

# Evaluation of percutaneous transluminal angioplasty screening using color Doppler ultrasonography

Keiji Tabuchi<sup>1,2</sup>, Toshio Kobayashi<sup>2</sup>, Junko Kumagai<sup>3</sup>, Naoko Takahashi<sup>3</sup>

1) Departments of Nursing, Omachi Tsuchiya Clinic, Hiroshima - Japan

2) Graduate School of Biomedical and Health Sciences, Hiroshima University, Hiroshima - Japan

3) Departments of Internal Medicine, Omachi Tsuchiya Clinic, Hiroshima – Japan

## Abstract

**Purpose:** Well-functioning vascular access is important in hemodialysis patients. The aim of this study was to assess stenosis using color Doppler ultrasonography as well as to investigate a possible association between the need for percutaneous transluminal angioplasty and hemodynamic parameters. **Methods:** A prospective study of the medical records of color Doppler ultrasonography routine examinations of 372 patients was conducted at a dialysis satellite clinic in Japan. Data were analyzed using logistic regression analysis and the receiver operating characteristic curve. The cutoff point for hemodynamic parameters was determined to explore the predictors of percutaneous transluminal angioplasty. **Results:** Logistic regression analysis showed that brachial artery flow volume, brachial artery resistance index and puncture point flow volume divided by the quantity of dialysis blood flow rate were independently associated with percutaneous transluminal angioplasty. Brachial artery resistance index over 0.61, brachial artery blood flow volume under 665 mL/min and puncture point flow volume divided by dialysis blood flow rates under 1.25 were predictive values of the need for percutaneous transluminal angioplasty. **Conclusions:** These parameters could be used as markers for assessing percutaneous transluminal angioplasty risk in hemodialysis patients. **Keywords:** Color Doppler ultrasonography, Percutaneous transluminal angioplasty, Vascular access

## Introduction

Arteriovenous fistula (AVF) has been demonstrated to be the most effective vascular access (VA) for increasing the long-term survival rate of hemodialysis (HD) patients (1). Well-functioning VA is important in HD patients. The most common cause of VA dysfunction is venous stenosis due to venous neointimal hyperplasia within the anastomosis (2-5). Percutaneous transluminal angioplasty (PTA) is considered the first-line treatment for venous stenosis (6-10).

Blood flow in VA can be assessed using color Doppler ultrasonography (CDUS). CDUS is a readily available, inexpensive and noninvasive method that has improved the longevity of VA by early detection of complications (11-13). CDUS can clearly demonstrate the position of AVF, which is used for HD access. It can also accurately measure the vascular diameter, blood flow volume (FV) and other hemodynamic parameters. Screening methods for stenosis include measurement of blood FV, vascular diameter, mean velocity (MnV), peak systolic velocity (PSV) and resistance index (RI) using CDUS (14-21).

In previous studies, the risk of PTA correlated with brachial artery FV lower 350-500 mL/min and / or brachial artery RI upper 0.6-0.7 (22-27).

Here, we present parameters measured using CDUS for the follow-up of VA, with particular reference to diagnosis of stenosis. The aim of this study was to assess stenosis with CDUS as well as to investigate a possible association between PTA and hemodynamic parameters.

## Patients and methods

### Patients

A total of 396 patients with renal failure treated with dialysis via radial artery VA were included in this study. A prospective study of the medical records of these patients from Sept 2013, including CDUS routine examinations for

every patient, was conducted at one dialysis satellite clinic in Japan. The non PTA group included patients who did not need PTA following CDUS routine examination for more than 1 year. The PTA group included patients who needed PTA after CDUS examination within 3 months. PTA of the patients was treated at the general hospital. Induction of the PTA was judged by PTA doctors. Patients were excluded from the study if they had an arteriovenous graft, an AVF that occluded suddenly and an ulnar AVF.

