Long-term outcomes of radiocephalic arteriovenous fistulas created in anatomical snuffbox or with VasQ external support device

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ABSTRACT

Objective: This study evaluates the long-term outcomes of radiocephalic arteriovenous fistulas (RCAVFs) created in the anatomical snuffbox (SB-AVF) or with the VasQ external support device (ES-RCAVF).

Methods: We conducted a single-center retrospective analysis including 394 primary AVFs created for hemodialysis access in patients with advanced kidney disease between November 2017 and October 2024. Outcomes examined included rates of access maturation, successful cannulation, patency (primary, assisted primary, and secondary), reintervention rates, and rates of juxta-anastomotic stenosis. Multivariate analyses were used to study the associations between baseline characteristics and clinical outcomes, aiming to identify variables that could inform algorithmic decision-making for optimal distal RCAVF configuration selection.

Results: The cohort consisted of 148 SB-AVFs and 246 ES-RCAVFs. ES-RCAVFs had significantly higher rates of 4-week maturation (81.9% vs 69.7%; $P = .009$), successful cannulation (82.6% vs 71.6%; $P = .044$), and tunneled dialysis catheter (TDC) removal (62.9% vs 56.9%; $P = .28$) at 6 months as compared with SB-AVFs. There was no significant difference in juxta-anastomotic stenosis rates (34% in the SB-group and 32% in the ES-group; $P = .734$) or 5-year patency rates between the two groups (26.1% vs 26.6% for primary [$P = .531$]; 51.2% vs 52.4% for assisted primary [$P = .778$]; and 56.5% vs 57.8% for secondary [$P = .1278$] patency rates) for the SB-AVF vs ES-RCAVFs, respectively. The number of interventions per patient year was 0.46 for SB-AVFs and 0.57 for ES-RCAVFs ($P = .998$). In the multivariate analysis, the VasQ significantly ($P = .001$) increased the probability of maturation, and female gender ($P = .007$) and diabetes ($P = .026$) significantly reduced that probability at 4 weeks. The VasQ also significantly increased the probability of overall maturation ($P = .002$). Female gender ($P = .003$) and older age ($P = .028$) negatively contributed to the probability of overall maturation. Moreover, VasQ significantly increased the probability of cannulation success ($P = .034$) and was the only significant factor for increased likelihood of TDC removal by 6 months ($P = .031$). Female gender ($P = .002$) and older age ($P = .006$) were associated with a significantly decreased likelihood of TDC removal.

Conclusions: Our findings indicated that, although ES-RCAVFs achieve superior short-term and long-term outcomes, SB-AVFs remain a valuable option for select patients—particularly younger and nondiabetic individuals—to preserve distal access sites for future use. (J Vasc Surg 2025;■:1-11.)

Keywords: Arteriovenous fistula; External support device; VasQ; Snuffbox-fistula; AVF; Radiocephalic fistula; Hemodialysis access; End-stage kidney disease

The distal-first algorithmic approach to vascular access (VA) creation has been driven by a goal to maintain anatomical options for hemodialysis (HD) patients. Even in this recent era of right access, right patient outlined by the 2019 Kidney Disease Outcomes Quality Initiative guidelines, the most distal arteriovenous fistula (AVF) option is still the preferred access, provided the probability of maturing into a functional fistula is equivalent to more proximal anastomotic locations.[1] The anatomical snuffbox AVF (SB-AVF) (Fig 1, *A*) is the most distal radiocephalic (RC) option possible but has a low use rate globally owing to the perception that clinical outcomes are poor. However, this perception is not aligned with the studies from experienced surgeons that have demonstrated up to 83% maturation and secondary patency (SP) rates that range from 65% to 92% at 1 year and 45% to 77% at 5 years.[2-5] Several comparison studies with RC AVFs (RCAVFs) have consistently reported equivalent clinical outcomes for SB-AVFs, even when demographics and comorbidities were matched, with a

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higher incidence of failure in diabetic patient population.[5-7] Those studies suggest that patients with vasculature suitable for SB-AVFs should be preferred over classic RCAVFs owing to equivalent outcomes.

The introduction of nitinol-based, permanent extravascular supported AVFs (ES-RCAVF) (VasQ, Laminate medical, Tel-Aviv, Israel) may impact this algorithmic preference based on the potential for improved outcomes. ES-RCAVFs have demonstrated consistently improved maturation and successful cannulation for AVFs in multiple studies over the last 8 years[8-16] by counteracting the unstable hemodynamic flow profile and increased wall tension from high transluminal pressure[17-19] (Fig 1, *B*). The long-term patency of ES-RCAVFs reported in previous single-arm studies[11,14] has yet to be assessed in a comparative analysis against unsupported AVFs. However, because an ES-option has yet to be developed for SB-AVFs, more proximal ES-RCAVFs may be a preferred option if superior rates of maturation with sustained long-term patency were achieved.

In this study, the clinical outcomes of a surgical program that has adopted both SB-AVF and ES-RCAVFs as a standard of care were assessed. The impact of surgical experience, demographics and usage of extravascular support were also determined in a multivariate analysis, and long-term outcomes for ES-RCAVFs were compared with unsupported SB-AVFs for the first time.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center retrospective analysis of prospectively collected registry data
- **Key Findings:** Radiocephalic arteriovenous fistulas (RCAVFs) created with an external support had significantly higher rates of 4-week maturation (81.9% vs 69.7%; $P < .001$), 6-month cannulation (82.6% vs 71.6%; $P = .027$), and tunneled catheter removal (62.9% vs 56.9%; $P = .028$) as compared with snuffbox RCAVFs. There was no significant difference in juxta-anastomotic stenosis rates or 5-year primary, assisted primary, and secondary patency rates between the two groups (26.1% vs 26.6% for primary [$P = .531$]; 51.2% vs 52.4% for assisted primary [$P = .778$]; 56.5% vs 57.8% for secondary [$P = .1278$]).
- **Take Home Message:** Although externally supported RCAVFs demonstrated several superior short-term and long-term outcomes, the creation of those in anatomical snuffbox should still be considered for selected patients, particularly younger and nondiabetic individuals, to maximize distal access options consistent with the end-stage kidney disease life plan.

