.016
Serum albumin, per 1 SD higher	1.30 (1.05 to 1.61)	0.017

563 complete cases, 409 maturation events, 15.4 events reference category. Confidence intervals are Wald per variable. Radiocephalic configuration is the intervals.

Table 4: Secondary endpoints and pre-specified sensitivity analyses.

Model	Term	Estimate	P value
Early revision ≤90 d (Firth logistic, OR)	Pre-operative duplex mapping	0.86 (0.53 to 1.39)	0.541
	Vein diameter, per 1 mm larger	0.60 (0.38 to 0.94)	0.025
	Female sex	0.86 (0.53 to 1.40)	0.547
	Diabetes mellitus	1.36 (0.85 to 2.20)	0.203
	Brachiocephalic (vs radiocephalic)	0.69 (0.39 to 1.22)	0.199
	Brachiobasilic (vs radiocephalic)	0.76 (0.31 to 1.82)	0.532
	Age, per 10 years older	1.08 (0.90 to 1.29)	0.418
Loss of primary patency (Cox, HR)	Pre-operative duplex mapping	0.77 (0.60 to 0.99)	0.046
	Vein diameter, per 1 mm larger	0.40 (0.31 to 0.51)	<0.001
	Female sex	1.29 (1.00 to 1.67)	0.046
	Diabetes mellitus	1.04 (0.81 to 1.35)	0.742
	Brachiocephalic (vs radiocephalic)	0.58 (0.43 to 0.78)	<0.001
	Brachiobasilic (vs radiocephalic)	0.48 (0.30 to 0.78)	0.003
	Age, per 10 years older	1.23 (1.12 to 1.36)	<0.001
Revisions in 12 months (Poisson, IRR)	Peripheral arterial disease	1.41 (0.98 to 2.03)	0.062
	Pre-operative duplex mapping	0.94 (0.70 to 1.24)	0.649
	Vein diameter, per 1 mm larger	0.52 (0.39 to 0.68)	<0.001
	Female sex	1.09 (0.82 to 1.44)	0.554
	Diabetes mellitus	1.12 (0.84 to 1.49)	0.432
	Brachiocephalic (vs radiocephalic)	0.59 (0.42 to 0.83)	0.002
	Brachiobasilic (vs radiocephalic)	0.48 (0.28 to 0.84)	0.009
Revisions in 12 months (neg. binomial, IRR)	Age, per 10 years older	1.07 (0.96 to 1.19)	0.204
	Pre-operative duplex mapping	0.94 (0.70 to 1.26)	0.668
	Vein diameter, per 1 mm larger	0.52 (0.39 to 0.68)	<0.001

		0.68)	
	Female sex	1.09 (0.81 to 1.45)	0.577
	Diabetes mellitus	1.12 (0.84 to 1.50)	0.442
	Brachiocephalic (vs radiocephalic)	0.59 (0.42 to 0.84)	0.003
	Brachiocephalic (vs radiocephalic)	0.48 (0.27 to 0.85)	0.012
	Age, per 10 years older	1.07 (0.96 to 1.20)	0.217
Landmark Cox from month 4, n=409, 65 events, EPV 16.2 -- EXPLORATORY (HR)	Pre-operative duplex mapping	0.77 (0.47 to 1.27)	0.310
	Vein diameter, per 1 mm larger	0.65 (0.44 to 0.97)	0.034
	Diabetes mellitus	0.79 (0.48 to 1.31)	0.359
	Age, per 10 years older	1.29 (1.06 to 1.56)	0.010
Sensitivity: maturation model without fistula configuration	Pre-operative duplex mapping (mediator-free model)	1.61 (1.06 to 2.45)	0.026
Sensitivity: all 608 analytic records, missingness indicators	Pre-operative duplex mapping (missing-indicator model)	1.52 (1.00 to 2.31)	0.049

The landmark model is exploratory: it conditions on remaining event-free at four months, which the exposure affects. The negative binomial model is a sensitivity analysis only — a likelihood-ratio test gave no evidence of overdispersion, so the Poisson estimates are the reported ones.

Table 4b: Kaplan-Meier primary patency at 6 and 12 months.

