Original Article

Correlation between preoperative Doppler ultrasonography-assessed specific accessory cephalic vein diameter-cephalic vein diameter ratio (r) and early dysfunction of Radial artery-Cephalic vein arteriovenous fistula: a single-center cross-sectional study

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Background: Accessory cephalic vein (ACV) ligation can circumvent immature arteriovenous fistula (AVF). However, no consensus has been reached on the definite timing of ACV ligation. This study aimed to retrospectively analyze the correlation between preoperative Doppler ultrasonography (DUS)-assessed specific ACV diameter-cephalic vein diameter ratio (r) and early dysfunction of Radial artery-Cephalic vein (RC)-AVF in order to improve the early maturity rate of RC-AVF.

Methods: A total of 258 patients who underwent RC-AVF at The Third Affiliated Hospital, Sun Yat-sen University from 1 June 2018 to 31 March 2022 were included in this study. The inclusion criteria were as follows: (I) cephalic vein ≥2.0 mm and radial artery ≥1.5 mm, suitable for RC-AVF establishment; (II) presence of an ACV. As per the specific r determined using preoperative DUS assessment, all patients were classified into two groups: Group A (r<0.8) and Group B (r≥0.8). Furthermore, patients in each group were divided into intervention and non-intervention subgroups based on the presence or absence of intraoperative ACV ligation, respectively. Patient data including age, sex, underlying disease, AVF side, and radial diameter were compared. The difference of maturity rate between participants in the intervention group and non-intervention group with different r values was analyzed, so as to obtain the relationship between different r values and maturity rate.

Results: No statistical differences were observed between the intervention and non-intervention subgroups in the two groups in terms of sex, age, comorbidities, complications, AVF side, radial artery, cephalic vein, and ACV diameters (P>0.05). When r<0.8, the maturity rates of the intervention group and the non-intervention group were 80% and 92.98%, respectively, χ^2=4.561. The difference in maturation rate between the intervention and non-intervention subgroups was insignificant (P=0.075) when r<0.8. When r≥0.8, the maturity rates of the intervention group and the non-intervention group were 89.83% and 45.45%, respectively, χ^2=25.943. The difference in maturation rates between the intervention and non-intervention subgroups was significant when r≥0.8 (P<0.001).

Conclusions: Preoperative DUS suggested a correlation between r≥0.8 and early immaturity of RC-AVF. Therefore, concurrent intraoperative ACV ligation should be carried out when preoperative r is ≥0.8, as it may reduce the early power dysfunction of RC-AVF.

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Keywords: Radial artery-Cephalic vein arteriovenous fistula (RC-AVF); accessory cephalic vein diameter (ACV diameter); cephalic vein diameter; Doppler ultrasonography (DUS)

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Introduction

Acute renal failure or end-stage renal disease requires renal replacement therapy, such as peritoneal dialysis (PD), hemodialysis (HD), and renal transplantation. The establishment of HD access can involve a central venous catheter (CVC), but may also require arterialization of a vein or interposition of a graft between an artery and a vein for the insertion of HD needles. Radial artery-Cephalic vein arteriovenous fistula (RC-AVF; Brescia-Cimino AVF) is a recommended mode of HD access (1). However, RC-AVF is associated with a high incidence of short-term complications, including early AVF dysfunction (2,3).

Early AVF dysfunction is defined as the inability of the AVF to become suitable for HD therapy (maturation failure) or failure within 3 months of use (4,5). The criteria for postoperative Doppler ultrasonography (DUS)-assessed AVF maturation have been reported to include the following: at least 500 mL/min flow, ≥5 mm vein diameter, and ≥5 mm distance from the skin (6). Venous stenosis or the presence of an accessory cephalic vein (ACV) are the two primary causes of early AVF dysfunction in the wrist. A parameter analysis using a lumped parameter model showed that the presence of accessory veins at preferred puncture site (i.e., the forearm) reduces the volume flow through the vessel segment at the preferred puncture site (7-9). In the light of these findings, large caliber accessory veins at a preferred puncture site may contribute to RC-AVF non-maturation by reducing the volume flow in the venous segment to be punctured. ACV ligation and stenosis dilatation can save 92% of patients with immature AVF (4,10). However, a consensus has not been reached on the definite timing of ACV ligation. Planken *et al.* (11) prospectively performed a magnetic resonance angiography (MRA) examination and found a correlation between large-caliber ACV and immaturity of RC-AVF.

