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Original Article

Effect of intradialytic change in blood pressure and ultrafiltration volume on the variation in access flow measured by ultrasound dilution

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Abstract

Background: Prospective access flow measurement is the preferred method for vascular access surveillance in hemodialysis (HD) patients. We studied the effect of intradialytic change in blood pressure and ultrafiltration volume on the variation in access flow measured by ultrasound dilution.

Methods: Access flow was measured 30 minutes, 120 minutes, and 240 minutes after the start of HD by ultrasound dilution in 30 patients during 89 HD sessions and evaluated for variation.

Results: The mean age of the 30 patients was 62 ± 11 years: 19 were male. The accesses comprised 16 fistulae and 14 grafts. The mean access flow over all sessions decreased by 6.1% over time (1265 ± 568 mL/min after 30 minutes, 1260 ± 599 mL/min after 120 minutes, and 1197 ± 576 mL/min after 240 minutes, $P < 0.01$ by repeated measures ANOVA). In addition, a $\geq 5\%$ decrease in mean arterial pressure during HD significantly reduced access flow ($P = 0.014$). However, no other variable (ultrafiltration volume, sex, age, presence of diabetes, type or location of access, body surface area, hemoglobin, serum albumin level) interacted significantly with the effect of time on access flow. Furthermore, mean arterial pressure did not correlate with ultrafiltration volume.

Conclusion: We conclude that the variation in access flow during HD is relatively small. Decreased blood pressure is a risk factor for variation in access flow measured by ultrasound dilution. In most patients whose blood pressures are stable during HD, the access flow can be measured at any time during the HD treatment.

Introduction

Periodic vascular access monitoring and surveillance can predict the presence of vascular access stenosis and subsequent thrombosis in patients undergoing hemodialysis (HD) [1]. Pre-emptive intervention to correct stenosis of the failing access prevents thrombosis and extends the life span of the vascular

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access in comparison with an attempted repair after a thrombotic event [2,3], although this issue has become controversial [4]. National Kidney Foundation Kidney Disease Outcome Quality Initiative (NKF-KDOQI) [5] and European best practice guidelines [6] recommend prospective surveillance of fistulae and grafts together with physical examination on a regular basis, and also recommend angiography and prompt preemptive intervention to correct stenosis, which may improve patency rates and may decrease the incidence of thrombosis. In addition, both guidelines recommend monthly measurement of access flow as the preferred tool for surveillance of fistulae and grafts. A decreased rate of access flow has been shown to be a significant predictor of vascular stenosis and subsequent thrombosis for both fistulae and grafts [7–9].

Measurement of access flow using the ultrasound dilution technique has been described by Krivitski and is a reliable method for screening for access dysfunction [10]. Its advantages over Doppler ultrasound are its reproducibility, low cost, operator-independence, and ability to provide rapid feedback before and after corrective intervention [11,12].

A clinically controversial issue that has been raised in regard to the measurement of access flow by ultrasound dilution is the variation in access flow according to the time of measurement during HD. The NKF-KDOQI guidelines recommend that the flow assessment should be performed during the first 1.5 hours of the treatment to eliminate error caused by decrease in cardiac output or blood pressure related to ultrafiltration and/or hypotension [5]. Restriction of the measurement time to within the first 1.5 hours of the treatment limits the number of measurements that can be performed by one operator, which is a significant issue in clinical practice, considering the number of patients who require prospective monthly measurement of access flow. However, whether the ultrafiltration volume significantly alters the access flow remains controversial [13].

The aim of this study was to evaluate whether access flow could be significantly reduced when measured late during HD. In addition, we evaluated whether high ultrafiltration volume or decrease in blood pressure at the end of HD could significantly reduce access flow. Overall, we evaluated whether access flow should be measured early during HD, or it could be measured at anytime during HD. The effect of patients' demographic parameters on the access flow was also evaluated.

Methods

Patients

Thirty patients undergoing chronic HD were enrolled. Inclusion criteria were patients on a three times per week HD schedule for longer than 3 months, age 18–74 years, interdialytic weight gain >1.0 kg, button-hole needle users in patients having fistulae for their vascular access, and ability to provide consent. Exclusion criteria were predialysis systolic blood pressure in supine position <90 mmHg, delivered blood flow rate for dialysis <300 mL/min, access flow <400 mL/min in fistulae, access flow <600 mL/min in grafts, and expected need for blood transfusions during the study. The blood pump flow rate was set at 300 mL/min, and the session time was 4 hours. For puncture, using 15-gauge needles, the rope ladder technique was used for grafts and button-hole needles were inserted to the fistulae to maintain the same needle site and direction. All patients provided informed consent to participation before study entry. The study protocol complies with the Declaration of Helsinki and was approved by the institutional review board of Seoul St. Mary's Hospital (KC10OISE0647).

