Original Article

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Clinical experience with ultrasound guided angioplasty for vascular access

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Background: The use of ultrasound guided percutaneous transluminal angioplasty (UG-PTA), which use ultrasound as an imaging modality, is an evolving strategy. But, in Korea, this method is rarely used. We report our experiences with UG-PTA with respect to technical success rates and complication rates compared to conventional PTA (C-PTA), performed between 2010 and 2015 at Samsung Changwon Hospital, Korea.

Methods: In our series, 53 cases of UG-PTA and 90 cases of C-PTA were reviewed, respectively. Cases of central vein stenosis, cephalic arch stenosis, arterial stenosis and thrombosis were excluded. However, cases of juxta-anastomotic stenosis and outflow vein stenosis were included.

Results: Technical success was achieved in 96.2% (51 of 53) of cases in the UG-PTA group and in 93.3% (84 of 90) of cases in the C-PTA group, respectively (P = 0.710). Technical failure was experienced in a total 8 cases (UG-PTA group: 2/53, 3.8%; C-PTA group: 6/90, 6.7%). No differences were observed in complications.

Conclusion: Duplex ultrasound-guided angioplasty for dialysis access in the outpatient setting is feasible, safe, and effective for peripheral venous stenotic lesions. It offers many advantages over conventional angiographic procedures, and, in the future, it has great potential to play a significant role in the management of these challenging patients.

Keywords: Angioplasty, Endovascular treatments, Percutaneous, Ultrasound

Introduction

Ultrasound-guided intervention eliminates the need for iodinated contrast agents [1–9]. This is especially important for patients with renal insufficiency not yet on dialysis in whom iodinated contrast or gadolinium-based magnetic resonance imaging contrast exposure could be detrimental, or those with severe allergy to iodinated contrast medium [1–9]. It also avoids the problems associated with radiation exposure for both patients and treating clinicians and uses equipment that is relatively inexpensive and readily available [1–9]. Since arteriovenous fistulas (AVFs) are constructed to be superficial so that they are easily accessible, the fistula can be quite simple to insonate. The extension of use of ultrasound imaging from diagnosing problems in AVFs to actually guiding the intervention represents a natural step forward. The visualization of the balloons, guide wires, and catheters is the simplest in AVF angioplasty as compared to other sites [1–9]. In recent reports [1–4], ultrasound guided percutaneous transluminal angioplasty (UG-PTA) that was performed under only sonographic guidance without using a fluoroscopic machine was as effective as conventional percutaneous transluminal angioplasty (C-

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PTA) for peripheral lesions. We evaluated the feasibility of UG-PTA for peripheral lesions in terms of technical success rates and complication rates compared to C-PTA, performed between 2010 and 2015 in the outpatient setting of Samsung Changwon Hospital (Changwon, Korea).

Methods

Materials

Patients underwent angioplasty between 2010 and 2015 in the outpatient setting of Samsung Changwon Hospital. Total 232 cases were analyzed. Seventeen cases of central lesion (7.3%), 7 cephalic arch stenosis (3.0%), 2 arterial stenosis (0.9%), and 21 thrombosis (9.1%) were excluded. Remaining 121 (52.2%) and 64 cases (27.5%) were inflow or outflow stenosis, respectively. Among them, 2 cases with an aneurysm (0.9%) and 3 cases with perforating vein stenosis (1.3%) were combined and excluded. Also we excluded 37 cases in which both ultrasound and fluoroscopic machine were used concurrently. Therefore, 143 cases of simple juxta-anastomotic stenosis (JAS) or outflow vein stenosis (OS) were included. All procedures were performed by an experienced nephrologist.