METHODS

Study design. Data from a prospectively collected anonymized registry at a dedicated tertiary VA center was derived and reviewed for this retrospective comparative analysis with VA creation between September 2017 and October 2024. Patients were evaluated preferentially by the same surgeon for a SB-AVF based on age, gender, and vessel diameter and quality (eg, in younger patients with adequate vessel sizes, small distance between the artery and the vein, and healthy artery, SB-AVF was preferred, whereas if those were subjectively deemed as inadequate, ES-RCAVF was the first choice). All AVFs were evaluated and created by the single surgeon (R.S.). ES-RCAVFs were created at the distal-to-mid forearm and done so with the VasQ as the standard of care since July 2018. SB-AVF and ES-RCAVF differed only in anatomical location and use of an ES as the target vessels and procedure technique were similar. Only primary AVFs were included in the analysis.

The study complies with the local ethics committee and institutional review board requirements and is in accordance with the Declaration of Helsinki. Patient consent was collected for every procedure.

Patient population. Patients who were referred for VA with chronic kidney disease, end-stage kidney disease (ESKD) or hyperlipoproteinemia, and were currently undergoing HD or preparing to initiate HD or apheresis, were analyzed. Each patient underwent a comprehensive preprocedural clinical assessment and duplex ultrasound (DUS) examination. A thorough review of the patient medical record was carried out to gather specific clinical data and comorbidities (age, gender, presence of a tunneled dialysis catheter [TDC], and diabetes). Clinical examination consisted of bilateral blood pressure measurements and palpation of the brachial, radial, and ulnar arterial pulses with performance of the modified Allen test. Standardized DUS examination was performed, including mapping of the arteries and superficial veins using tourniquet. As recommended by the VA guidelines,[20] minimum (and continuous across the length of the forearm) requirement for the forearm cephalic vein diameter was ≥2 mm with at least one available outflow vein toward the upper arm (cephalic, basilic, and/or perforator) with ≥2 mm inner diameter. For the radial artery (RA), a minimum inner diameter of ≥1.6 mm was used for forearm ES-RCAVFs and ≥2 mm for the SB-AVFs. Those were evaluated and documented for each patient and analyzed for the study. Calcified RAs were not excluded from AVF creation if the Doppler examination was not pathological and the DUS examination was able to visualize the lumen of the artery with the above diameters. The decision as to which AVF should be created was generally made based on the algorithm with AVFs created as distal as possible first, yet always individually selected.[21] Hence, SB-AVF was the most distal choice of AVF creation.

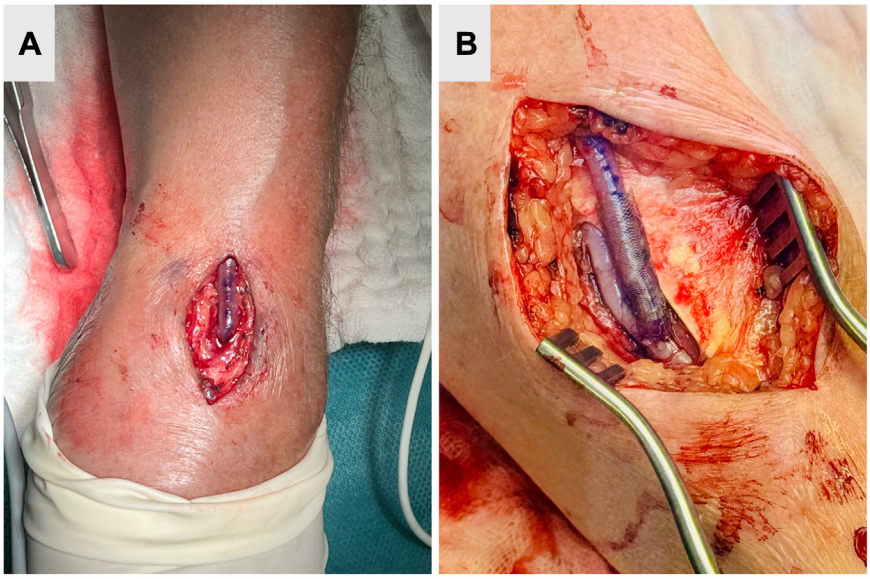

Fig 1. Intraoperative images of snuffbox (SB) **(A)** and externally supported **(B)** radiocephalic arteriovenous fistula (RCAVF).

Surgical technique and evaluation methods. The VasQ is a 2.5-cm-long braided nitinol device that wraps around the vein with a laser-cut brace that sits over the anastomosis.[16] The creation of SB- and ES-RCAVFs followed similar procedural steps: under axillary block the forearm cephalic vein and the RA were carefully dissected (no-touch technique) and clamped after administration of 2000 to 3000 IU heparin. After ligation of the distal end of the cephalic vein, the vein was pre-dilated with heparinized saline and, when ES-RCAVF was the planned procedure, both the artery and the vein were measured using the disposable device model selection tool[16] to choose the suitable size from six models. The ES was then placed around the vein. The arteriotomy and venotomy of approximately 5 to 6 mm for SB-AVF and 6 to 8 mm for ES-RCAVF was performed and the end-to-side anastomosis was created at 30 to 50° with a 7-0 continuous monofilament suture. After finishing the anastomosis, flow measurement was performed using the DUS examination (brachial artery flow [Qa]) and transit time flow measurement around the juxta-anastomotic vein segment. Finally, for ES-RCAVFs, the ES-device was positioned around the anastomosis and connected at the eyelets with a 5-0 monofilament suture around the RA. Additional flow measurement was carried to exclude any twisting or compression of the vein within the device (eg, if the flow dropped). The wound was closed using the standard technique.