Study design

In this prospective observational study, access flow was measured 30 minutes, 120 minutes, and 240 minutes after the start of the HD session. Access flow was measured in three consecutive sessions in 29 patients, and in two consecutive sessions in one patient. Therefore, a total of 267 measurements of access flow during 89 HD sessions were analyzed.

Access flow measurement

Access flow was measured by ultrasound dilution using a Transonic HD03 HD monitor (Transonic Systems, Inc., Ithaca, NY, USA) as previously described [10]. Briefly, the dialyzer blood pump was stopped, and the dialysis lines were reversed from their normal configuration. Two ultrasound dilution sensors were clamped onto the bloodlines, one on the arterial line and one on the venous line. While the blood pump flow rate was returned to 300 mL/minute, a bolus of isotonic saline (indicator) was injected into the venous drip chamber. The Transonic software automatically calculated the access flow from the measurements from the two sensors.

The blood pressure was recorded every hour during HD. The body surface area, hemoglobin and serum albumin levels were measured at the 1st day of measurement of access flow.

Statistical analysis

Data are presented as mean $\pm$ standard deviation (SD). The variation in access flow over time (after 30 minutes, 120 minutes and 240 minutes of HD) was analyzed using repeated measures ANOVA. The reproducibility of access flow at the indicated time of HD was analyzed by an intraclass correlation coefficient. The interactions between the effects of time and other variables on access flow were determined by two-way mixed-effects repeated measures ANOVA. Pearson correlation coefficients (r values) were used to determine the relationships between access flow and ultrafiltration volume or blood pressure. Differences were considered statistically significant when the P-value was <0.05. The SAS system for Windows (Version 9.2) was used for all analyses.

Results

Patient characteristics

The 30 patients included 19 men and 11 women with a mean $\pm$ SD age of 62 ± 11 years. There were 12 (40%) diabetics. The vascular accesses included 16 (53%) fistulae and 14 (47%) grafts and half were located in the forearm. Seventeen patients (57%) were undergoing conventional hemodialysis, and 13 patients (43%) hemodiafiltration. The body surface area of the patients was 1.59 ± 0.13 m^2, and the ultrafiltration volume/HD session was 2.64 ± 0.92 L (Table 1). No clinical event of vascular access dysfunction occurred during the study.

Variation of access flow over time

The mean access flow over all 89 sessions decreased over time (1265 ± 568 mL/min after 30 minutes, 1260 ± 599 mL/

min after 120 minutes, and 1197 ± 576 mL/min after 240 minutes, $P < 0.01$). Multiple comparisons, showed that access flow was significantly lower after 240 minutes than after 30 minutes or 120 minutes. The access flow decreased on average by 68 mL/min in absolute value and by 6.1% in relative value (Fig. 1).

Reproducibility of access flow measured by ultrasound dilution

The reproducibility of access flow measured 30 minutes, 120 minutes, and 240 minutes after the start of the HD on the three consecutive HD sessions was analyzed by intraclass correlation coefficient. The coefficient was 0.906 after 30 minutes, 0.909 after 120 minutes, and 0.927 after 240 min, showing that measurement of access flow by ultrasound dilution was highly reproducible.

Table 1. Patient characteristics at the start of the study

Variable	Value
Number of patients	30
Male, *n* (%)	19 (63.3)
Age (y)	62 ± 11
Diabetes mellitus, *n* (%)	12 (40)
Type of access	
Fistulae, *n* (%)	16 (53.3)
Grafts, *n* (%)	14 (46.7)
Location of access	
Forearm, *n* (%)	15 (50.0)
Upper arm, *n* (%)	15 (50.0)
Age of access (mo)	53 ± 49
Dialysis treatment	
Conventional hemodialysis, *n* (%)	17 (56.7)
Hemodiafiltration, *n* (%)	13 (43.3)
Body surface area (m^2)	1.59 ± 0.13
Hemoglobin (g/L)	109 ± 9.0
Serum albumin (g/L)	38 ± 3.0

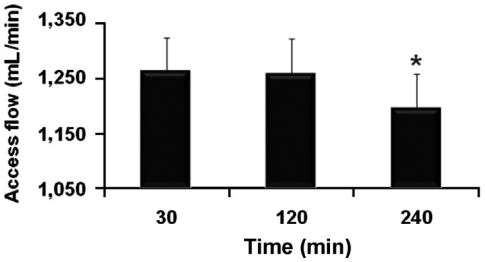

Figure 1. Access flow measured by ultrasound dilution 30 min, 120 min, and 240 minutes after start of hemodialysis. Data are presented as the mean ± standard error of the mean. $P = 0.0001$ by repeated measures ANOVA. $^*P < 0.01$ vs. 30 minutes and 120 minutes by multiple comparisons.