Group	Month	Primary patency (95% CI)	At risk	Events
Clinical examination only	6	65.1% (59.8-70.9)	179	98
Clinical examination only	12	56.7% (51.0-63.0)	115	20
Pre-operative duplex mapping	6	69.1% (64.2-74.4)	213	98
Pre-operative duplex mapping	12	62.6% (57.3-68.4)	121	16

Events are those occurring in the interval preceding each time point.

Table 5: Model diagnostics.

Diagnostic	Value
Observations in the primary model	563
Events (functional maturation)	409
Non-events (failed to mature)	154
Events per variable (minority class)	15.4
C-statistic (AUC, 95% CI), apparent	0.767 (0.725 to 0.807)
C-statistic, optimism-corrected (200 bootstraps)	0.745
Brier score	0.163
Calibration slope (apparent)	1.00
Calibration intercept (apparent)	-0.00
Hosmer-Lemeshow	chi-sq=9.04, df=8, P=0.339
Multicollinearity (VIF / GVIF^(1/2df))	duplex_mapping=1.04; vein_c=1.24; art_sd=1.09; female=1.01; diabetes=1.04; fistula_config=1.12; prior_cvc=1.04; age10=1.06; alb_sd=1.04
Cox proportional hazards, global test	chi-sq=2.70, df=8, P=0.952
Cox PH, most non-proportional covariate	age10 (P=0.324)
Cox PH, global test, landmark model	chi-sq=1.96, df=4, P=0.742

Landmark model events / EPV	65 events, EPV 16.2
Negative binomial dispersion (theta)	not identifiable (collapses to Poisson)
Overdispersion, negative binomial vs Poisson	LR chi-sq=0.90, one-sided P=0.171 -- no overdispersion; report Poisson
Firth logistic engine	Firth penalised logistic regression; Wald confidence intervals derived from the penalised information matrix.
Complete cases, early-revision model	608

Calibration slope and intercept are apparent values from the fitting sample and are 1 and 0 by construction; the optimism-corrected C-statistic is the informative discrimination measure.

Figure 1. Adjusted odds ratios for functional maturation within six months, from the multivariable logistic model of Table 3. Points are odds ratios, horizontal lines 95% confidence intervals, plotted on a logarithmic scale.

