



Transit Time Flowmetry and Vein Size Are Predictive of Arteriovenous Fistula Maturation

Yelee Kwon, M.D.^{1,*}, Young Jong Cho, M.D.^{2,*}, Pil Je Kang, M.D.¹, Won Chul Cho, M.D., Ph.D.³

¹Department of Thoracic and Cardiovascular Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul; Departments of ²Radiology and ³Thoracic and Cardiovascular Surgery, Gangneung Asan Hospital, University of Ulsan College of Medicine, Gangneung, Korea

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Corresponding author

Won Chul Cho
Tel 82-33-610-3267
Fax 82-33-640-8070
E-mail chomedy172@naver.com
ORCID
<https://orcid.org/0000-0002-3858-6516>

*These authors contributed equally to this work.

Background: This study aimed to assess the effect of vessel size and flow characteristics on the maturation of autogenous radiocephalic arteriovenous fistulae (RCAVFs).

Methods: We retrospectively reviewed records of patients undergoing RCAVF creation at a single medical center from January 2013 to December 2019. Operative variables were compared between patients whose fistulae matured and those whose fistulae failed to mature.

Results: Overall, 152 patients (33 of whom were women) with a mean age of 62.6±13.6 years underwent RCAVF creation; functional maturation was achieved in 123. No statistically significant differences were observed between patients in whom maturation was or was not achieved in terms of the following variables: female sex (20.3% vs. 25.0%), radial artery size (2.5 vs. 2.4 mm), and pulsatility index (0.69 vs. 0.62). Low intraoperative transit time flowmetry (TTF; 150.4 vs. 98.1 mL/min) and small vein size (2.4 vs. 2.0 mm) were associated with failure of maturation. The best cutoff diameter for RCAVF TTF and cephalic vein size were 105 mL/min and 2.45 mm, respectively.

Conclusion: In patients who undergo RCAVF creation, vein diameter on preoperative ultrasonography and intraoperative TTF are predictors of functional maturation. We identified an intraoperative TTF cutoff value that can be used for intraoperative decision-making.

Keywords: Arteries, Veins, Fistula

Introduction

The optimal method of achieving vascular access for hemodialysis in patients with end-stage renal disease is an autogenous arteriovenous fistula (AVF) due to its higher patency rate and lower complication rate than prosthetic grafts [1,2]. Nonetheless, the high primary AVF maturation failure rate (20%–50%) remains a major obstacle to the use of AVFs [3,4]. Studies have recommended various optimal ranges of vessel size the maturation of radiocephalic AVFs (RCAVFs) [5,6]. However, no agreed-upon guideline regarding vessel size for RCAVFs has been established. Furthermore, the relationship between intraoperative blood flow measurements of AVFs and maturation has not been adequately characterized.

The objective of this study was to assess the effect of vessel size and flow characteristics on the maturation of au-

togenous RCAVFs. Therefore, we investigated the clinical effects of intraoperative transit time flow measurements and preoperative vessel diameter on AVF maturation outcomes.

Methods

Patients

We retrospectively reviewed charts from patients undergoing RCAVF creation at a single medical center (Gangneung Asan Hospital) from January 2013 to December 2019. Patients who underwent brachiocephalic AVF creation were excluded to ensure uniformity. The primary outcome measure was primary fistula maturation. Fistula maturation was defined as a minimum of 5 successful hemodialysis attempts using the RCAVF. Cases in which sur-



gical intervention (e.g., venous branch ligation) was required to assist maturation were considered successful.

Surgical technique

In most cases, AVF construction was performed under local anesthesia, and the non-dominant arm was preferentially selected for the access site. Vascular examination using duplex ultrasonography with a high-frequency (5–9 MHz) linear transducer was performed preoperatively in the operating room just before anesthesia by a cardiovascular surgeon in all cases. Vein mapping with venous tourniquet occlusion 5 cm below the antecubital fossa was conducted to evaluate vessel size at possible access sites. RCAVF was created with end-to-side arteriovenous anastomosis using a running suture with local heparin administration. Papaverine solution was also administered locally in the cephalic vein lumen during anastomosis for dilatation, whereas mechanical distention of the vein was not performed in any cases due to concerns that it would injure the endothelium of the vein.

The intraoperative flow characteristics of the RCAVF were assessed with transit time flowmetry (TTF) using a transonic perivascular flow probe (Transonic Systems Inc., Ithaca, NY, USA) This was performed within a few minutes of establishing RCAVF. An appropriate-sized probe (2, 3, 4, or 6 mm) was placed around the outflow vein of the RCAVF within 5 mm of the anastomosis site. The mean flow and pulsatility index (PI) were measured. All flow data were measured under stable conditions, with a systemic arterial pressure of >90 mm Hg and a pulse rate between 50 and 110 per minute. In cases with TTF <50 mL/min, prostaglandin E1 was administered intravenously for 24 hours for vasodilation to assist in the maturation of the RCAVF.