The interaction between the effects of time and blood pressure on access flow

To determine if a decrease in blood pressure affected access flow, we compared the access flow between the sessions in which the mean arterial pressure (MAP) measured after 240 min had decreased by ≥ 5% compared with pre-HD MAP and sessions in which the MAP did not decrease by ≥ 5% (represented as the decreased MAP group versus the non-decreased MAP group; Table 2). Repeated measures ANOVA revealed that the time factor significantly affected access flow ($P < 0.001$), which decreased over time. A ≥ 5% decrease in MAP, reduced access flow by 12.3%. With regard to a group effect, the access flow was significantly lower in the decreased MAP group than in the non-decreased MAP group ($P = 0.008$). In addition, there was a significant interaction between the effects of time and MAP group on access flow ($P = 0.014$), which suggested that the decrease in blood pressure during HD affected access flow.

The interactions between access flow and other variables

The interactions were next analyzed between access flow and other variables, including ultrafiltration volume, sex, age, presence of diabetes, type and location of access, body surface area, and hemoglobin and serum albumin levels. Analysis of the access flow based on the ultrafiltration volume (< 2 L vs. ≥ 2 L or < 3 L vs. ≥ 3 L) showed no significant interaction between the effects of time and ultrafiltration volume on access flow (Table 3). In addition, there were no significant interactions between the effects of time and any of other variables including sex, age, presence of diabetes mellitus, type and location of access, body surface area, hemoglobin and serum albumin levels.

Correlation between change in MAP and ultrafiltration volume

To determine whether a large ultrafiltration volume decreased blood pressure, we examined the correlation between the change in MAP during HD and ultrafiltration volume. The MAP did not correlate with the ultrafiltration volume in the total group of sessions ($P = 0.997$) or in the subanalysis of the sessions in which the MAP was ≥ 5% lower after 240 minutes than pre-HD ($P = 0.949$).

Discussion

In this study, we found the variation in access flow during HD to be relatively small (6.1%). The NKF-KDOQI guidelines on access flow surveillance clearly recommend prospective trend analysis based on monthly measurement rather than

Table 2. Interactions between the effects of the difference in mean arterial pressure (MAP) after 240 min of hemodialysis (HD) and time (30 min, 120 minutes, and 240 minutes after the start of HD) on access flow

Group	MAP (mmHg)		Access flow (% change)			*P*
	Pre-HD	240 min	30 min	120 min	240 min	
Decreased (MAP ≥ 5%; *n* = 28)	95.5 ± 11.0	82.3 ± 10.2	100	94.3 ± 11.6	87.7 ± 13.1	Time effect < 0.001
Nondecreased (MAP < 5%; *n* = 61)	91.2 ± 11.3	98.3 ± 13.0	100	101.0 ± 13.5	96.7 ± 16.7	Group effect 0.008
						Time × Group effect 0.014

Table 3. Interactions between the effects of ultrafiltration (UF) volume and time (30 min, 120 min, and 240 minutes after the start of hemodialysis) on access flow

Variables	Group	Time: access flow (% change)			*P*
		30 min	120 min	240 min	Time × Group effect
UF volume	< 2 L (n=27)	100	98.5 ± 13.1	94.4 ± 17.7	0.915
	≥ 2 L (n=62)	100	99.1 ± 13.4	99.1 ± 15.5	
UF volume	< 3 L (n=65)	100	99.4 ± 14.3	95.0 ± 16.3	0.480
	≥ 3 L (n=24)	100	95.0 ± 16.3	90.9 ± 15.5	

responding to a single isolated abnormal value. Furthermore, a patient should be referred for angiography when the access flow in the graft has decreased by > 25% over a 4-month period [5].

As clinical decisions are usually based on reductions of access flow by > 25%, the 6.1% variation in access flow during HD is relatively small and clinically insignificant.

