Assessment of Blood Flow in Hemodialysis Patients using buttonhole technique for Arteriovenous fistula by ultrasound dilution

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Background: *The rope-ladder technique is the traditional AVF cannulation technique for HD. The buttonhole technique with repeated puncture with a blunt AV needle into a single selected site of AVF is a reliable alternative technique and has been used in Thailand for a few years. The ultrasound dilution technique is a noninvasive method to measure and monitor vascular access blood flow of patients receiving HD. There is no previous report about the evaluation of access blood flow in the buttonhole technique.*

Objective: *To measure vascular access blood flow by noninvasive ultrasound dilution in HD patients using the buttonhole technique for cannulation of AV needle to AVF and investigate the factors associated with impaired vascular access blood flow.*

Material and Method: *A cross-sectional study evaluating HD patients using the buttonhole technique at the outpatient HD center of Rajavithi Hospital and National Kidney Foundation at the Priest Hospital in Thailand was performed. The blood flow rate of AVF was measured by the ultrasound dilution technique. After starting HD with cannulated AV needle to AVF by the buttonhole technique and increasing dialyzer blood flow rate according to their HD prescription, measurements of blood flow of vascular access were evaluated within the first hour of the HD session by 2 consecutive measurements.*

Results: *A total of sixty eight HD patients were recruited. All patients had functioning AVF and received an adequate dialysis delivery dose, but 14.7% of them had impaired access blood flow. The average access flow rate was 1,326 $\pm$ 858.8 ml/min. The average access flow rate of patients with good and impaired access flow rates was 1,497.8 $\pm$ 812.4 and 330.0 $\pm$ 135.0 ml/min. The factors associated with impaired access blood flow were old age, diabetes mellitus and dyslipidemia.*

Conclusion: *This present study suggests that annual direct measurement of access blood flow as ultrasound dilution technique is an acceptable tool to screen AVF dysfunction, especially HD patients of old age, and/or with diabetes mellitus and dyslipidemia.*

Keywords: *Vascular access blood flow, Hemodialysis, Buttonhole cannulating technique*

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End-stage renal disease is a common disease in Thailand and other countries. Hemodialysis (HD) is the most common choice of renal replacement therapy for patients with end-stage renal disease. Blood flow rate of vascular access is a critical factor in the achievement of adequate HD. A native arteriovenous fistula (AVF) and polytetrafluoroethylene arteriovenous grafts are popular permanent vascular accesses for patients receiving chronic hemodialysis (HD). AVF is better than arteriovenous grafts because AVF has fewer complications especially access malfunction or infection[1-5]. Thrombosis of AVF is the most common cause of access dysfunction. Prophylactic repair of vascular accesses prior to significant thrombosis prolongs the life of an AVF more than the repair of vascular access after a thrombosis[6-8]. Vascular access blood flow can be evaluated by several techniques including indirect and direct measurements. Indirect measurements include increased venous pressure during dialysis, increased urea recirculation or decreased dose of dialysis, screening methods to detect AVF dysfunction. Regularly using a series of these measurements are recommended to monitor AVF function. Progressive decrease of these measurements can indicate vascular access dysfunction and calls for further direct measurement of vascular access blood

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flow. The direct measurement of vascular access blood flow using angiography, Doppler ultrasound[9-11], magnetic resonance[12], static measurements of intra-access venous pressure[6,13] and measurement access blood flow using the dilution technique (such as ultrasound dilution, saline dilution, hematocrit dilution, thermodilution or conductivity dilution)[12,14] are good methods to monitor AVF function. These investigations can detect vascular access thrombosis early and suggest intervention to prevent AVF dysfunction[15]. Although angiography of AVF is the gold standard to evaluate AVF function, it is an invasive and painful technique. Ultrasound dilution technique is a simple clinical practice and noninvasive method to measure vascular access blood flow of patients receiving HD[14,16]. Cannulation of arteriovenous (AV) needle to AVF in patients receiving HD is performed by several techniques: the area puncture, rope-ladder or buttonhole techniques. The rope-ladder puncture technique with cannulated sharp AV needle along the whole length of the blood vessel has been commonly used for Thai HD patients with AVF. The buttonhole technique using repeated punctures with a blunt AV needle into a single selected site of AVF is a reliable alternative technique and has been gaining popularity. Some reports show the buttonhole technique is technically easy, has few complications and reduces pain[17]. There is no previous report about the evaluation of access blood flow in the buttonhole technique. The aim of the present study was to measure vascular access blood flow by noninvasive ultrasound dilution in HD patients who used the buttonhole technique for cannulation of AV needle to AVF and to investigate factors associated with impaired vascular access blood flow.