Ultrasonographic scanning of VA was performed with a 10-MHz linear probe (SSD-3500; Aloka, Tokyo, Japan). CDUS routine examinations were conducted before the HD session. To evaluate failure of blood removal, the following measurements were obtained using CDUS: the puncture point FV divided by the quantity of dialysis blood flow rate (FV/QB). QB was determined considering Kt/V, gender, age, height and weight. Kt/V is a parameter used to quantify hemodialysis treatment adequacy, it is dependent on the pre- and post-dialyzer clearance (K), dialysis time (t), and volume (V) of distribution. Kt/V was usually set at  $\geq 1.2$  in this study. QB was decided by a doctor who specializes in dialysis. QB was adopted as a part of the important parameter in dialysis conditions. The decision of QB may individually vary according to the doctor. However, the setting range of QB is limited, and the error was determined to be less.

Data were collected on measured hemodynamic parameters, including brachial artery FV (mL/min), vascular diameter (mm), MnV (cm/s), brachial artery RI, PSV (cm/s), radial artery and puncture point FV (mL/min), vascular diameter (mm), MnV (cm/s), and the parameters of puncture point FV/QB were calculated.

Measurement of the puncture point is performed using CDUS near the skin; therefore, it is necessary to ensure that there are no errors in measurements when compared with CDUS deep in vessels. CDUS was performed by an operator who had received guidance from experts. Furthermore, we used large amount of jelly, and the procedure was carefully performed to avoid pressing the blood vessel and to prevent errors in measurement while adjusting the angle.

### Statistical analysis

For continuous variables, the means and standard deviations were reported. For categorical variables, percentages were reported. Baseline characteristics were compared between the PTA and non-PTA groups using t-test and  $\chi^2$  test as appropriate. Binomial logistic regression analysis was performed to explore the predictors of PTA. Then, logistic regression was performed to explore the relationships between the need for PTA and the remaining CDUS measures. If significant predictors were identified, an area under the receiver operating characteristic (ROC) curve was calculated to assess the cutoff point for the risk of PTA. If the area under the ROC curve (AUC) was significant, the value, which yielded the combination of the highest true positive fraction (TPF: sensitivity) and the lowest false positive fraction (FPF: specificity), was used as the cutoff point for the measure. All analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 22.0) for Windows, and the significance level was set at  $p < 0.05$  (two-tailed).

### Ethics

The purpose and details of this study were fully explained to patients, and the study was initiated after obtaining their consent. The study protocol was approved by the ethics committee of the hospital.

## Results

### Patient background

After excluding patients with missing data of analytic variables, 372 patients were found to be eligible for inclusion in the study. Table 1 shows the baseline characteristics of 372 patients enrolled in the present study. The average age of patients was 69.09 years (range from 37 to 97 years), and there were 232 males (62.3%) and 140 (37.7%) females. Average dialysis duration was 6.06 years, and the underlying diseases were diabetic nephropathy in 44.4% and chronic glomerulonephritis in 35.2%.

Table 1. Patients' backgrounds

<b>Study subjects</b>	
Number of patients	372
Sex (male / female)	232 / 140
Average age (range)	69.87(37–97) years old
Average dialysis duration (range)	6.06(0.1–25.8) years
Cause of ESRD	Diabetic nephropathy: 165 patients (44.4%) Chronic glomerulonephritis: 131 patients (35.2%) Nephrosclerosis: 33 patients (8.8%) Polycystic kidney disease: 9 patients (2.4%) Other diseases: 34 patients (9.1%)

ESRD = end-stage renal disease.

The PTA group included 108 patients, and the non-PTA group included 264 patients. The PTA group to become PTA 3 months is required, and the cases with stenosis less than 50% were studied. The characteristics of both the control subjects and HD patients are summarized in Table 2. The t-test showed a significant difference in the duration on HD (years) and all hemodynamic parameters. With respect to QB, no statistically significant difference was observed between the two groups.