The change in MAP during HD did not correlate with the variation in access flow in the total group of sessions, because the MAP measured before HD, and 30 minutes, 120 minutes, and 240 minutes after the start of the HD session was not different. We next compared the access flow between the sessions in which the MAP measured after 240 min had decreased by ≥ 5% or 10% compared with pre-HD MAP and sessions in which the MAP did not decrease by ≥ 5% or 10%. We found that a ≥ 5% decrease in MAP during HD reduced access flow after 240 min by an average of 12.3%, and this reduction was statistically significant. A ≥ 10% decrease in MAP during HD also significantly reduced access flow. Based on our results, we would recommend that any significantly decreased measurement of access flow in a patient in whom MAP had decreased by ≥ 5% should be rechecked at the next session. Krivitski [14] similarly recommended that if a significant decrease in MAP had been observed, the clinician should confirm any reduction in access flow by repeating the measurement at the next session before referring the patient for angiography. Rehman et al. measured access flow serially 30 minutes, 90 min, and 150 min after the start of HD and found a strong correlation between access flow and the MAP 90 min after the initiation of HD, with each 10% decrease in MAP resulting in an 8% decrease in access flow [15]. They concluded that access flow could be measured up to 2–2.5 h after the start of HD and suggested postponing measurement in patients in whom MAP had decreased more than 15%. By contrast, Agharazii et al. [13] found that the measurements of access flow made within the first and last 30 min of HD in 50 patients did not differ. The access flow decreased by 11.7% over the course of the HD session, but this reduction dropped to 4.9% when the access flows were corrected for a MAP of 100 mmHg using the following equation: $Qac' = Qac$ (100/MAP), where Qac' is the corrected access flow and MAP is the actual mean arterial pressure at the time of measurement. They concluded that the variation in access flow during HD was relatively small, especially when the values were corrected for MAP. Therefore, access flow can be measured by the ultrasound dilution method at any time during HD.

In our study, the ultrafiltration volume did not affect access flow during HD. In addition, it was not correlated with the change in MAP. A net reduction in the effective circulating plasma volume due to an imbalance between the ultrafiltration rate and the plasma refilling rate has been shown to induce intradialytic hypotension during HD. However, intradialytic hypotension is caused not only by the reduced circulating plasma volume but also by the impaired physiologic adaptation to the reduced plasma volume by means of constriction of resistance vessels, increased heart rate and myocardial contractility, and constriction of capacitance vessels [16,17]. Recently, an automatic biofeedback system for controlling blood volume changes during HD has been studied in hypotension-prone HD patients. This system is based on the concept of blood volume tracking to prevent hypovolemia and works by continuous modification of the ultrafiltration rate and dialysate conductivity. In the studies, the use of blood volume controlled HD reduced the frequency of intradialytic hypotensive episodes by 30–50% in comparison with conventional HD [18–20]. These results clearly demonstrate that ultrafiltration volume is not the only cause of hypotension during HD. Therefore, ultrafiltration volume might not be an independent risk factor for either the decrease in blood pressure or the variation in access flow during HD.

Measurement of access flow by ultrasound dilution takes at least 10 min. As we are well aware of the importance of monthly vascular access surveillance, measuring the access flow only within the initial 1.5 h of HD, in accordance with the NKF-KDOQI guidelines, requires a greater number medical personnel to measure access flow in all patients and results in higher medical expenses.

The limitations of this study include the small number of patients. Because this was prospective observational study, we did not decide the number of patients based on the statistical sample size evaluation. Thirty patients were not enough to confirm the effect of the parameters measured in this study on the variation in the access flow during HD.

In conclusion, access flow measurement by the ultrasound dilution method is very reproducible, and the variation in access flow during HD (6.1%) is relatively small, as clinical decisions for vascular access dysfunction requiring angiography are usually based on reductions of access flow by > 25%. Because decreased blood pressure during HD (MAP reduction by > 5%) is a risk factor for reduced access flow, any clinically significant reduction in access flow in patients in whom MAP has also decreased should be confirmed at the next HD session. However, in most patients whose blood pressures remain stable during HD, access flow can be measured at any time during the HD treatment.

Conflicts of interest

All contributing authors declare no conflict of interest.