The present study retrospectively analyzed the correlation between preoperative DUS-assessed specific ACV diameter-cephalic vein diameter ratio (r) and early RC-AVF dysfunction. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-23-271/rc).

Methods

Data sources

In this retrospective cross-sectional study, 258 patients who underwent RC-AVF at the Vascular Surgery Center of The Third Affiliated Hospital, Sun Yat-sen University from 1 June 2018 to 31 March 2022 were analyzed retrospectively. Assuming bilateral α=0.05 and that 20% of the cases would be lost to follow-up and rejection, a total of at least 176 patients were included in the final calculation. The inclusion criteria were as follows: (I) cephalic vein ≥2.0 mm and radial artery ≥1.5 mm, suitable for RC-AVF establishment; (II) presence of an ACV (*Figure 1*). The exclusion criteria were as follows: (I) DUS-confirmed vascular variation; (II) absence of an ACV. All cases were followed up successfully for 1, 3, 6, and 12 months. The study was approved by the Medical Ethics Committee of The Third Affiliated Hospital, Sun Yat-sen University (No. II2023-014-01) and informed consent was provided by all participants. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

Patient characteristics

All patients were divided into Group A and Group B based on their r values measured by DUS. We determined the cut-off score of r according to Planken *et al.*'s (11) finding that accessory vein caliber was the only parameter with significant predictive value for RC-AVF non-maturation as determined by the stepwise forward logistic regression analysis (66.6%±10.5% *vs.* 88.9%±8.9%, P=0.01). Subsequently, patients in each group were further classified into intervention and non-intervention subgroups based on the presence or absence of intraoperative ACV ligation, respectively (in the intervention group, 4-0 nylon thread was used to ligate the ACV under direct vision, and the ligature

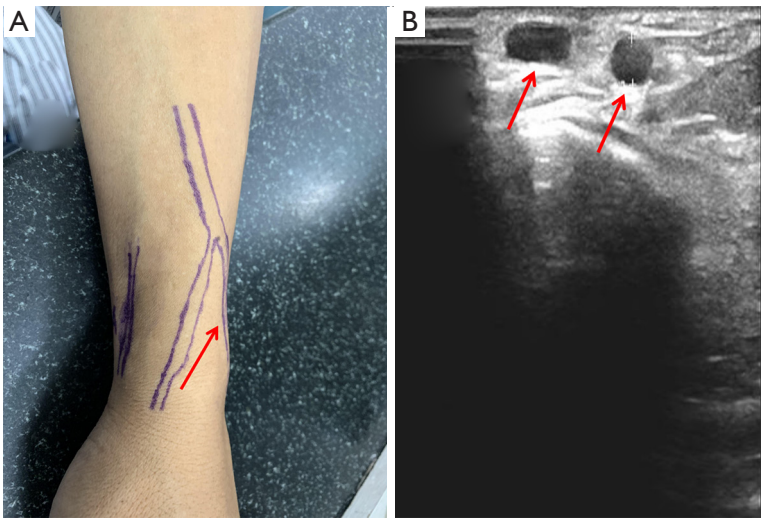

Figure 1 The relative position of the ACV and the cephalic vein on the body surface and Doppler ultrasonography. (A) The red arrow indicates the body surface where the ACV drains into the cephalic vein; (B) the red arrows indicate the position of the cephalic vein (left) and the ACV (right) on the Doppler ultrasonography. ACV, accessory cephalic vein.

Table 1 The r≥0.08 and r<0.8 group characteristics of the patients with and without intervention

Characteristics	r<0.8			r≥0.8		
	Intervention group (n=114)	No-intervention group (n=30)	P value	Intervention group (n=55)	No-intervention group (n=59)	P value
Age (years)	51±15.1	51±14.2	>0.05	55±13.2	53±14.6	>0.05
Sex (male)	85 (74.6)	24 (80.0)	>0.05	34 (61.8)	41 (69.5)	>0.05
Hypertension	98 (86.0)	27 (90.0)	>0.05	52 (94.5)	52 (88.1)	>0.05
Diabetes	39 (34.2)	12 (40.0)	>0.05	25 (45.5)	24 (40.7)	>0.05
Peripheral vascular diseases	13 (11.4)	2 (40.7)	>0.05	11 (20.0)	6 (10.2)	>0.05
Peritoneal dialysis	5 (4.4)	1 (3.3)	>0.05	5 (9.1)	5 (8.5)	>0.05
Hemodialysis	76 (66.7)	21 (70.0)	>0.05	42 (76.4)	47 (79.7)	>0.05
Location of AVFs (left)	103 (90.4)	27 (90.0)	>0.05	50 (90.9)	52 (94.5)	>0.05
Radial artery diameter (mm)	2.2±0.4	2.3±0.3	>0.05	2.2±0.3	2.1±0.4	>0.05