Follow-up and outcomes. Regular follow-ups and Qa measurements were performed 1 to 2 days after the surgery, in 4 weeks to assess maturation, and every 3 to 12 months as standard protocol. Rates of access maturation, successful cannulation, patency (primary, assisted patency, and secondary), reintervention rates, abandonment of AVF, the incidence of juxta-anastomotic stenosis (JAS), and removal of TDC were examined as end points. The type and number of reinterventions were documented accordingly.

Maturation was defined as access suitable for two-needle cannulation and HD-flow of approximately 300 mL/min with a Qa of ≥500 mL/min and target vein diameter of ≥5 mm. Unassisted maturation was defined as achieving maturation based on surgeon's examination (chronic kidney disease patients) before any unplanned intervention.[20,22] Functional maturation was the successful two-needle cannulation for six consecutive HD sessions (referred to as cannulation). Unassisted cannulation was defined as successful two-needle cannulation of VA for six consecutive dialysis sessions in ESKD or hyperlipoproteinemia patients before any unplanned intervention. Primary patency (PP), assisted primary patency (APP), and SP were defined per guidelines.[20] Any unplanned surgical or endovascular procedure performed on the VA circuit was counted as an intervention. The juxta-anastomotic region is generally variably defined as the first 2 cm of the outflow vein.[23-25] For this study, the venous JAS was the area starting from the anastomosis and extending 2.5 cm for SB-AVFs and approximately 3.5 cm (1 cm cranial to the ES device) for the ES-RCAVFs.

The study end point was either October 1, 2024, the date of last known follow-up visit, date of death, or access abandonment.

Statistical analysis. Basic exploratory analysis was conducted for study variables to generate descriptive statistics. Arithmetic means and standard deviations (SDs)

Table I. Preoperative demographics and details (n = 394)

	SB-RCAVF (n = 148)	ES-RCAVF (n = 246)	*P* value
Age, years[a]	57.4 (12.2-87)	64.6 (22.4-89.8)	**<.0001**
Gender[a]			**.0314**
Female	35 (23.65%)	84 (34.15%)	
Male	113 (76.35%)	162 (65.85%)	
Diabetes[a]	40 (27.2%)	108 (44.6%)	**.0005**
Indication for VA[a]			
Dialysis (ESKD)	73 (49.3%)	125 (50.8%)	.3905
Preemptive (CKD IV-V)	73 (49.3%)	115 (46.75%)	
Apheresis	2 (1.35%)	6 (2.4%)	
TDC at time of AVF creation[a]	67 (45.3%)	115 (46.9%)	.7553
Preoperative RA diameter, mm[b]	2.31 ± 0.32	2.24 ± 0.38	**.0238**
Preoperative forearm cephalic vein diameter, mm[b]	2.69 ± 0.66	2.71 ± 0.58	.2892

CKD, Chronic kidney disease; *ES*, external support; *ESKD*, end-stage kidney disease; *max*, maximum; *min*, minimum; *RA*, radial artery; *RCAVF*, radiocephalic arteriovenous fistula; *SB*, snuffbox; *TDC*, tunnelled dialysis catheter; *VA*, vascular access.
Values are mean (minimum-maximum), number (%), or mean ± standard deviation.
Boldface entries indicate statistical significance.
[a]Fisher exact test.
[b]Kolmogorov-Smirnov test.

were calculated for continuous variables, while frequencies and percentages were used for categorical variables. The Pearson test was applied to assess normality assumptions for continuous variables. Baseline demographic differences between the SB and ES groups were analyzed using *t* tests for normally distributed continuous variables, and Mann-Whitney *U* tests for non-normally distributed variables. Categorical variable differences were evaluated using chi-squared tests of independence or Fisher's exact tests, as appropriate. Time to patency loss were assessed for both groups using Kaplan-Meier or cumulative event analyses. Censoring events included loss to follow-up, patient death, or reaching the study period's end without the event of interest. Multivariate analyses was performed using logistic regression for binary variables and Cox proportional hazards regression with Kaplan-Meier survival curves for time-to-event analyses. All statistical analyses were conducted using JMP version 15 (Cary, NC).

RESULTS

Demographics. From September 2017 to October 2024, 1083 VAs were created with 148 primary SB-AVFs starting November 2017 and 246 primary ES-RCAVFs starting July 2018. The median follow-up for ES-RCAVFs was 459 days (range, 1-2247 days; SD = 535.2), while it was 382 (range, 1-2113 days; SD = 491) for the SB-AVFs ($P = .93$). At 5 years, death or lost-to-follow up was observed in 79 SB-AVF patients and 155 ES-RCAVF patients. Significantly more female ($P = .031$), elderly (>65 years) ($P<.0001$), and diabetic patients ($P = .0005$) with smaller preoperative RA size ($P = .024$) underwent ES-RCAVFs as their primary access creation (Table I).

JAS. JAS was observed in this study at a rate 4.5% at 6 weeks and 17.5% at 6 months with no significant difference observed between SB-AVF and ES-RCAVF groups. No significant difference was observed for total JAS between SB-AVFs at 34% and ES-RCAVF at 32% ($P = .734$). In a multivariate analysis no factors were significant in predicting JAS at 6 weeks. By 6 months, ESKD ($P = .006$), female gender ($P = .047$), and older age ($P = .006$) were significant factors in the development of JAS (Table II).