Figure 1. Adjusted associations with functional AVF maturation

Odds ratio (95% CI) shown at right; * P < 0.05

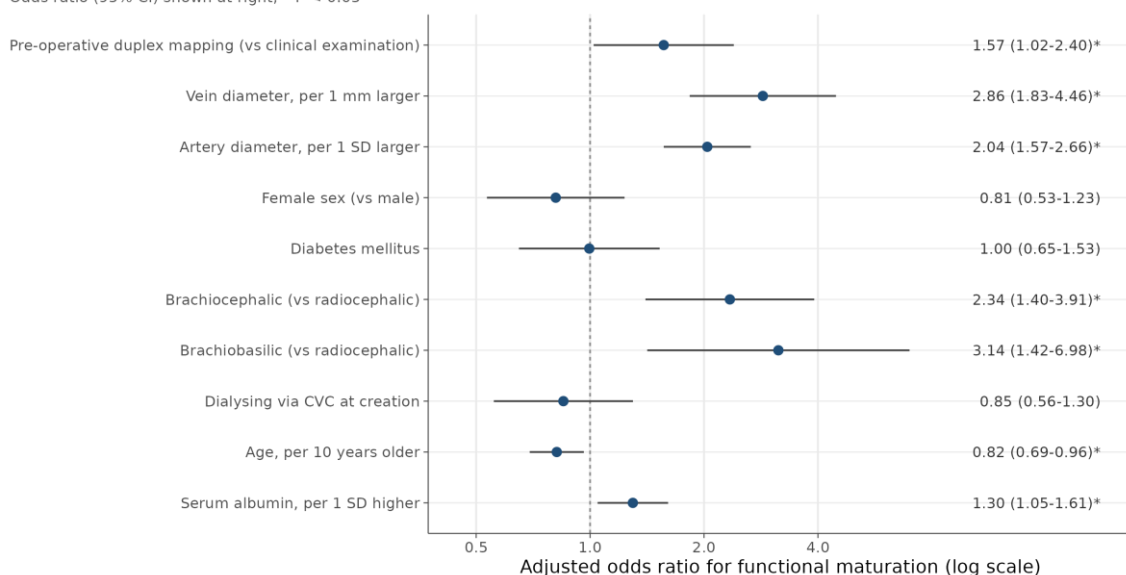


Figure 2. Functional maturation at six months by fistula configuration and mapping strategy. Bars are observed proportions with Wilson 95% confidence intervals; labels give matured/total. The lower maturation seen in

mapped brachiocephalic fistulas reflects selection — mapping steered patients with the poorest veins toward proximal configurations.

Figure 2. Functional maturation by fistula configuration and mapping strategy

Bars show the proportion matured with Wilson 95% CI; labels are matured/total

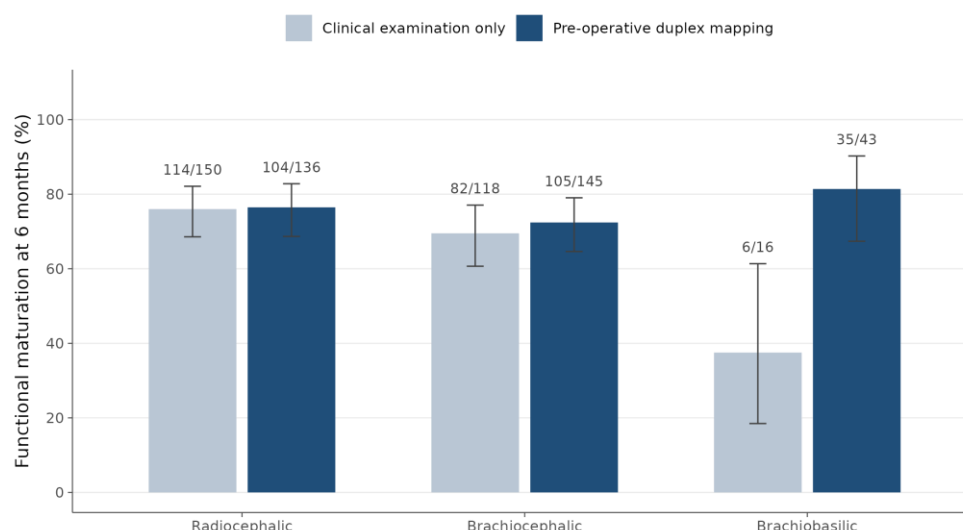


Figure 3: Kaplan-Meier estimates of primary patency by mapping strategy, with pointwise 95% confidence bands and numbers at risk. The steep early decline is non-

maturation, which the composite endpoint counts as immediate loss of primary patency.