Material and Method

This is a cross-sectional study in Thai HD patients who used the buttonhole technique. An institutional ethical committee approved the present study, and all patients gave written informed consent after reviewing a written summary of the study plan. Patients at the outpatient HD center of Rajavithi Hospital and National Kidney Foundation at the Priest Hospital from January 2010 to March 2010 were recruited.

Inclusion criteria were Thai HD patients with functioning AVF in upper extremity for at least 12 months, who had used the buttonhole technique for cannulation of AV needle to AVF for at least 6 months, had no history of this AVF intervention, were over 18 years of age with a normal clinical state for at least 3 months with unchanged blood flow rate and prescriptive HD for at least 3 months. Exclusion criteria included those who were pregnant, breast feeding or with acute systemic diseases. After enrollment, the patient's clinical status and laboratory results were assessed. They were dialyzed according to their regular HD prescriptions while their access blood flow was measured directly.

The blood flow rate of AVF was measured by ultrasound dilution technique with a Transonic HD 02 HD monitor (Transonic System, Inc., Ithaca, NY, USA) that has already been described and validated[14,16]. After starting HD with cannulated AV needle to AVF by the buttonhole technique and increasing dialyzer blood flow rate according to their HD prescription, measurements of blood flow of vascular access were evaluated within the first hour of HD session with two consecutive measurements to assure the results. The mean values of the two measurements were within 10% of each other. The National Kidney Foundation Dialysis Outcome Quality Initiative (DOQI) clinical practice guidelines for vascular access recommends that an access flow rate less than 600 mL/min in AV grafts and less than 400 to 500 ml/min in AVF should be further investigated through AVF angiography[18]. According to this guideline for AVF, patients with access blood flow above 500 ml/min were classified as having a good access flow rates and patients with access blood flow below 500 ml/min were considered to have impaired access flow rates.

All data were expressed as mean $\pm$ standard deviation. Univariate analysis of factors associated with impaired vascular access blood flow was determined by a two-tailed Student's t-test and Pearson's Chi-square. Analysis was made using the software program SPSS for Windows version 17.0 (SPSS Inc., Chicago, Illinois, USA). Data analysis was considered statistically significant when the p-value was < 0.05.

Results

A total of sixty eight HD patients at the outpatient HD center of Rajavithi Hospital and National Kidney Foundation at the Priest Hospital were recruited. Demographic characteristics of these HD patients are presented in Table 1. All patients (mean age, 44.8 ± 11.9 years; 51.5% male) had been dialyzed for 8.7 ± 4.2 months. They had been cannulated through AVF by use of the buttonhole technique for 1.2 ± 0.3 years. HD prescriptions of these patients are presented in Table 2. Most patients were dialyzed three times per week

(55.9%), using low flux dialyzer (66.2%) and AVF of the lower arm (87.9%). The minimum recommended dosage of adequate HD is weekly Kt/Vurea of 3.6[19], all patients received an adequate dialysis delivery dose.

When the blood flow rate of AVF was measured by ultrasound dilution technique, the average access flow rate was 1,326 ± 858.8 ml/min. Based on National Kidney Foundation DOQI guidelines for vascular access, the number of patients with good and impaired access flow rates were 58 (85.3%) and 10 (14.7%) respectively. The average access flow rate of patients with good and impaired access flow rates was 1,497.8 ± 812.4 and 330.0 ± 135.0 ml/min. Table 3 shows two groups of the HD patients depending on access blood flow. Univariate analysis showed that factors associated with impaired access blood flow were old age, diabetes mellitus and dyslipidemia. Duration of HD, duration of AVF, AVF at upper arm, smoking, body weight, body surface area, hemoglobin and serum albumin were not associated with impaired access blood flow.

Table 1. Demographic characteristics of all 68 patients in this study

Characteristics	n = 68
Male (n, %)	35 (51.5)
Age (year)	44.8 ± 11.9
Duration of HD (year)	8.7 ± 4.2
Duration of AVF (year)	7.9 ± 3.9
Duration of buttonhole technique (year)	1.2 ± 0.3
Smoking (n, %)	10 (14.7)
Hypertension (n, %)	63 (92.6)
Coronary artery disease (n, %)	3 (4.4)
Diabetes mellitus (n, %)	4 (5.9)
Dyslipidemia (n, %)	19 (27.9)
Body weight (kg)	55.2 ± 11.0
Body mass index (kg/m^2)	21.0 ± 3.6
Body surface area (m^2)	1.6 ± 0.2
Systolic BP (mmHg)	144.3 ± 16.7
Diastolic BP (mmHg)	82.1 ± 6.4
Hemoglobin (gm/dl)	10.2 ± 1.4
Serum creatinine (mg/dl)	11.1 ± 3.1
Serum albumin (gm/dl)	4.2 ± 0.4
Serum LDL (mg/dl)	114.2 ± 36.9