Maturation. Maturation at 4 weeks was 77.4%, with the overall maturation at 90.5%. A significantly greater proportion of ES-RCAVFs matured both at 4 weeks (81.9% vs 69.7%; $P = .009$) and overall (93.6% vs 85.5%; $P = .011$) (Fig 2). Unassisted maturation was not significantly different (ES-RCAVFs 78.2% vs SB-AVF 74.3%; $P = .383$). On multivariate analyses (Table II), implantation of an ES ($P = .001$) was associated with a significantly increased probability of maturation to occur, whereas female gender ($P = .007$) and diabetes ($P = .026$) significantly decreased that probability at 4 weeks. ES also significantly increased the probability of overall maturation ($P = .002$), but diabetes was no longer a negative factor. Female gender ($P = .003$) and older age ($P = .028$) negatively contributed to the probability of overall maturation to occur.

Cannulation and TDC dwell time. The time from AVF creation to successful cannulation in patients who were on HD at the time of AVF creation was 92.4 ± 106.9 days for SB-AVFs and 89.8 ± 107.7 days for the ES-RCAVFs, respectively ($P = .8890$). In patients who reached ESKD or apheresis, successful cannulation at

Table II. Multivariate analysis for juxta-anastomotic stenosis, maturation, cannulation and tunnelled dialysis catheter (*TDC*) removal against arteriovenous fistula (*AVF*) type, surgeon experience, end-stage kidney disease (*ESKD*), gender, age, diabetic status, and preoperative vessel diameter

	6 month JAS		4-Week Maturation		Total Maturation		6 Months unassisted cannulation[a]		6 Months cannulation[a]		6 months TDC removal[a]	
Factors	OR [95%-CI]	*P* value	OR [95%-CI]	*P* value	OR [95%-CI]	*P* value	OR [95%-CI]	*P* value	OR [95%-CI]	*P* value	HR [95%-CI]	*P* value
ES-RCAVF	0.8 [0.4-1.4]	.40	2.6 [1.5-4.5]	**.001**	3.4 [1.6-7.4]	**.002**	2.7 [1.2-6.4]	**.02**	2.3 [1.1-5.0]	**.03**	2.3 [1.1-5.1]	**.03**
Experience	0.6 [0.3-1.1]	**.08**	0.99 [0.6-1.7]	.96	1.3 [0.6-2.8]	.48	0.9 [0.4-2.1]	.89	0.8 [0.4-1.6]	.80	1.2 [0.6-2.4]	.68
ESKD	2.2 [1.3-4.0]	**.006**	0.7 [0.4-1.1]	.13	0.6 [0.3-1.2]	.16	-	-	-	-	-	-
Female	1.9 [1.0-3.5]	.05	0.5 [0.3-0.8]	**.007**	0.3 [0.1-.7]	**.003**	0.2 [0.1-0.6]	**.001**	0.18 [0.1-0.4]	<.**001**	0.3 [0.1-0.7]	**.002**
Age >65	2.2 [1.2-4.0]	**.006**	0.7 [0.4-1.1]	.11	0.4 [0.2-0.7]	**.03**	0.4 [0.2-0.9]	**.04**	0.6 [0.3-1.5]	.35	0.4 [0.2-0.7]	**.006**
Diabetes	1.4 [0.8-2.5]	.28	0.6 [0.3-0.9]	**.03**	1.0 [0.5-2.2]	.99	1.01 [0.4-2.4]	.98	0.7 [0.3-1.5]	.37	0.7 [0.3-1.6]	.41
Arterial diameter	1.2 [0.7-2.2]	.58	0.8 [0.5-1.4]	.48	0.5 [0.3-1.1]	.11	0.5 [0.2-1.1]	.08	0.4 [0.2-0.96]	**.04**	1.1 [0.5-2.2]	.88
Vein diameter	0.7 [0.4-1.2]	.20	1.4 [0.8-2.4]	.21	0.8 [0.4-1.7]	.64	1.2 [0.6-2.9]	.58	1.3 [0.6-2.8]	.44	1.0 [0.4-2.4]	.95

ES, External support; *JAS*, juxta-anastomotic stenosis; *HR*, hazard ratio via Cox regression; *OR*, odds ratio calculated via logistic regression; *RCAVF*, radiocephalic arteriovenous fistula.
Boldface entries indicate statistical significance.
[a]Assessed for ESKD patients only.