Data are shown as mean ± standard deviation or n (%). AVF, arteriovenous fistula.

was performed by the same surgeon). Data on patients' age, sex, underlying disease, AVF side, and radial artery diameter were collected (*Table 1*). During the preoperative evaluation at our center, the surgeon and the color Doppler ultrasonographer simultaneously measured the cephalic vein, ACV, and radial artery and record the data in the color DUS report. Further, we retrospectively collected data on the preoperative cephalic and ACV diameters and related maturation status were recorded (*Table 2*). The termination criteria for the follow-up included the following: (I) death of the patient; (II) termination of AVF due to ligation and occlusion of RC-AVF for various reasons or another limb or location having been re-established, resulting in unnecessary AVF HD. The criteria for postoperative DUS-assessed AVF maturation included the following: (I) at least 500 mL/min of blood flow with a vein diameter ≥5 mm and ≥5 mm distance from the skin within 3 months; (II) 2 or more successful HD sessions through a puncture within 3 months.

Table 2 Preoperative measurement of Doppler ultrasound

Preoperative	r<0.8				r≥0.8			
	Intervention group	No-intervention group	χ^2	P value	Intervention group	No-intervention group	χ^2	P value
Accessory veins diameter (mm)	1.4±0.4	1.4±0.4	–	>0.05	2.0±0.4	2.0±0.3	–	>0.05
Cephalic vein diameter (mm)	2.6±0.6	2.7±0.7	–	>0.05	2.4±0.3	2.3±0.4	–	>0.05
Maturation rate	80% (24/30)	92.98% (106/114)	4.561	0.075	89.83% (53/59)	45.45% (25/55)	25.943	<0.001

Data are shown as mean ± standard deviation or percentage.

Statistical analysis

Data analysis was performed using the software SPSS 25.0 (IBM Corp., Armonk, NY, USA). A descriptive analysis was conducted for all the participants. The categorical variables were expressed as numbers and percentages. Measurement data were expressed as mean ± standard deviation ($\bar{x}$±s) if they had normal distributions, whereas enumeration data were expressed as (%) and examined using the χ^2 test. A statistically significant difference was indicated when P<0.05.

Results

Patients in Group A were further classified into intervention (Group Aa, the ACV was ligated intraoperatively) and non-intervention subgroups (Group Ab, the ACV was not ligated intraoperatively) based on a threshold of r<0.8. Group Aa included 85 males and 29 females with a mean age of 51±15.1 years, whereas Group Ab included 24 males and 6 females with a mean age of 51±14.2 years. Similarly, patients in Group B were further divided into intervention (Group Ba, the ACV was ligated intraoperatively) and non-intervention subgroups (Group Bb, the ACV was not ligated intraoperatively) based on a threshold of r≥0.8. Group Ba included 34 males and 21 females with a mean age of 55±13.2 years, whereas Group Bb included 41 males and 18 females with a mean age of 53±14.6 years. No statistical differences were observed between the intervention and non-intervention subgroups in the two groups in terms of sex, age, comorbidities, complications, and AVF side (P>0.05).

Patients in both groups were divided into intervention and non-intervention subgroups according to the criteria of r<0.8 and r≥0.8, respectively, to observe the differences in ACV diameter and cephalic vein diameter between the two subgroups. The difference in ACV diameter and cephalic vein diameter was insignificant between subgroups regardless of r values. When r<0.8, the maturity rates of the intervention group and the non-intervention group were 80% and 92.98%, respectively, χ^2=4.561. The difference in maturation rate between the intervention and non-intervention subgroups was insignificant (P=0.075) when r<0.8. When r≥0.8, the maturity rates of the intervention group and the non-intervention group were 89.83% and 45.45%, respectively, χ^2=25.943. The difference in maturation rates between the intervention and non-intervention subgroups was significant when r≥0.8 (P<0.001). Thus, ACV diameter and cephalic vein diameter were not indicators of AVF maturation, whereas r was an indicator of VF maturation rate. Moreover, ACV ligation improved early AVF maturation when r≥0.8 (*Table 2*).