Ultrasound guided angioplasty (UG-PTA)

After the patient was comfortably positioned on the operating table, the ipsilateral upper extremity was prepped and draped in the usual sterile manner (Fig. 1). A Z-one scanner (ZONARE Medical Systems, San Francisco, CA, USA) was used in all cases and it was placed on the side of intervention providing good monitor visibility for the operator. The keyboard was covered with a sterile plastic cover (Fig. 1). A variety of scan heads inserted into a sterile plastic sleeve with coupling gel were used to

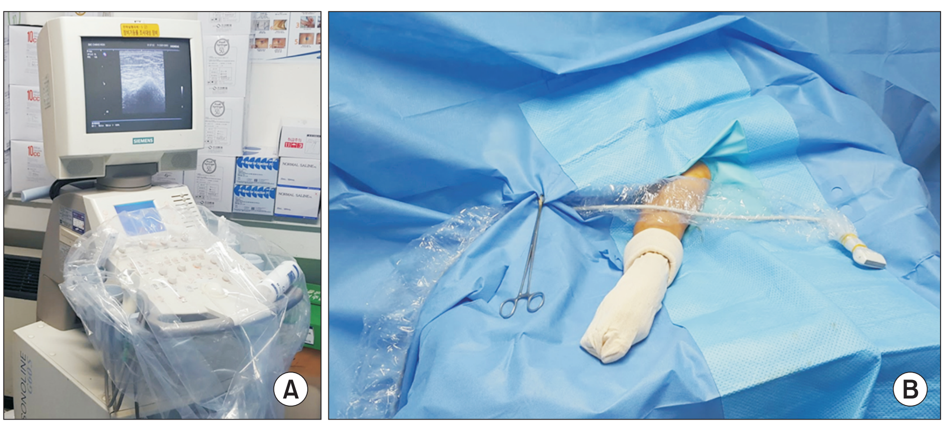

Figure 1. Room set up for ultrasound guided angioplasty. (A) Ultrasound machine, the keyboard was covered with a sterile plastic cover. (B) Patients arm was drapped with usual aseptic methods and linear probes was covered with a sterile cover.

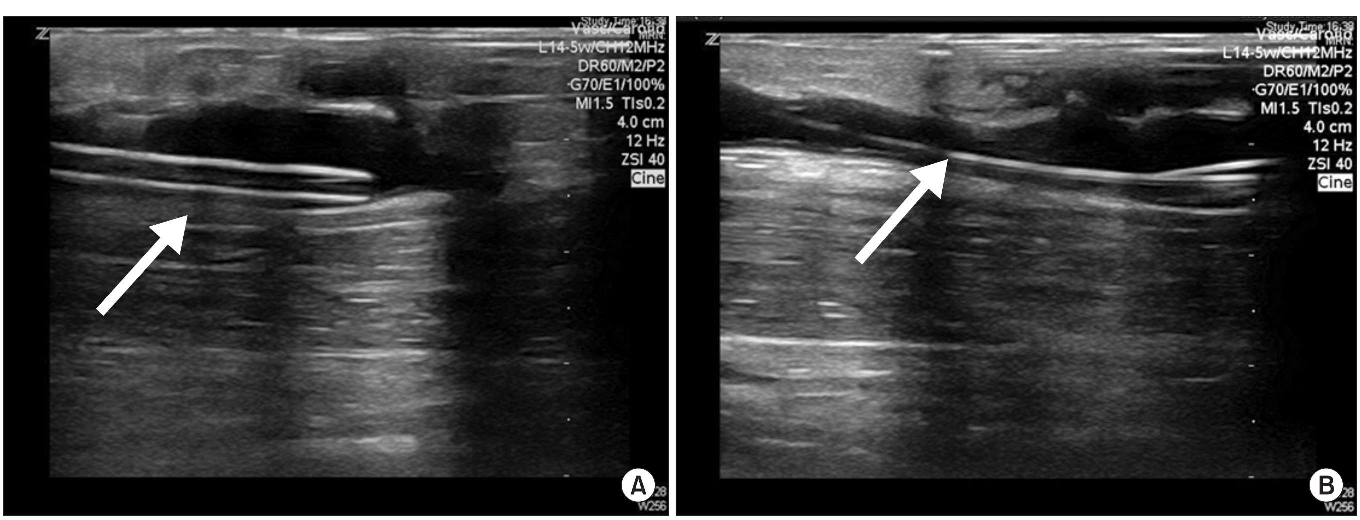

Figure 2. The sheath (A) and guidewire (B) (arrows) can be clearly visualized under ultrasound.