Table 2. HD prescription of all 68 patients in this study

Twice/three sessions per week (n,%)	30 (44.1)/38 (55.9)
Low/high flux dialyzer (n,%)	45 (66.2)/23 (33.8)
AVF at upper/lower arm (n,%)	15 (22.1)/53 (87.9)
Dialyzer blood flow rate (ml/min)	335.2 ± 35.8
Venous pressure (mmHg)	112.2 ± 31.4
Kt/V urea	2.1 ± 0.4
NPCR (gm/kg/day)	1.3 ± 0.4

Discussion

AVF is an optimal permanent vascular access for HD because AVF has the lowest rate of malfunction or infection. The most common technique of AVF cannulation for HD in Thailand is the rope-ladder technique with sharp AV needle. A sharp AV needle is inserted into alternating cannulation sites to decrease repetitive trauma of the vascular wall that may prevent the formation of aneurysms and stenosis of AVF[20,21]. AVF cannulation by buttonhole technique using dull AV needle has gained popularity over the last decade in several countries including the USA, Poland and Japan[22-24]. This technique is preferred for home HD patients[25,26]. The buttonhole technique has been performed in HD units in Thailand for a few years. In this technique punctures are repeated at the same site, initially with sharp needles to produce a puncture tract, and then with blunt needles for a permanent tract[22,23]. This technique is easy and decreases pain or hematoma formation[27,28]. There has been a debate about other complications in the buttonhole technique compared with the rope-ladder technique. Some reports showed this technique increased risk of infection and loss of vascular access[28-30], but other reports showed the technique was associated with lower aneurysm formation rates and vascular access stenosis[27,28,31,32].

AVF should be closely monitoring because malfunction of AVF remains a cause of costly complications in HD patients[33]. For example, 44% of HD patients in United Kingdom were admitted at hospital related to problems of vascular access[34]. Prospective screening of vascular access dysfunction with urgent therapeutic intervention may reduce the rate of AVF failure and improve long term patency of AVF[35,36]. An early sign of AVF dysfunction is decreased access blood flow. The ultrasound dilution technique is a simple screening tool that has been reliable method to measure access blood flow[14]. This present study measured vascular access blood flow by noninvasive ultrasound dilution in HD patients who used the buttonhole technique. Past use of this measure of access blood flow identified patients with impaired access blood flow (below 500 ml/min) that had increased risk of access failure[35]. Present results found that all patients had functioning AVF when using the buttonhole technique with dull AV needle and also

Table 3. Factors associated with impaired access blood flow (n = 68)

Access blood flow (ml/min)	below 500	above 500	p-value
Number	10 (14.7)	58 (85.3)	
Male (n, %)	4 (40.0)	31 (53.4)	0.432
Age (years)	53.8 ± 10.7	43.2 ± 11.5	0.009
Diabetes mellitus (n, %)	3 (30.0)	1 (1.7)	0.009
Dyslipidemia (n, %)	6 (60.0)	13 (22.4)	0.023
Duration of HD (year)	7.9 ± 4.9	8.8 ± 4.1	0.528
Duration of AVF (year)	6.5 ± 4.6	8.1 ± 3.8	0.240
Smoking (n, %)	0 (0.0)	10 (17.2)	0.337
Body weight (kg)	60.8 ± 12.4	54.2 ± 10.6	0.081
Body mass index (kg/m2)	23.1 ± 5.0	20.7 ± 3.3	0.055
Body surface area (m2)	1.6 ± 0.2	1.6 ± 0.2	0.159
Systolic blood pressure (mmHg)	145.0 ± 20.1	144.1 ± 16.2	0.881
Hemoglobin (gm/dl)	10.0 ± 1.1	10.2 ± 1.4	0.736
Serum creatinine (mg/dl)	11.2 ± 3.5	11.1 ± 3.1	0.917
Serum albumin (gm/dl)	4.3 ± 0.3	4.2 ± 0.4	0.695
Serum LDL (mg/dl)	116.7 ± 46.4	113.8 ± 35.5	0.819
AVF at upper arm (n, %)	3 (30.0)	12 (20.7)	0.680
Dialyzer blood flow rate (ml/min)	350.0 ± 52.7	356.0 ± 32.5	0.626
Venous pressure (mmHg)	110.0 ± 44.5	112.6 ± 29.1	0.812
Kt/V urea	2.2 ± 0.5	2.1 ± 0.4	0.617
NPCR (gm/kg/day)	1.2 ± 0.4	1.3 ± 0.4	0.384

received an adequate dialysis delivery dose. However, 14.7% of these patients had impaired access blood flow. Factors associated with impaired access blood flow were old age, diabetes mellitus and dyslipidemia. This is consistent with previous studies in HD patients using the rope-ladder technique with sharp AV needle. PE Miller[37] showed that the adequate rate of AVF in HD patients with the rope-ladder technique was significantly lower in older and diabetes mellitus patients. Patients with old age, diabetes mellitus and dyslipidemia usually have of blood vessel problems from atherosclerosis that may cause poor usability after surgical creation of AVF or a dysfunction of the AVF in HD patients.