Statistical analysis

The statistical analysis was performed using R ver. 3.6.1 (The R Foundation for Statistical Computing, Vienna, Austria). Operative variables were compared between patients whose RCAVFs matured and those whose RCAVFs did not mature using the independent t-test. Results were expressed as mean±standard deviation. A receiver operating characteristic (ROC) curve was used to calculate the optimal cutoff value of statistically significant variables.

The study was approved by the Institutional Review Board of Gangneung Asan Hospital (IRB approval no., 2020-08-009). Informed consent was not obtained because

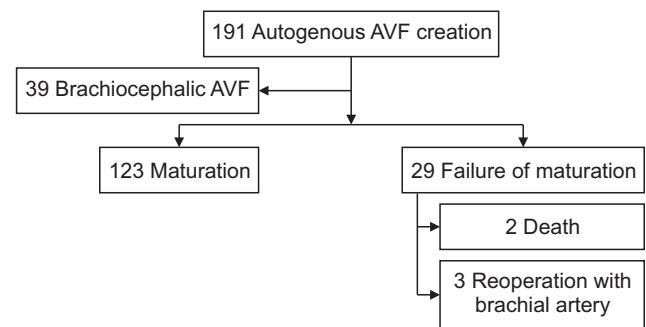


Fig. 1. Flowchart of the patient cohort. AVF, arteriovenous fistula.

this was a retrospective study using clinical practice data.

Results

During the study period, 191 autogenous AVFs were created at our institution. Thirty-nine patients who underwent brachiocephalic AVF were excluded. In total, 152 patients (33 of whom were women, 21.7%) with a mean age of 62.6 ± 13.6 years underwent primary RCAVF creation. The mean diameter of the radial artery and cephalic vein was 2.3 ± 0.5 mm (range, 1.0–3.5 mm) and 2.4 ± 0.5 mm (range, 1.0–4.0 mm), respectively.

Overall, 123 patients (80.9%) achieved functional maturation of the RCAVF. Two patients died before maturation and 3 underwent re-operation with a brachiocephalic or brachioaxillary fistula (Fig. 1). Venous branch ligation was performed in 17 patients, of whom 13 subsequently achieved maturation. The other 4 patients underwent reoperation for AVF, using either an arteriovenous graft or brachioaxillary AVF.

No statistically significant differences were observed between patients in whom maturation was or was not achieved in terms of the following variables: age (62.1 ± 13.6 years versus 64.8 ± 13.4 years, $p=0.349$), female sex (20.3% versus 25.0%, $p=0.400$), radial artery size (2.5 versus 2.4 mm, $p=0.482$), and PI (0.69 versus 0.62, $p=0.207$). However, low intraoperative TTF (150.4 versus 98.1 mL/min, $p<0.001$) and small vein size (2.4 versus 2.0 mm, $p<0.001$) were associated with failure of maturation (Table 1). Female sex was associated with a smaller radial artery size ($p=0.01$), but no statistically significant difference in cephalic vein size ($p=0.597$) or TTF was noted ($p=0.936$) (Table 2).

Subsequently, an ROC curve was used to identify the optimal predictive value for RCAVF maturation in our cohort. The ROC curves based on RCAVF TTF and cephalic vein diameter are shown in Figs. 2 and 3. The best cutoff

Table 1. Comparison of variables among patients according to functional maturation of the fistula

Variable	Maturation (n=123)	Failure of maturation (n=29)	p-value
Age (yr)	62.1±13.6	64.8±13.4	0.349
Female sex	25 (20.3)	9 (25.0)	0.397
Radial artery size (mm)	2.5	2.4	0.482
Cephalic vein size (mm)	2.4	2.0	<0.001
Transit time flowmetry (mL/min)	150.4	98.1	<0.001
Pulsatility index	0.69	0.62	0.207

Values are presented as mean±standard deviation, number (%), or number.

Table 2. Comparison of variables by sex among patients with functional maturation of the fistula

Variable	Male (n=98)	Female (n=25)	p-value
Radial artery size (mm)	2.5	2.2	0.010
Cephalic vein size (mm)	2.4	2.5	0.597
Transit time flowmetry (mL/min)	150.6	149.3	0.936
Pulsatility index	0.69	0.66	0.539
Duration of maturation (day)	63.9±25.3	68.4±25.7	0.627

Values are presented as number or mean±standard deviation.

values for RCAVF TTF and cephalic vein diameter were 105 mL/min (area under the curve [AUC], 0.71) and 2.45 mm (AUC, 0.70), respectively.

Discussion

In this study cohort, functional maturation was achieved in 80.9% of patients, and low intraoperative TTF and small vein size were associated with maturation failure (p<0.001 for both).