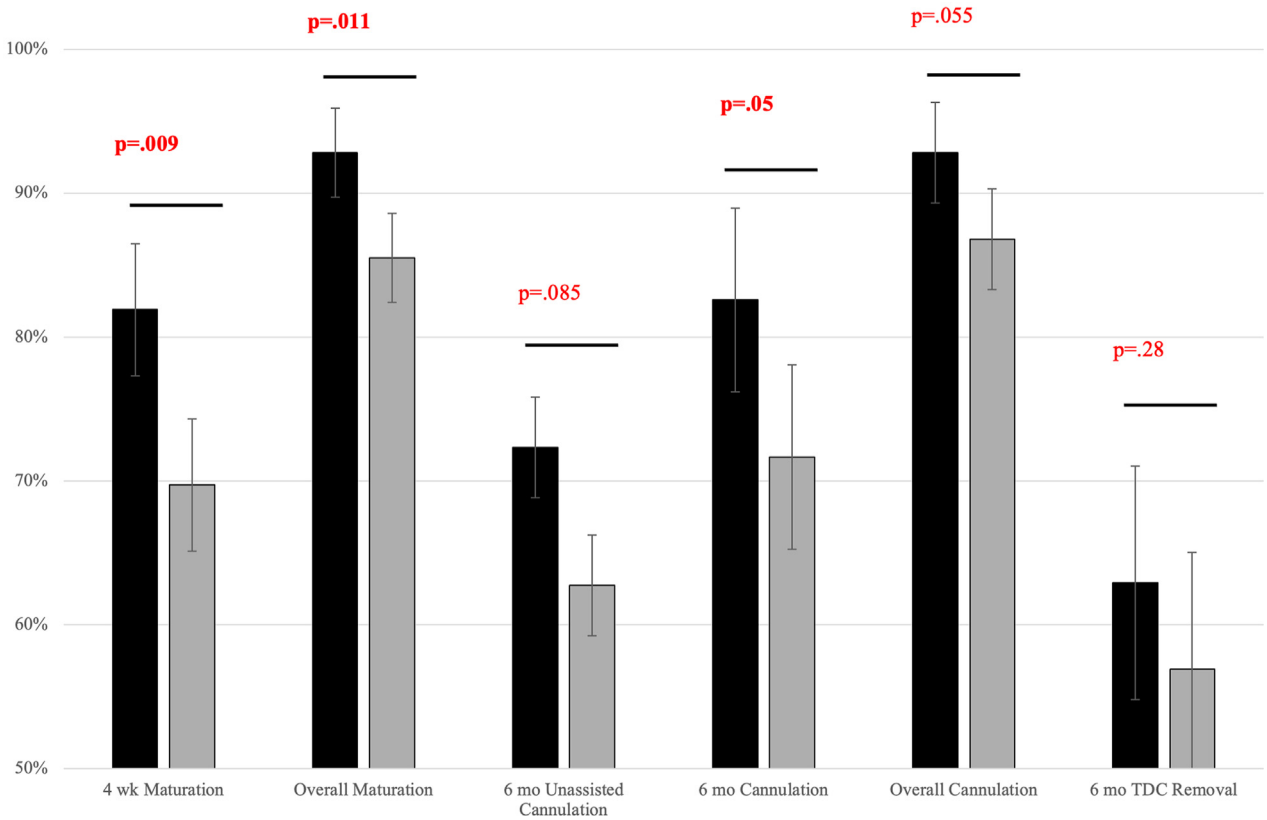

Fig 2. Comparison of maturation, cannulation metrics and tunneled dialysis catheter (TDC) dwell time between externally supported (black) and snuffbox (SB) (gray) radiocephalic arteriovenous fistula (RCAVF), including the standard error.

6 months was 78.4% with overall cannulation rate at 90.5% (68.9% unassisted). A significantly greater proportion of ES-RCAVFs achieved successful cannulation at 6 months (82.6% vs 71.6%; $P = .044$), but not for unassisted (72.7% vs 62.7%; $P = .082$) or overall (92.8% vs 86.8%; $P = .056$) (Fig 2). In a multivariate analysis, ES significantly increased the probability of successful cannulation ($P = .034$), as well as unassisted cannulation ($P = .023$) at 6 months. Female gender was a significant negative factor for both metrics ($P < .001$ and $P = .001$, respectively), whereas older age was the only significant negative factor for unassisted cannulation, and a larger