insonate the fistulas according to the anatomic location and depth. Generally, more superficial (< 1 cm deep) fistula structures in the upper arm can be insonated by a 12 MHz compact linear probe. All arteriovenous (AV) fistulas were accessed with a single entry needle under duplex guidance. All procedures were completed via a 6 to 8 French (Fr) sheath (Fig. 2). In addition, a 0.035-inch curved tip or straight tip guidewire (Glide wire®; Terumo Medical Corporation, Somerset, NJ, USA) was inserted and carefully negotiated through the stenosis and parked in the proximal artery (during retrograde cannulation) or the distal vein (during antegrade cannulation, Fig. 2). These maneuvers were safely performed owing to real-time visualization of the wire tip in the lumen under duplex guidance. In cases of tight stenosis, a straight tip guidewire with or without 5 F Glidecath® (Terumo Medical Corporation, Somerset, NJ, USA) support was used, and in cases of difficult passage at the anastomotic area, a curved tip catheter with or without a hockey stick catheter (4 F internal mammary catheter) was used. We chose the balloons based on precise duplex measurements of the venous diameter. Balloon introduction and alignment across the stenosis and inflation were performed under ultrasound B-mode control (Fig. 3, 4).

Data collection and statistical analysis

The following data were assessed: patient's age, sex, underlying disease, causes of intervention (low access flow such as blood flow less than 200 mL/min, cannulation difficulty, fistula pulsation, pain during dialysis, fistula thrombosis), underlying pathologic findings detected by ultrasonography and physical examination (inflow stenosis, OS), success rates, and complication rates. Juxta-anastomotic stenosis was defined by stenosis affecting the anastomosis, or the radial artery and cephalic vein in the region of the anastomosis, and/or a combination of them, not affecting the puncture areas. Outflow vein stenosis was defined by stenosis affecting outflow vein including the puncture area and excluding juxta-anastomotic area. Technical success was defined as achievement of a residual stenosis less than 30%, disappearance of abnormal findings of physical examination and achievement of significant hemodynamic improvement. All the computer-based files were analyzed using the appropriate statistical tests according to the type of vari-

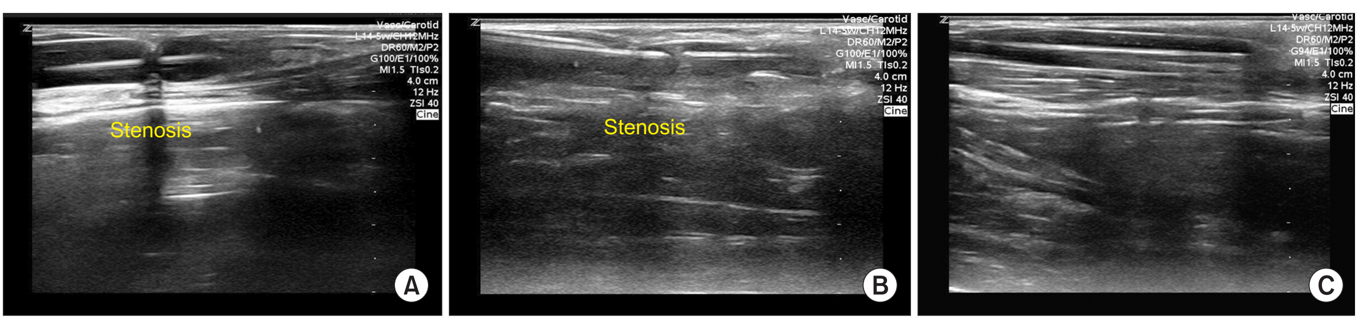

Figure 3. The waist can be clearly visualized (A, B) as the balloon is inflated and stenosis is treated (C).