Table2 . Clinical characteristics of the patients in PTA groups and non-PTA groups

	Total	Group PTA	Group non-PTA	Pvalue
Age (years old)	69.09 ± 11.26	70.79 ± 10.63	68.39 ± 11.43	0.06
Number of patients (male / female)	372(232 / 140)	108 (60 / 48)	264(172 / 92)	0.09 <sup>†</sup>
Duration on hemodialysis (years)	6.06 ± 5.2	5.20 ± 5.50	6.70 ± 4.30	0.02
Cause of ESRD (DM / non-DM)	372(165 / 207)	108(59 / 49)	264(106 / 158)	0.004 <sup>†</sup>
QB(ml / min)	247.65 ± 35.03	241.75 ± 35.03	249.58 ± 35.66	0.06
Brachial artery FV (ml / min)	1069.18 ± 505.31	634.07 ± 304.74	1229.03 ± 469.62	<0.001
Brachial artery Vascular diameter (mm)	5.29 ± 0.90	4.88 ± 0.84	5.44 ± 0.88	<0.001
Brachial artery MnV (cm / s)	78.85 ± 30.64	55.72 ± 23.39	87.41 ± 28.27	<0.001
Brachial artery PSV (cm / s)	128.57 ± 39.57	107.21 ± 34.19	136.52 ± 38.47	<0.001
Brachial artery RI	0.57 ± 0.10	0.67 ± 0.09	0.55 ± 0.08	<0.001
Radial artery FV (ml / min)	698.21 ± 366.69	419.51 ± 229.3	807.27 ± 352.02	<0.001
Radial artery Vascular diameter (mm)	3.96 ± 0.89	3.58 ± 0.77	4.11 ± 0.88	<0.001

Radial artery MnV (cm / s)	94.31 ± 44.15	68.94 ± 32.03	103.74 ± 43.94	<0.001
Puncture point FV (ml / min)	556.74 ± 333.61	345.54 ± 319.87	651.75 ± 323.41	<0.001
Puncture point Vascular diameter (mm)	5.72 ± 1.68	5.06 ± 1.79	6.01 ± 1.54	<0.001
Puncture point MnV (cm / s)	38.45 ± 24.72	30.50 ± 26.52	41.61 ± 24.56	<0.001
Puncture point FV / QB	2.27 ± 1.39	1.45 ± 1.32	2.67 ± 1.41	<0.001

\* $\chi^2$  test; Data are expressed as mean ± standard deviation.

DM = diabetes mellitus; ESRD = end-stage renal disease; FV = flow volume; MnV = mean velocity; PSV = peak systolic velocity; PTA = percutaneous transluminal angioplasty; QB = quantity of dialysis blood flow rate; RI = resistance index.

The  $\chi^2$  test showed a significant difference in the underlying disease (diabetes mellitus, DM/non-DM). Table 3 shows the results of logistic regression analysis of odds ratio correlated with PTA. Logistic regression analysis showed that brachial artery FV ( $p < 0.001$ ), brachial artery RI ( $p < 0.001$ ) and puncture point FV/QB ( $p < 0.001$ ) were independently associated with PTA, and showed multiple adjusted  $R^2$  of 0.56 ( $p < 0.001$ ). In addition, brachial artery RI showed the highest odds ratio (1.09, 95% confidence interval [CI] 1.046-1.136,  $p < 0.001$ ).

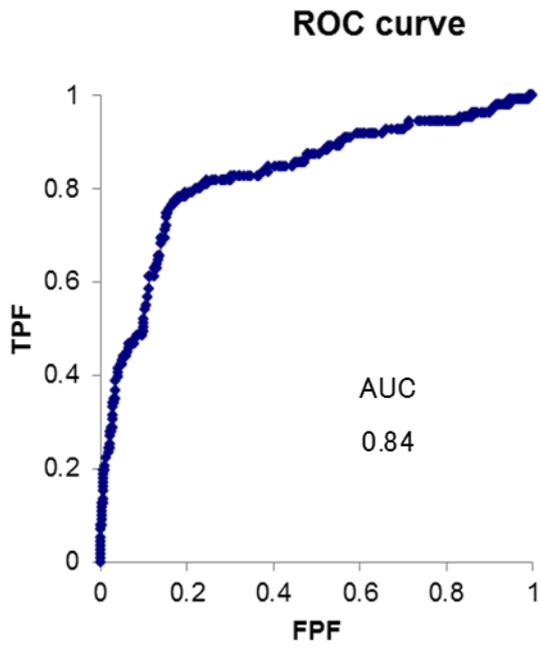
**Table 3 logistic regression analysis of risk factors correlated with PTA**