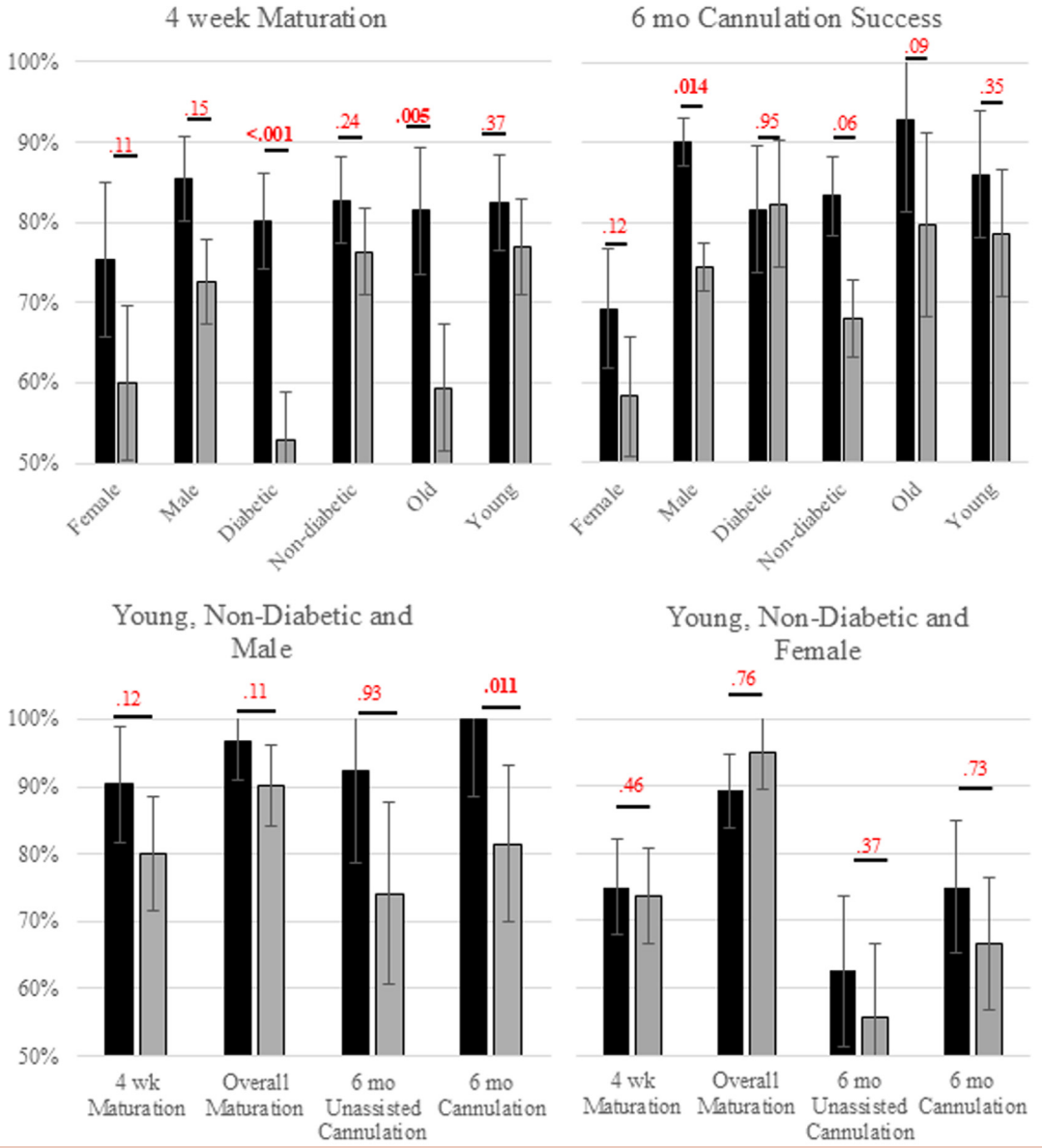

Fig 3. Comparison of maturation, cannulation metrics, and tunneled dialysis catheter (TDC) dwell time between externally supported (black) and snuffbox (SB) (gray) radiocephalic arteriovenous fistula (RCAVF), including standard error for gender, diabetic status, and age.

preoperative arterial diameter was a significant negative factor for only 6-month cannulation ($P = .04$) (Table II).

There were 67 SB-AVF (45.3%) and 115 ES-RCAVF (46.7%) patients who had a TDC at the time of AVF creation. From those, information on TDC removal was available for 160 patients (62/67 SB-AVFs and 98/115 ES-AVFs) owing to death of 2 and loss to follow-up of 20. Of these, 81.8% of TDCs were removed: 79% in the SB and 83.7% in the ES group ($P = .529$). Mean dwell time was 135.2 ± 71.2 days and 143.8 ± 84.8 days for SB- and ES-RCAVFs, respectively ($P = .567$). By 6 months, 60.6% of the TDCs were removed with no statistical difference between SB-AVF at 56.9% and ES-RCAVF at 62.9% ($P = .28$) (Fig 2). However, in a multivariate analysis, ES-RCAVF ($P = .031$) was the only significant factor for increased likelihood of TDC removal by 6 months. Female gender ($P = .002$) and older age ($P = .006$) significantly decreased the likelihood of TDC removal.

Maturation and cannulation based on age, diabetic status, and gender. Significant differences in maturation rates at 4 weeks were retained for diabetic and elderly patients. Nondiabetic and younger patients reported a small, nonsignificant difference in favor of ES-RCAVFs. Overall maturation rates correlated with the 4-week maturation data, albeit greater in magnitude. Cannulation rates at 6 months were significantly greater for males with ES-RCAVF as compared with SB-AVFs and