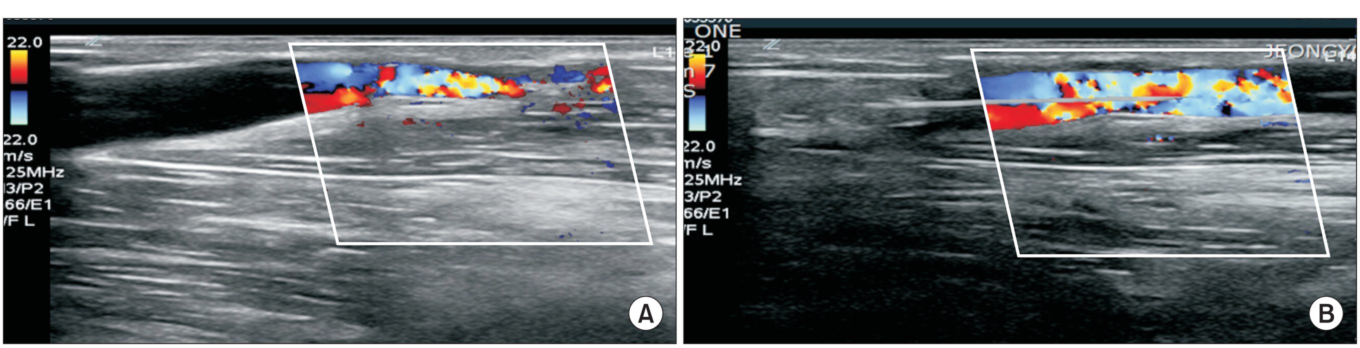

Figure 4. Color Doppler images of stenosis lesion before and after ultrasound guided percutaneous transluminal angioplasty.

ables. The quantitative variables (age, weight, height, etc.) were reported in terms of mean and standard deviation, whereas the qualitative variables were reported in terms of percentage. For continuous variables, the means and standard deviations were reported. Baseline characteristics were compared between two groups using *t*-test and chi-square test as appropriate. Primary patency between two groups was compared by Kaplan-Meier analysis. All analyses were performed using the IBM SPSS Statistics ver 20.0 for Windows (IBM Co., Armonk, NY, USA).

Results

In our series, 53 cases of UG-PTA and 90 cases of C-PTA were reviewed. The age and sex ratio of patients were not different between the two groups (64.0 ± 11.0 years vs. 66.6 ± 10.9 years, $P = 0.163$; number of females, 23 [43.4%] vs. 44 [48.9%], $P = 0.604$). The most common types of fistula were radio-cephalic fistula (RCF) and brachio-cephalic fistula (BCF) (Table 1). The proportion of cases of maturation failure was not different between the two groups (18.9% [10 of 53], vs. 32.2% [29 of 90], $P > 0.05$). In the UG-PTA group, low access flow ($n = 40$) and pulsating fistula ($n = 13$) were the most common causes; and in the C-PTA group, low access flow ($n = 57$) and pulsating fistula ($n = 33$) were the most common causes of intervention. Anatomic causes of access dysfunction detected by preoperative duplex ultrasound and physical examination were as follows: JAS 40 vs. 57 (UG-PTA vs. C-PTA) and OS 13 vs. 33. Technical success was achieved in 96.2% (51 of 53) of cases in the UG-PTA group and in 93.3% (84 of 90) of cases in the C-PTA group, respectively ($P = 0.710$, Table 2). Technical failure was experienced in total 8 cases (UG-PTA group: 2/53, 3.8%; C-PTA group: 6/90, 6.7%, respectively). Causes of technical failure were an inability to cross an occluded stenosis ($n = 1$) and thrombosis ($n = 1$) in the UG-PTA group, and an inability to pass the catheter ($n = 1$), resistant stenosis ($n = 1$), elastic recoil ($n = 2$), thrombosis ($n = 1$), and sheath hematoma ($n = 1$) in the C-PTA group. Vessel rupture as a major complication occurred in 2 cases of the UG-PTA group and in 1 case of the C-PTA group. All these cases were rescued by balloon tamponade technique and the access function was successfully restored. Other complications included access thrombosis in 1 case each of the UG-PTA group and the C-PTA group, aneurysm development in 1 case of the C-PTA group and sheath hematoma in 1 case of the C-PTA group. All complications were Grade B as Society of Interventional Radiology (SIR) Classification System

Table 1. Baseline characteristics

	UG-PTA (n = 53)	C-PTA (n = 90)	P
Age (yr)	64.0 ± 11.0	66.6 ± 10.9	0.163
Female	23 (43.4)	44 (48.9)	0.604
Types of access			0.681
Radiocephalic	31 (58.5)	46 (51.1)	
Brachiocephalic	17 (32.1)	31 (34.4)	
Basilic vein transposition	1 (1.9)	3 (3.3)	
PTFE graft	1 (1.9)	6 (6.7)	
Radiobasilic transposition	3 (5.7)	4 (4.4)	
Maturation failure	10 (18.9)	29 (32.2)	0.119
Clinical Problem			0.143
Low access flow*	40 (75.5)	57 (63.3)	
Pulsatility	13 (24.5)	33 (36.7)	
Ultrasonography findings			0.143
Juxta-anastomotic stenosis	40 (75.5)	57 (63.3)	
Outflow vein stenosis	13 (24.5)	33 (36.7)	

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

C-PTA, conventional percutaneous transluminal angioplasty; PTFE, polytetrafluoroethylene; UG-PTA, ultrasound guided percutaneous transluminal angioplasty.