Discussion

ACV ligation could improve AVF maturation rates (4). However, a scientific approach is required to evaluate the timing of such ligation, thus avoiding unnecessary and detrimental surgical procedures. Additionally, second-stage ACV ligation requires waiting for AVF maturation. Consequently, patients may become psychologically burdened and nervous, thus delaying AVF maturation.

This study retrospectively analyzed the correlation between preoperative DUS-assessed r value and early RC-AVF dysfunction. The immaturity rate was significantly higher in patients who did not undergo concurrent ACV ligation than in those who underwent concurrent ACV ligation when r≥0.8.

The AVF maturation rate was 45.45% when r≥0.8 if concurrent intraoperative ACV ligation was not performed. This low value is unacceptable despite the already expected lower RC-AVF maturation rate compared to the cubital AVF maturation rate.

Preoperative arterial and venous diameters are valuable parameters for predicting the maturity of RC-AVF (12,13). However, radial artery and cephalic vein diameter

Figure 2 Before and after treatment of early AVF dysfunction. (A) The red arrows indicate the area for when r≥0.8, venous hypertension resulted in the destruction of the accessory cephalic vein valve, and the patient's fingers developed swelling, cyanosis, and AVF dysfunction; (B) after ligation of the accessory cephalic vein (the red arrow indicates puncture point), the patient's symptoms improved (red circle) and the AVF matured. AVF, arteriovenous fistula.

measurements cannot adequately assess maturation individually. Planken *et al.* (11) discovered a correlation between large-diameter ACV and immaturity of RC-AVF. Furthermore, their other studies (14,15) showed that venous flow in the punctured segment reduced when r was larger. The low inflow resistance of large-diameter ACVs resulted in reduced blood return and flow in the punctured vessel segment. Moreover, the reduced outflow resistance decreases intravascular pressure, resulting in a reduced diameter of the vessel being punctured. Some patients had venous hypertension resulting in disruption of the ACV valves when r values were large, resulting in swelling and cyanosis of the fingers and AVF dysfunction, which were relieved by ACV ligation, along with flow improvement (*Figure 2*). In this way, access-induced ischemia was excluded preoperatively. The improvement of cyanosis after postoperative ligation of the ACV also indicates that the ischemia was not caused by access.

Planken *et al.* (11) first suggested the significance of preoperative use of MRA to study the ACV and predict the clinical RC-AVF immaturity. However, the implementation of MRA is difficult in clinical practice. MRA is expensive and time-consuming. In contrast, using gadolinium-containing contrast agents in patients with end-stage renal disease may result in nephrogenic systemic fibrosis (NSF) (15,16). DUS, a non-invasive technique, can provide valuable information for predicting fistula maturation such as intravascular diameter and arteriovenous lesions before and after AVF construction (17,18). Preoperative DUS can improve the success rate of AVF establishment (19). According to the studies of Mihmanli *et al.* (12) and Georgiadis *et al.* (20), the failure rate without preoperative DUS reaches 25%, whereas this value could be reduced to 6% with preoperative DUS. DUS has been confirmed to be a cost-effective and efficient means of assessing AVF maturity and monitoring complications (21). DUS has become the first-line test for preoperative assessment of AVF establishment and AVF dysfunction (6). Therefore, in this study, DUS was used for preoperative evaluation.

In the study of Planken *et al.* (11), the statistical difference in the r value between Group A and Group B was presented, and the range of r for Group B was between 0.8 and 0.978. Therefore, we used 0.8 as the threshold for grouping in this study. In addition, Haq *et al.* (22) found that the flow in the ACV was 31% of the flow in the cephalic vein when r>0.66 in their calculation of the AVF hydrodynamic model.

The present study has some limitations. This study was conducted retrospectively, not as a prospective randomized controlled trial. As surgeons judge whether to perform ligation according to their experience, this study is bound to be biased. This is also the purpose of this study, so as to provide certain evidence to improve the assessment of whether it is reasonable to perform ACV ligation. The grouping technique was not sufficiently reasonable due to the small sample size, referring to Planken *et al.* (11) only.

Conclusions

Preoperative DUS suggested that r≥0.8 is associated with early RC-AVF immaturity. Therefore, intraoperative ACV ligation should be performed when preoperative r≥0.8 and doing so may reduce early RC-AVF dysfunction.

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Footnote

Reporting Checklist: The authors have completed the

STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-23-271/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-23-271/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All patients who participated in this study signed an informed consent form, and this study was approved by The Third Affiliated Hospital, Sun Yat-sen University (No. II2023-014-01). The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

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