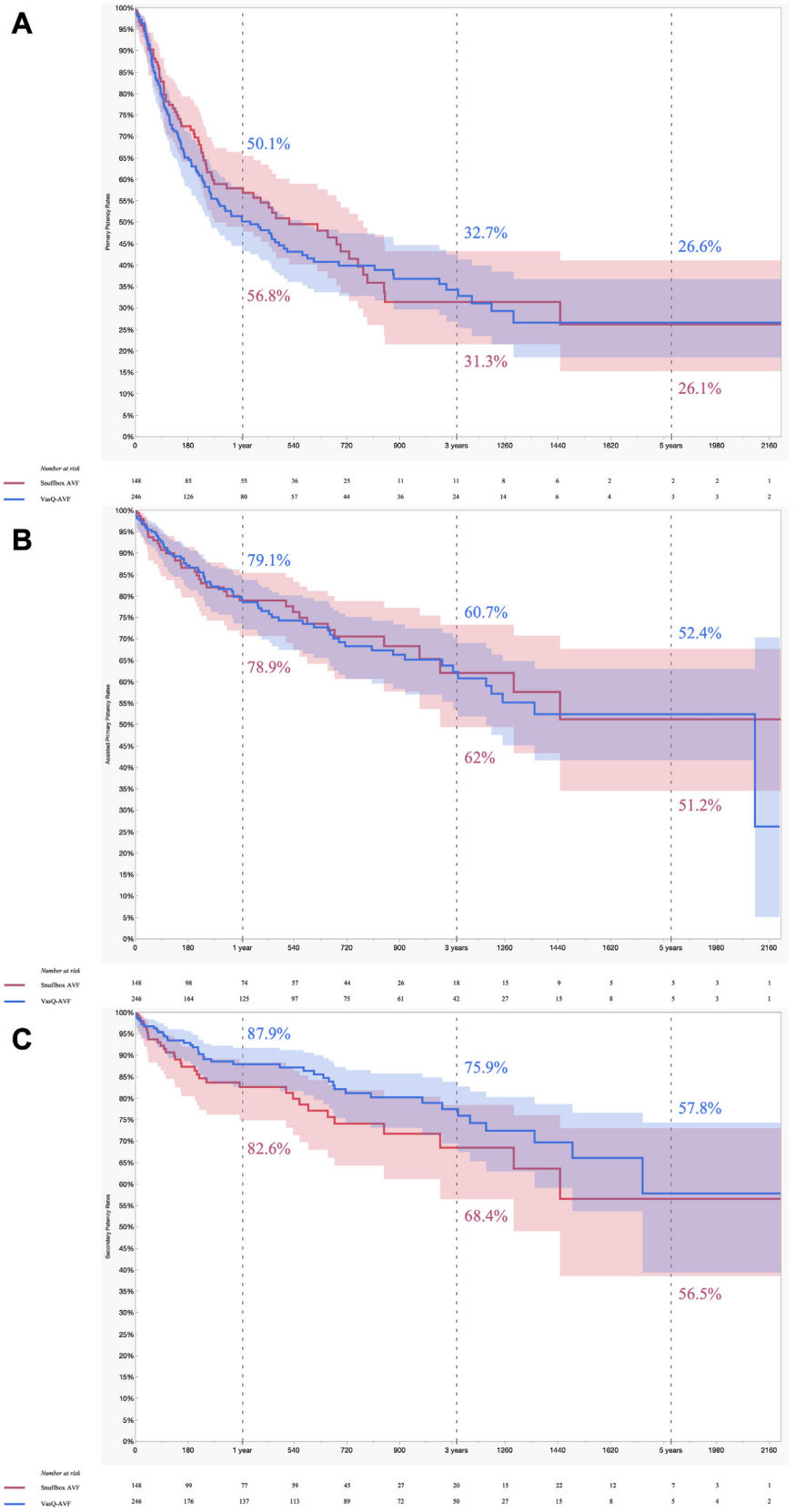

Fig 4. Kaplan-Meier survival curves for primary **(A)**, primary assisted **(B)**, and secondary **(C)** patency rates.

Table III. Multivariate analysis for patency rates against arteriovenous fistula (*AVF*) type, surgeon experience, end-stage kidney disease (*ESKD*), gender, age, diabetic status, and vessel diameter

	Primary patency		Assisted primary patency		Secondary patency	
Factors	HR [95%-CI]	*P* value	HR [95%-CI]	*P* value	HR [95%-CI]	*P* value
ES-RCAVF	1.0 [0.8-1.4]	.88	1.0 [0.7-1.6]	.85	1.7 [1.0-2.8]	**.033**
Experience	1.1 [0.8-1.6]	.40	1.5 [0.9-2.3]	.088	1.6 [0.9-2.8]	.083
ESKD	0.6 [0.5-0.8]	**.001**	0.7 [0.5-1.0]	.074	0.7 [0.5-1.2]	.21
Female	0.9 [0.6-1.2]	.38	0.7 [0.4-1.0]	.065	0.7 [0.4-1.1]	.11
Age >65 years	0.8 [0.6-1.0]	.067	0.9 [0.6-1.3]	.45	0.7 [0.4-1.1]	.15
Diabetes	0.8 [0.6-1.0]	.087	1.2 [0.8-1.7]	.52	1.0 [0.6-1.6]	.86
Arterial diameter	0.9 [0.7-1.3]	.70	0.9 [0.6-1.3]	.50	0.8 [0.5-1.3]	.39
Vein diameter	0.1.2 [0.9-1.7]	.17	1.1 [0.7-1.7]	.62	1.1 [0.7-1.9]	.64

ES, External support; *JAS*, juxta-anastomotic stenosis; *HR*, hazard ratio via Cox regression; *OR*, odds ratio calculated via logistic regression; *RCAVF*, radiocephalic arteriovenous fistula.
Boldface entries indicate statistical significance.

trended greater, albeit not statistically significant, for female nondiabetic patients (Fig 3). No differences in cannulation rates were observed for diabetic patients despite the significantly greater maturation rates reported for ES-RCAVF as compared with SB-AVF. The combined effect of younger, nondiabetic, and male patients demonstrated a similar trend of improved maturation and cannulation outcomes for ES-RCAVF. However, the combined effect of younger, nondiabetic, and female gender resulted in equivalent outcomes for both ES-RCAVF and SB-AVF.

Patency rates. PP, APP, and SP rates were not significantly different between the two groups over the 5-year follow-up (Fig 4, *A-C*); however, SP trended to be higher for ES-RCAVFs. PP-rates at 1, 3, and 5 years were 57.8%, 31.3%, and 26.1% for the SB-AVFs and 50.1%, 32.8%, and 26.6% for the ES-RCAVFs, respectively ($P = .531$). APP rates at 1, 3, and 5 years were 78.9%, 62.0%, and 51.2% for the SB-AVFs and 79.1%, 60.8%, and 52.4% for the ES-RCAVFs, respectively ($P = .778$). Finally, SP rates at 1, 3, and 5 years were 82.6%, 68.4%, and 56.5% for the SB-AVFs and 87.9%, 75.9%, and 57.8% for the ES-RCAVFs, respectively ($P = .1278$). In total, AVFs were abandoned in 75 patients during the study period: 22.3% of SB-AVFs (33/148) and 17.1% of ES-RCAVFs (42/246) ($P = .204$). In a multivariate analysis, ESKD ($P = .001$) was the only significant negative factor for PP; no factors reported statistical significance for APP. For SP, ES-RCAVF ($P = .033$) was also a significant contributing factor to higher rates with no significant negative factors observed (Table III).

Reinterventions. Numerically, 97 reinterventions were performed in 49 patients to maintain the VA (129 interventions in 70 patients counting the abandonment/transition to another access) in patients with SB-AVFs. For ES-RCAVF patients, there were 237 reinterventions in 113 patients to maintain the VA (278 interventions in 127 patients, including the abandonment/transition to another access). In total, there were numerically fewer, albeit not a significantly different number of, interventions per patient year for the SB-AVFs at 0.46 compared with 0.57 for ES-RCAVFs ($P = .998$). Planned cephalic vein elevation was performed in 4% of SB-AVFs (6/148) and 6.9% of ES-RCAVFs (17/246) ($P = .368$).

There were no cases of symptomatic HD access-induced distal ischemia in either group during the whole study period.