*Blood flow less than 200 mL/min.

Table 2. Success and complication rates of UG-PTA and C-PTA

	UG-PTA (n = 53)	C-PTA (n = 90)	P
Success rate	51 (96.2)	84 (93.3)	0.710
Causes of failure			
Impossible guidewire passage	1	0	
Impossible catheter passage	0	1	
Resistant stenosis	0	1	
Sheath hematoma	0	1	
Elastic recoil	0	2	
Thrombosis	1	1	
Complication			0.710
No	50 (94.3)	86 (95.6)	
Yes	3 (5.7)	4 (4.4)	
Vein rupture	2	1	
Thrombosis	1	1	
Aneurysm		1	
Sheath hematoma		1	
Procedure time (min)	72 ± 43	75 ± 35	0.68
One year primary patency (%)	47.7	57.7	0.15

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

C-PTA, conventional percutaneous transluminal angioplasty; UG-PTA, ultrasound guided percutaneous transluminal angioplasty.

for Complications. No one case for transition to fluoroscopic guidance was made. Procedure times between two groups were not different (72 ± 43 minutes vs. 75 ± 35 minutes, $P > 0.05$). By Kaplan-Meier analysis, the 1-year primary patency was similar in the U-PTA compared C-PTA: 47.7% vs. 57.7%, $P = 0.15$ (Fig. 5). In, UG-PTA group, Doppler scan showed brachial artery flow volume increased from 400.4 ± 149.1 mL/min to 796.7 ± 561.1 mL/min ($P = 0.001$, Fig. 6) and showed brachial artery resistive index decreased from 0.68 ± 0.12 to 0.57 ± 0.13 ($P = 0.001$; Fig. 5).

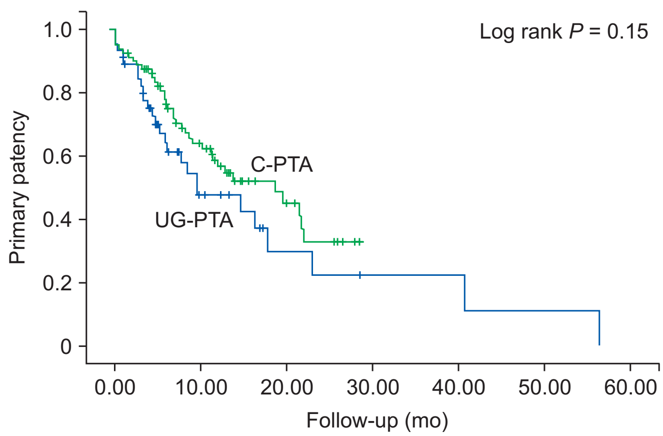

Figure 5. By Kaplan-Meier analysis. The 1-year primary patency was similar in the UG-PTA compared C-PTA (47.7% vs. 57.7%, $P = 0.15$). C-PTA, conventional percutaneous transluminal angioplasty; UG-PTA, ultrasound guided percutaneous transluminal angioplasty.