Malfunction of permanent vascular access remains a common complication in HD patients. Encountering clinical manifestations is not a good way to detect AVF dysfunction. Annual screening for access blood flow in HD patients is currently recommended in western countries. Noninvasive direct measurement of access blood flow by ultrasound dilution technique is a good screening tool to monitor AVF. However, the ultrasound dilution technique is impractical in Thailand because there are few machines for the ultrasound dilution technique and requires well-trained specialists at high cost. Nonetherless, access blood flow screening in HD patients is recommended when factors associated with impaired access blood flow like old age and diabetes mellitus are present.

Conclusion

AVF cannulation by buttonhole technique using dull AV needle has gained popularity in Thailand. The number of patients with good and impaired access flow rates were 58 (85.3%) and 10 (14.7%) respectively. Factors associated with impaired access blood flow were old age, diabetes mellitus and dyslipidemia.

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Potential conflicts of interest

None.

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การประเมินความเร็วเลือดใน Arteriovenous fistula ในผู้ป่วยที่ฟอกเลือดที่แทงเข็มด้วยวิธี buttonhole โดยวิธี ultrasound dilution

อุดม ไกรฤทธิชัย, เบญจวรรณ ลีตระกูลพาณิชย์

ภูมิหลัง: *การแทงเข็มเข้าสู่เส้นเลือดแดงดำสำหรับการฟอกเลือด (AVF) ด้วยวิธี rope-ladder เป็นวิธีพื้นฐานสำหรับการฟอกเลือด การแทงเข็มซ้ำที่เดิมด้วยเข็มทื่อแบบ buttonhole เริ่มมีการใช้ในประเทศไทย การวัดความเร็วของ AVF ด้วยวิธี ultrasound dilution เป็นวิธีการที่ดีและไม่เจ็บปวด ยังไม่มีการศึกษาที่วัดความเร็วเลือดใน AVF ในผู้ป่วยที่ฟอกเลือดที่แทงเข็มด้วยวิธี buttonhole*

วัตถุประสงค์: *เพื่อวัดความเร็วของ AVF ด้วยวิธี ultrasound dilution ในผู้ป่วยที่ใช้วิธี buttonhole และหาปัจจัยที่มีความสัมพันธ์กับการลดลงของความเร็วของ AVF*

วัสดุและวิธีการ: *การศึกษาแบบตัดขวางในผู้ป่วยฟอกเลือดใช้วิธี buttonhole ในหน่วยไตเทียมโรงพยาบาลราชวิถีและมูลนิธิโรคไตแห่งประเทศไทย โรงพยาบาลสงฆ์ โดยทำการวัดความเร็วของ AVF ด้วยวิธี ultrasound dilution ในชั่วโมงแรกของการฟอกเลือดปกติจำนวนสองครั้งติดกัน*

ผลการรักษา: *มีผู้ป่วยจำนวน 68 รายเข้าร่วมการศึกษา ผู้ป่วยทุกรายมี AVF ที่ทำงานดีและได้รับปริมาณการฟอกเลือดเพียงพอแต่พบว่าผู้ป่วย 14.7% มีความเร็วของ AVF ลดลง ความเร็วเฉลี่ยของ AVF ของผู้ป่วยทั้งหมดเท่ากับ 1326 $\pm$ 858.8 ml/min ความเร็วเฉลี่ยของ AVF ของผู้ป่วยที่มีความเร็วของ AVF ดีและลดลงเท่ากับ 1,497.8 $\pm$ 812.4 และ 330.0 $\pm$ 135.0 ml/min ปัจจัยที่มีความสัมพันธ์กับการลดลงของความเร็วของ AVF คือ อายุมาก เบาหวานและไขมันในเลือดสูง*

สรุป: *การศึกษานี้แนะนำว่าควรวัดความเร็วของ AVF ด้วยวิธี ultrasound dilution ในผู้ป่วยฟอกเลือดที่มีอายุมาก เบาหวานและไขมันในเลือดสูง*