Figure 3. Primary patency by pre-operative mapping strategy

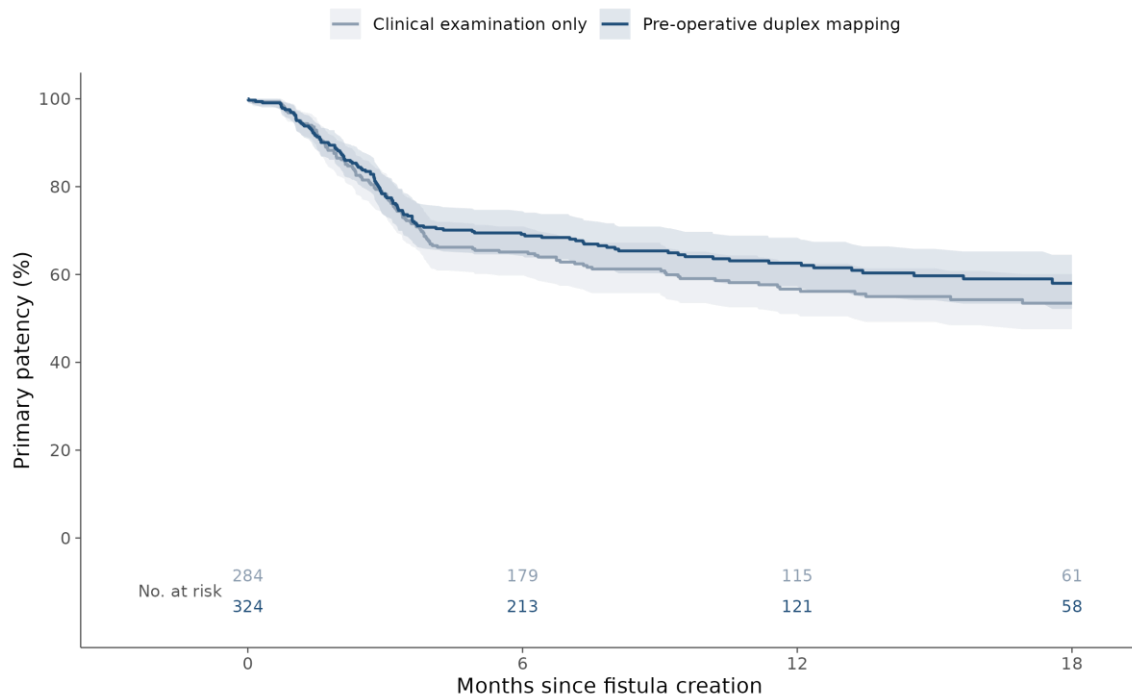
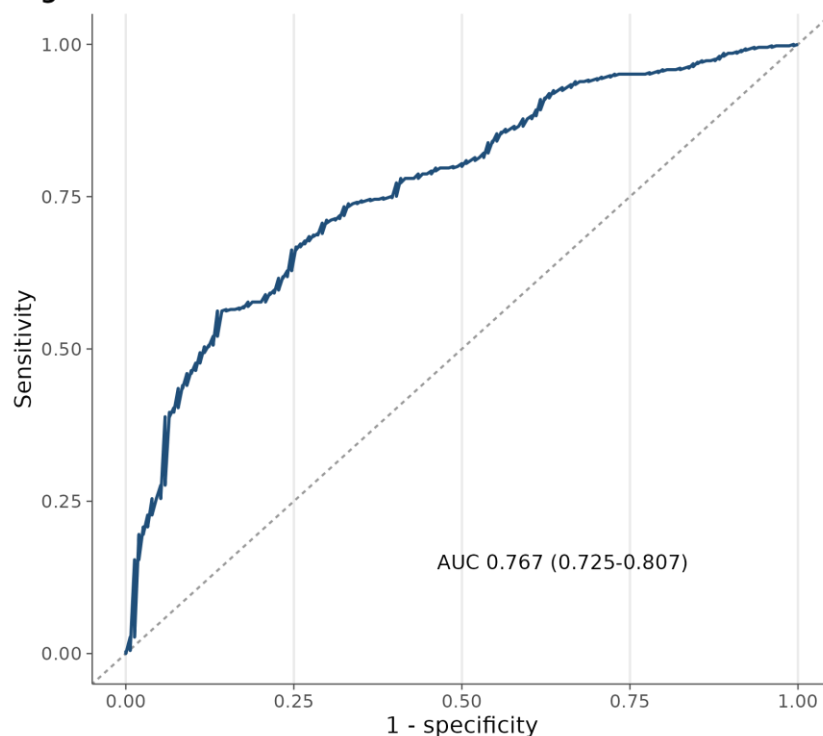


Figure S1. Receiver operating characteristic curve for the multivariable maturation model. The apparent C-

statistic is shown; the optimism-corrected value of 0.745 is the one to quote.

Figure S1. Discrimination of the multivariable maturation model



CONCLUSION

In this single center cohort using clinical data, pre-operative duplex mapping was associated with better AVF maturation after adjustment for baseline differences (OR 1.57, 95% CI 1.02–2.40). The crude comparison showed little difference because mapping was more often used in higher-risk patients. Vein diameter remained the strongest predictor of maturation. Mapping was not associated with early revision or the overall revision burden at 12 months, while the apparent patency benefit was largely driven by the maturation outcome itself. Given the limited statistical power, these findings suggest a possible modest benefit rather than providing definitive evidence.

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