Discussion

For evaluating dysfunctional access, the first and most cost-effective method is physical examination [10–13]. Ultrasonography confirms the physical examination results such as inflow stenosis, outflow stenosis, or simply deep-seated vein and provides important information about the functional severity such as brachial artery flow rates [14–17]. The ultrasound findings with physical examination determine the treatment methods, such as angioplasty, revision surgery or conservative management. Direct fistulography without ultrasound examination may lead to many unnecessary interventions and anatomic knowledge before the intervention is essential. The highlight of ultrasound guided intervention is exact diagnosis of stenosis and functional severity by ultrasound [18]. If hemodynamically significant stenotic area can be visualized by ultrasonography, you can treat the problem of vascular access. Complete occlusion of the stenotic lumen elevates the risk of failure of angioplasty. Early detection of complete occlusion by ultrasound lead to surgical consultation. If the other underlying lesions are missed on ultrasound such as combined inflow and outflow lesion, missed treatment of the undetected lesion leads to failure of the endovascular procedure and also to persistence or new development of vascular access malfunction. In our 1 case of BCF, PE and ultrasound made the diagnosis of a JAS. We decided to do UG-PTA. After UG-PTA, a weak fistula thrill changed to a strong pulsa-

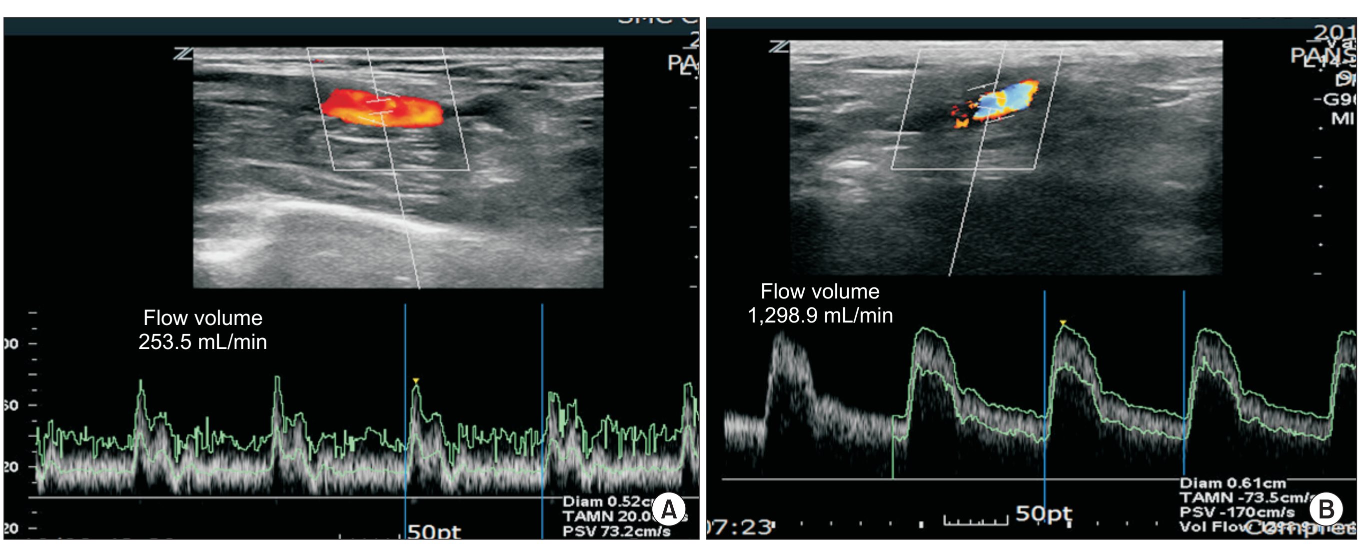

Figure 6. Brachial artery flow volume change before and after of ultrasound guided percutaneous transluminal angioplasty.

tion. The underlying cephalic arch stenosis problem appeared after improvement of inflow stenosis. This is the weakness of ultrasound intervention. But, cases of multiple lesions were only 1 case in this case series. The other weakness of ultrasound guided intervention is complex anatomical problems such as aneurysm and perforating vein pathology. These lesions require multiple views for guidewire passage and dye infusion for complex anatomy. In other peripheral simple lesions such as outflow and juxta-anastomotic area stenosis, guidewire tracing and passage require lesser effort. Except for complete occlusion and complex anatomy, in cases of simple stenotic area, an overall evaluation of the inflow artery to the superior vena cava on angiography may not be necessary if a preoperative exact diagnosis is made by ultrasound.