	P value	Odds ratio	95%CI	
			Lower	Upper
Brachial artery FV	0.000	0.995	0.992	0.997
RI	0.000	1.090	1.046	1.136
Puncture point FV / QB	0.000	0.985	0.985	0.995

Multiple adjusted  $R^2 = 0.56$ ,  $p < 0.001$ .

CI = confidence interval; FV = flow volume; QB = quantity of dialysis blood flow rate; RI = resistance index.

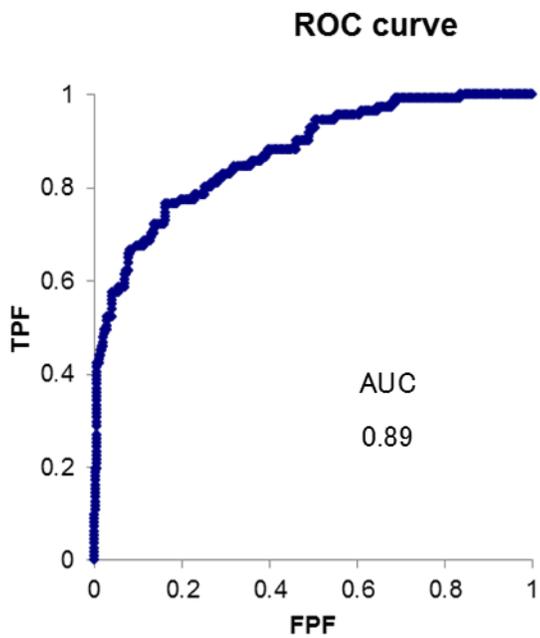
Figure 1 shows the ROC curve for brachial artery RI to predict PTA, and the AUC was observed to be 0.84 (95% CI 0.79-0.89). The optimal cutoff point for brachial artery RI was determined to be 0.61 (FPF: 0.18, TPF: 0.78 and likelihood ratio: 16.56). Figure 2 shows the ROC curve for brachial artery FV to predict PTA, the AUC was observed to be 0.89 (95% CI 0.84-0.93). The optimal cutoff point for brachial artery FV was determined to be 665 (FPF: 0.08, TPF: 0.658 and likelihood ratio: 22.87). Furthermore, Fig. 3 shows the ROC curve for puncture point FV/QB to predict PTA, and the AUC was observed to be 0.82 (95% CI 0.76-0.87). The optimal cutoff point for puncture point FV/QB was determined to be 1.25 (FPF: 0.09, TPF: 0.62 and likelihood ratio: 17.69).



Cutoff point	FPF	TPF	Likelihood ratio
0.61	0.18	0.78	16.56

	Non-PTA	PTA
n	264	108
mean $\pm$ SD	0.54 $\pm$ 0.08	66 $\pm$ 0.09
min	0.31	0.38
max	0.79	0.86

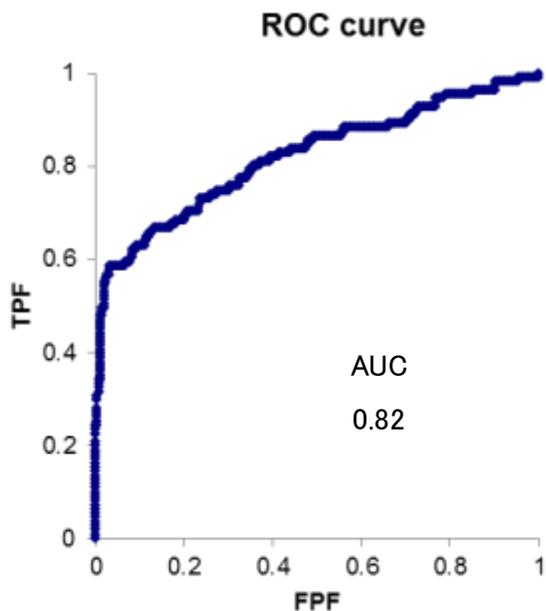
Figure 1. ROC for Brachial artery RI to discriminate PTA.