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References

[1] Kim HS, Park JW, Chang JH, Yang J, Lee HH, Chung W, Park YH, Kim S: Early vascular access blood flow as a predictor of long-term vascular access patency in incident hemodialysis patients. *J Korean Med Sci* 25:728–733, 2010

[2] Besarab A: Access monitoring is worthwhile and valuable. *Blood Purif* 24:77–89, 2006

[3] Lilly RZ, Carlton D, Barker J, Saddekni S, Hamrick K, Oser R, Westfall AO, AIlon M: Predictors of arteriovenous graft patency after radiologic intervention in hemodialysis patients. *Am J Kidney Dis* 37:945–953, 2001

[4] Paulson WD: Access monitoring does not really improve outcomes. *Blood Purif* 23:50–56, 2005

[5] National Kidney Foundation. NKF KDOQI Guidelines: Clinical Practice Guidelines and Clinical Practice Recommendations, 2006 updates. Available at: 〈http://www.kidney.org/professionals/KDOQI/guideline_upHD_PD_VA/index.htm〉 [Date accessed August 20, 2012].

[6] Tordoir J, Canaud B, Haage P, Konner K, Basci A, Fouque D, Kooman J, Martin-Malo A, Pedrini L, Pizzarelli F, Tattersall J, Vennegoor M, Wanner C, ter Wee P, Vanholder R: EBPG on vascular access. *Nephrol Dial Transplant*;22(Suppl 2):ii88–ii117, 2007

[7] May RE, Himmelfarb J, Yenicesu M, Knights S, Ikizler TA, Schulman G, Hernanz-Schulman M, Shyr Y, Hakim RM: Predictive measures of vascular access thrombosis: A prospective study. *Kidney Int* 52:1656–1662, 1997

[8] Neyra NR, Ikizler TA, May RE, Himmelfarb J, Schulman G, Shyr Y, Hakim RM: Change in access blood flow over time predicts vascular access thrombosis. *Kidney Int* 54:1714–1719, 1998

[9] Kim YO, Yang CW, Yoon SA, Chun KA, Kim NI, Park JS, Kim BS, Kim YS, Chang YS, Bang BK: Access blood flow as a predictor of early failures of native arteriovenous fistulas in hemodialysis patients. *Am J Nephrol* 21:221–225, 2001

[10] Krivitski NM: Theory and validation of access flow measurement by dilution technique during hemodialysis. *Kidney Int* 48: 244–250, 1995

[11] Lopot F, Nejedly B, Sulkova S, Blaha J: Comparison of different techniques of hemodialysis vascular access flow evaluation. *J Vasc Access* 5:25–32, 2004

[12] Besarab A, Asif A, Roy-Chaudhury P, Spergel LM, Ravani P: The native arteriovenous fistula in 2007, Surveillance and monitoring. *J Nephrol* 20:656–667, 2007

[13] Agharazii M, Clouâtre Y, Nolin L, Leblanc M: Variation of intra-access flow early and late into hemodialysis. *ASAIO* 46:452–455, 2000

[14] Krivitski NM: Access flow measurement during surveillance and percutaneous transluminal angiography intervention. *Semin Dial* 16:304–308, 2003

[15] Rehman SU, Pupim LB, Shyr Y, Hakim R, Ikizler TA: Intradialytic serial vascular access flow measurements. *Am J Kidney Dis* 34: 471–477, 1999

[16] Daugirdas JT: Pathophysiology of dialysis hypotension: an update. *Am J kidney Dis* 38:S11–S17, 2001

[17] Sherman RA: Intradialytic hypotension: an overview of recent, unresolved and overlooked issues. *Semin Dial* 15:141–143, 2002

[18] Santoro A, Mancini E, Basile C, Amoroso L, Giulio SD, Usberti M, Colasanti G, Verzetti G, Rocco A, Imbasciati E, Panzetta G, Bolzani R, Grandi F, Polacchini M: Blood volume controlled hemodialysis in hypotension-prone patients: A randomized, multicenter controlled trial. *Kidney Int* 62:1034–1045, 2002

[19] Franssen CFM, Dasselaar JJ, Sytsma P, Burgerhof JGM, de Jong PE, Huisman RM: Automatic feedback control of relative blood volume changes during hemodialysis improves blood pressure stability during and after dialysis. *Hemodialysis Int* 9:383–392, 2005

[20] Gil HW, Kwon YJ, Song HC, Kim YO, Kim JK, Han BG, Lee SY, Bang K, Kim YS: Clinical evaluation of Hemocontrol in Korean hypotension-prone hemodialysis patients: A multicenter prospective crossover study. In: American Society of Nephrology Kidney Week, October 30–November 4, 2012, San Diego, CA, USA.