Most previous reports assessing the association between failure of maturation and the size of the vein used showed findings consistent with our results [6,7]. Our study results lead us to recommend a cephalic vein of ≥2.45 mm (AUC, 0.70) in order to optimize the functional maturation outcomes.

TTF is a simple measure of the exact flow rate of the targeted vessel in the operative field. Therefore, if the TTF is too low, revision of the anastomosis site can be performed immediately. Intraoperative TTF is commonly used in coronary artery bypass surgery to assess graft flow and has been found to show significant correlations with graft patency in both short-term and mid-term evaluations [8]. However, few studies have applied intraoperative TTF to analyze AVF creation [9]. Our study found that TTF was a

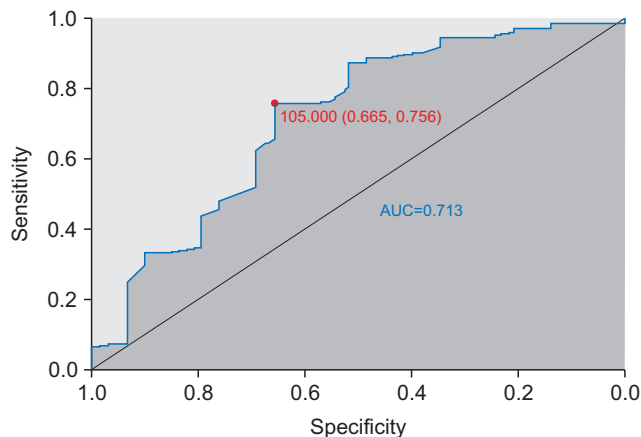


Fig. 2. Receiver operating characteristic curve of RCAVF intraoperative transit time flowmetry, indicating that values <105 mL/min predicted maturation failure. RCAVF, radiocephalic arteriovenous fistula; AUC, area under the curve.

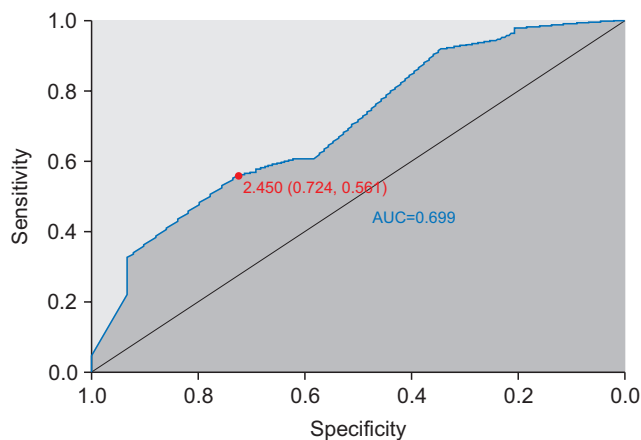


Fig. 3. Receiver operating characteristic curve of cephalic vein diameter, indicating that values <2.45 mm predicted maturation failure. AUC, area under the curve.

predictor of RCAVF maturation (p<0.001) and identified a TTF of ≥105 mL/min as the most suitable cutoff value (AUC, 0.71). Doppler ultrasonography can also be used to measure the flow rate. However, ultrasound measurements may have inter-observer differences due to compression on the vessels, whereas TTF does not have this source of possible error. Additionally, Doppler ultrasonography can only be checked after surgical wound closure, meaning that cases requiring revision of the AVF necessitate re-opening of the surgical site.

Although previous studies have reported that female sex was associated with an increased risk of failure of maturation [6], our study showed no significant differences according to sex in maturation (p=0.400) or in cephalic vein size (p=0.597) and TTF (p=0.936), both of which were in-

dependently associated with maturation failure.

Our study has several limitations. The sample size was relatively small; however, our number is comparable to that of most previous reports. This was a retrospective study, with inherent shortcomings. Although our study identified a cephalic vein size of ≥ 2.45 mm and TTF of ≥ 105 mL/min as risk factors for maturation failure, there were some patients with a cephalic vein size < 2.0 mm and TTF < 100 mL/min who nonetheless achieved maturation ($n=21$). Non-operative factors such as patient compliance with postoperative hand exercises may have influenced the maturation rate. Because we did not check the vein size before using a tourniquet for mapping in this study, cephalic vein distensibility might not be reflected. Further research would be necessary to clarify the potential relationship between vein distensibility and maturation of the AVF.

In conclusion, in this study cohort of patients who underwent RCAVF creation, vein diameter on preoperative ultrasonography and intraoperative TTF were identified as predictors of functional maturation. Intraoperative TTF is an easy method to predict successful fistula maturation and can be used for intraoperative decision-making.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

ORCID

Yelee Kwon: <https://orcid.org/0000-0003-4386-7520>

Young Jong Cho: <https://orcid.org/0000-0003-2881-9221>

Pil Je Kang: <https://orcid.org/0000-0002-7587-0911>

Won Chul Cho: <https://orcid.org/0000-0002-3858-6516>

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