UG-PTA for vascular access malfunction was found to be comparable to C-PTA under fluoroscopy with regard to the incidence of complications and early results, including the duration of the technical procedure [1–9]. This study differs from the previous study as only peripheral lesion and cases of simple stenosis were included, but it confirms the previous successful results. Because the treatment targets of ultrasound-guided PTA for vascular access are superficial vessels, fluoroscopy assistance is frequently not required. For this reason, the patient can be treated in the examination room or on the dialysis bed, which is suited for a vascular access intervention that requires rapid handling [1–9]. In a simple lesion such as puncture point stenosis, UG-PTA is very effective because it can be performed in the procedure room near the hemodialysis room after hemodialysis without any delay. But in central vein lesions, imaging is difficult by using ultrasound; therefore C-PTA was performed in our hospital. But, in well-experienced centers, UG-PTA can be performed for central venous and cephalic arch lesions with specialized ultrasonography probes [1]. In cases of arterial stenosis, focal stenosis occurring near the anastomosis could be treated via retrograde approach during UG-PTA, but diffuse occlusive lesions were difficult to treat by UG-PTA. In our center, UG-PTA was performed in cases of peripheral venous stenosis such as JAS and cases of OS. Cases of cephalic arch stenosis, central vein stenosis and arterial proper stenosis were treated by C-PTA. In our center, the central and arterial lesions accounted for 20.3% of all intervention cases (47/232). They needed C-PTA procedure. Remaining 121 and 64 cases were inflow and outflow stenosis and evaluated by ultrasound. Complex 37 cases were used both methods. Sixty-one percent of all angioplasties were simple peripheral lesion. Although only 22.8% of angioplasties were performed by US-PTA alone in this report, author suggest two third of all PTA can be performed by US-PTA alone. Although access thrombosis can also be treated by UG-PTA [1], but the number of such cases was small (UG-PTA, 5 cases; C-PTA, 16 cases), and therefore they were excluded. Because we adopt a fistula-first policy for access creation, there were very little AV graft cases as compared with AVF.

Using ultrasound guidance for intervention of AVFs offers many advantages. It uses equipment that is relatively inexpensive and readily available [1–9]. It avoids the problems associated with radiation exposure for both patients and treating clinicians [1–9]. It also eliminates the need for contrast agents, which is particularly helpful as many of these patients have severe impairment of renal function, but are not yet on dialysis [1–9]. The use of ultrasound as the imaging modality also removes a major barrier to performing these procedures in the office setting. Fluoroscopic imaging equipment is expensive, and occupies a great deal of space. Radiation safety and local and regional regulatory issues add even more complexity. Ultrasound equipment is readily available in most dialysis centers. It is relatively inexpensive, and is used in a variety of other related applications, such as diagnostic vascular imaging and venous intervention [1–9]. In our clinic, for peripheral stenotic lesions such as JAS or OS, the choice of treatment modality such as UG-PTA or C-PTA depends on the availability of machine. In comparison to C-PTA, some technical points were considered [5]. While advancing the guide wire, the guide wire tip was closely monitored. The main problem associated with performing UG-PTA is the risk of introducing the guide wire too deep or too shallow, which may result in vein damage or prevent completion of the procedure [5]. As a branching point, a steerable guide wire and/or a directional angiocatheter were used. In a very tight stenosis area or in an acute angle anastomotic area, guide wire passage may be difficult and guidewire stuffing using an angiocatheter is required to place the guidewire at the appropriate site [5]. On balloon expansion, the area was easily marked by the balloon. Use of ultrasonography for visualization of stenosis also allows for precise fitting of balloon diameter to the diameter of the fistula [5]. A serious complication of endovascular treatment is vessel rupture following dilatation and extravascular blood leakage [2–6]. During ultrasound-guided treatment, extravascular transudation of blood can be captured in real time, and the rupture can be addressed quickly. Furthermore, the balloon can be filled with distilled water, which makes it possible to inflate the balloon rapidly and thus easily stop bleeding by compression from within the vessel.

In conclusion, this study demonstrated that UG-PTA showed comparable to C-PTA in selective patients. And because UG-PTA minimize radiation exposure to patients and medical attendees, it can be considered as the alternative option in selective patients.

Conflicts of interest

All authors have no conflicts of interest to declare.