Cutoff point	FPF	TPF	Likelihood ratio
665	0.08	0.65	22.87

	Non-PTA	PTA
n	264	108
mean $\pm$ SD	1229 $\pm$ 469	634 $\pm$ 304
min	307	122
max	2902	1714

Figure 2. ROC for Brachial artery FV to discriminate PTA.



Cutoff point	FPF	TPF	Likelihood ratio
1.25	0.09	0.62	17.69

	Non-PTA	PTA
n	264	108
mean $\pm$ SD	2.67 $\pm$ 1.4	45 $\pm$ 1.32
min	0.71	0.26
max	8.09	4.14

Figure 3. ROC for Puncture point FV / QB to discriminate PTA.

## Discussion

Maintenance of well-functioning VA is essential for the smooth continuation of HD treatment in HD patients. In the present study, we investigated the correlations between the VA screening method using CDUS and the presence or absence of PTA.

Previous studies have reported that the risk of PTA was significantly correlated with insufficient blood flow during dialysis which involved brachial artery FV of 350-500 mL/min or lower and a brachial artery RI of 0.6-0.7 or higher (22-27). The present study supported that the brachial artery RI cutoff associated with PTA was 0.61, which is similar to previous reports indicating brachial artery RI of 0.6-0.7. The result of brachial artery RI shown in the present PTA-based study supports the findings of these previous studies.

However, the present study indicated that the brachial artery cutoff FV associated with PTA was 665 mL/min, which was greater than that in the previous reports (350-500 mL/min). It was considered because of the early follow-up necessary in satellite clinics. Our clinic is dependent on PTA treatment at a general hospital to avoid the risk of shunt occlusion of the patient. This requires an early follow-up.

In addition, puncture point FV/QB (cutoff level puncture point FV/QB = 1.25) was found to be a new indicator for the failure of blood removal. Puncture point FV showed a margin 1.25 times that of the blood pump flow rate. CDUS was performed before HD. Circulating blood volume was gradually reduced by water removal from blood because blood removal failure may affect dialysis.

If there is branching of blood vessels, brachial artery FV and brachial artery RI did not predict blood flow decreases within the main line VA. In this case, FV/QB is considered to be an effective indicator.

The present study revealed that brachial artery FV, brachial artery RI and puncture point FV/QB were significant predictors for the risk of PTA induction. We propose that brachial artery FV is 665 mL/min or more, brachial artery RI is 0.61 or less and puncture point FV/QB is 1.25 or more, which would also be effective indicators of well-functioning VA in HD patients (in the case of satellite clinics without PTA equipment). In this PTA group, retrospective confirmation of

the PTA predictive value was performed using the three parameters: brachial artery RI of  $\geq 0.61$  was observed in 86 patients in the PTA group (79.6%), brachial artery FV of  $\leq 665$  mL/min was observed in 71 patients in the PTA group (65.7%) and puncture point FV/QB of  $\leq 1.25$  was observed in 67 patients in the PTA group (62.0%). Brachial artery RI and brachial artery FV greater than the cutoff was observed in 90 patients in the PTA group (83.3%). This was considered by including the puncture point FV/QB. Ninety-seven patients (89.8%) were above the cutoff in one of three parameters. Puncture point FV/QB improved the PTA hitting ratio of 6.5%.

There are some limitations in the present study. The sample size of the study was small. However, it would be meaningful to develop an appropriate guideline for the risk of PTA in HD patients. Therefore, further study is needed to investigate the changes of VA in HD patients using a longitudinal study design.

## Conclusion

In conclusion, there were significant correlations among the markers of brachial artery FV, brachial artery RI and puncture point FV/QB assessing the risk of PTA. These parameters could be used as markers for assessing PTA risk in HD patients.

## Disclosures

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