DISCUSSION

This long-term comparative analysis of RCAVFs demonstrated superior outcomes for ES-RCAVFs over SB-AVFs, which challenges prior published literature.[6] The superior outcomes for ES-RCAVFs reported here were likely the result of the clinical effect of ES, which is intended to mitigate wall tension and stabilize hemodynamics of the fistula.[26] Those were observed despite the disproportionate representation of factors associated with lower maturation and patency rates, such as female gender, diabetes, and older age.[27-30] ES-RCAVFs were also found to be a significant positive factor in maintaining long-term SP, suggesting clinical benefits extend beyond the maturation phase. However, the possibility to convert a failed SB-AVF to successful ES-RCAVF suggests that SB-AVF should still be considered for selected patients, particularly younger and nondiabetics, to maximize the most distal options for a functioning fistula and long-term VA.

The improved outcomes of ES-RCAVFs may not come as surprise to many who have a negative perception of SB-AVFs, despite the consistent equivalent outcomes between the two anastomotic locations reported in the literature.[6,7] That negative perception may stem from higher rates of failures and JAS, which have been reported as ≤77%,[31-33] especially when it occurs during the initial experience that surgeons have with the technique. JAS rates reported here were lower than previously reported and trended to decrease with

experience albeit not statistically significant (Table II). Given the similarities in technique and vessel size and quality, including outflow target, generally equivalent outcomes should be expected between SB-AVF and RCAVFs without ES as has been shown in the literature, and additional consideration should be given to the more distal anastomotic location.

Previous experience with ES-RCAVFs at this center led to its adoption as the standard of care since 2018 owing to the observed reduction in primary failure and improved 6-month PP as compared with RCAVFs without ES.[15] Other groups have observed a similar improvement in avoiding primary failure in favor of early maturation.[8,11,12,34] However, reports on improvement in PP with ES have been mixed with some studies demonstrating a significant benefit,[11,15] with others experiencing no significant benefit.[8,35] For example, Karydis et al[12] reported in a randomized controlled study a significant decrease in stenosis and improvement in functional success; however, that decrease did not translate into a significant decrease in 6-month PP. Ultimately, deciding on access type and location should not be based on PP alone, but also consider the probability of achieving functional success and long-term durability. This study adds to the ES literature by showing the consistent and significant improvement in early maturation and cannulation rates[11,12,14] and extending for several years beyond creation in terms of SP. When examining the SP Kaplan-Meier curves, the increased risk of primary failure without ES can be observed by the steeper decline over the first 6-months for SB-AVFs (Fig 4). After 6 months, the SP curves run parallel for the remaining 4.5 years, suggesting that avoidance of early failure was maintained in the long term. Additionally, the presence of a permanent ES did not interfere with the ability to maintain SP through standard interventional techniques as described previously.[14]

From our perspective, SB-AVFs should not be abandoned for ES-RCAVFs despite the significant improvement in maturation and successful cannulation rates observed here. However, other criteria for SB-AVF patient selection in addition to vessel size and quality may need to be considered. Factors that negatively impact maturation rates here, such as female gender, diabetes, and older age, have been reported in multiple previous studies as well and should be a part of the AVF selection algorithm.[27-30] SB-AVFs tended to be more sensitive to these factors as compared with ES-RCAVFs, which only seemed to be negatively impacted by female gender. One potential option would be to select only "lower risk" patients for SB-AVF as suggested by Twine et al with their DISTAL scoring system.[36] However, we observed that ES-RCAVFs for lower-risk patients (ie, young nondiabetic males) still tended to have improved outcomes for maturation and cannulation over SB-AVFs (Fig 3). Counterintuitively, young nondiabetic females with SB-AVFs achieved nearly equivalent outcomes as ES-RCAVFs. This result was not due to better outcomes in SB-AVFs, but more so a greater decrease in outcomes of ES-RCAVFs for that specific subset. In these selected female patients, SB-AVFs may be the preferred access owing to the more distal location to maximize the probability of creating a functioning forearm access while retaining the most vessel options.

An interesting observation was the similar incidence of JAS for SB-AVFs and ES-RCAVFs despite the superior maturation and successful cannulation rates for ES-RCAVFs. However, observed lack of difference does not support the conclusion that the ES mechanism of action lacks a clinical impact on JAS. First, SB-AVFs have yet to report any increased risk of JAS as compared with forearm RCAVFs in the published literature. In fact, the proximity of the artery and the vein in SB-AVF decreases the need for extensive dissection and transposition, which likely decreases the risk of surgical trauma that can lead to JAS. The risk of twisting the vein is lower, and the angle between the artery and the vein remains sharp. As computational fluid dynamic simulations show, a preferable angle of the anastomosis of $<46.5°$ creates less turbulences and hence lower risk of neointimal hyperplasia, and the ES supports an angle of 40° to 50°, whereas the SB-AVF angle is sharper at 30° to 40°. Theoretically, SB-AVFs may have a lower risk of JAS than RCAVFs that were matched using ES. This finding would explain the lower rates of JAS reported here than it has been observed in several studies, including the large, multicenter, prospective HFM study.[37,38] The disconnect between similar JAS rates, yet still improved maturation and cannulation rates for ES-RCAVF, suggest ES might also be working on a different aspect of failure such as changes in configuration, optimized hemodynamics from a tapered outflow and protection from external compression in early and also long-term stages after the AVF creation.

Limitations of this study include its retrospective and nonrandomized design, which could bias the results. Including AVFs mainly performed by a single surgeon prevents interoperator bias, yet may make the technique surgeon specific, lacking the component of reproducibility in the general population of surgeons. The selection bias, however, is minimized by including all RCAVFs, and the possible high competence of dedicated VA center might support reporting good outcomes of both types of RCAVFs, which still demonstrated several significant advantages of the ES-RCAVFs.

CONCLUSIONS

This study demonstrated that ES-RCAVFs achieve the highest probability for short-term maturation and cannulation and sustained long-term patency. However, SB-AVFs remain a valuable option for selected patients—particularly younger and nondiabetic individuals—to preserve distal access sites for future use.

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Writing the article: RS, MH
Critical revision of the article: RS, MH
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