References

[1] Wakabayashi M, Hanada S, Nakano H, Wakabayashi T: Ultrasound-guided endovascular treatment for vascular access malfunction: results in 4896 cases. *J Vasc Access* 14:225-230, 2013

[2] Gorin DR, Perrino L, Potter DM, Ali TZ: Ultrasound-guided angioplasty of autogenous arteriovenous fistulas in the office setting. *J Vasc Surg* 55:1701-1705, 2012

[3] Wang J, Blebea J, Kennedy T, Salvatore M, Kelly P: Technical aspects of duplex ultrasound-guided angioplasty of arteriovenous fistulae. *J Vasc Ultrasound* 33:150-154, 2009

[4] Gallagher JJ, Boniscavage P, Ascher E, Hingorani A, Marks N, Shiferson A, Jung D, Jimenez R, Novak D, Jacob T: Clinical experience with office-based duplex-guided balloon-assisted maturation of arteriovenous fistulas for hemodialysis. *Ann Vasc Surg* 26:982-984, 2012

[5] Bojakowski K, Góra R, Szewczyk D, Andziak P: Ultrasound-guided angioplasty of dialysis fistula - technique description. *Pol J Radiol* 78:56-61, 2013

[6] Marcello N: Color doppler & vascular accesses for hemodialysis. Milano: *Witchtig Editor*, 110-123, 2011

[7] Marks N, Hingorani A, Ascher E: New office-based vascular interventions. *Perspect Vasc Surg Endovasc Ther* 20:340-345, 2008

[8] Ascher E, Hingorani A, Marks N: Duplex-guided balloon angioplasty of failing or nonmaturing arterio-venous fistulae for hemodialysis: a new office-based procedure. *J Vasc Surg* 50:594-599, 2009

[9] Huang HL, Chen CC, Chang SH, Hung KC, Hsieh IC, Chang HJ, Wen MS, Fang JT: Combination of duplex ultrasound-guided manual declotting and percutaneous transluminal angioplasty in thrombosed native dialysis fistulas. *Ren Fail* 27:713-719, 2005

[10] Trerotola SO, Ponce P, Stavropoulos SW, Clark TW, Tuite CM, Mondschein JI, Shlansky-Goldberg R, Freiman DB, Patel AA, Soulen MC, Cohen R, Wasserstein A, Chittams JL: Physical examination versus normalized pressure ratio for predicting outcomes of hemodialysis access interventions. *J Vasc Interv Radiol* 14:1387-1394, 2003

[11] Salman L, Beathard G: Interventional nephrology: Physical examination as a tool for surveillance for the hemodialysis arteriovenous access. *Clin J Am Soc Nephrol* 8:1220-1227, 2013

[12] Asif A, Leon C, Orozco-Vargas LC, Krishnamurthy G, Choi KL, Mercado C, Merrill D, Thomas I, Salman L, Artikov S, Bourgoignie JJ: Accuracy of physical examination in the detection of arteriovenous fistula stenosis. *Clin J Am Soc Nephrol* 2:1191-1194, 2007

[13] Gallego Beuter JJ, Hernández Lezana A, Herrero Calvo J, Moreno Carriles R: Early detection and treatment of hemodialysis access dysfunction. *Cardiovasc Intervent Radiol* 23:40-46, 2000

[14] Pietura R, Janczarek M, Zaluska W, Szymanska A, Janicka L, Skublewska-Bednarek A, Szczerbo-Trojanowska M: Colour Doppler ultrasound assessment of well-functioning mature arteriovenous fistulas for haemodialysis access. *Eur J Radiol* 55:113-119, 2005

[15] Lomonte C, Meola M, Petrucci I, Casucci F, Basile C: The key role of color Doppler ultrasound in the work-up of hemodialysis vascular access. *Semin Dial* 28:211-215, 2015

[16] Zamboli P, Fiorini F, D'Amelio A, Fatuzzo P, Granata A: Color Doppler ultrasound and arteriovenous fistulas for hemodialysis. *J Ultrasound* 17:253-263, 2014

[17] Guedes Marques M, Ibeas J, Botelho C, Maia P, Ponce P: Doppler ultrasound: a powerful tool for vascular access surveillance. *Semin Dial* 28:206-210, 2015

[18] Bacchini G, Cappello A, La Milia V, Andrulli S, Locatelli F: Color doppler ultrasonography imaging to guide transluminal angioplasty of venous stenosis. *Kidney Int* 58:1810-1813, 2000