Digital pressure and oxygen saturation measurements in the diagnosis of chronic hemodialysis access-induced distal ischemia

Mohammad-Hadi S. Modaghegh, MD,[a] **Bahman Roudsari, MD, PhD,**[b] and **Shahab Hafezi, MD,**[a] *Mashhad, Iran; and Seattle, Wash*

Objective: **Hemodialysis access-induced distal ischemia (HAIDI) can be classified as acute (on the first postoperative day), subacute (≤1 month), or chronic (>1 month), based on the time of onset after access creation. The diagnosis is mainly clinical. However, performing additional tests is beneficial in further assessment of patients. The purpose of this study was to evaluate the use of finger pressure and oxygen saturation measurements for the diagnosis of chronic HAIDI.**

Methods: **A total of 20 patients with chronic HAIDI (cases) and 40 asymptomatic hemodialysis patients (controls) were matched for age, sex, etiology of end-stage renal disease, and type of arteriovenous access. Basal digital pressure (BDP), digital pressure during manual compression of access, digital brachial index (DBI), change in digital pressure with access compression (CDP), digital pressure of the contralateral side, and bilateral oxygen saturation (O_2 Sat) were measured in all patients.**

Results: **In the case group, compression of the arteriovenous fistula (AVF) increased mean BDP from 61 ± 26 to 118 ± 28 mm Hg ($P < .001$), which failed to reach the non-AVF side mean digital pressure of 151 ± 25 mm Hg ($P < .001$). In addition, O_2 Sat of the AVF side was significantly lower than the contralateral side (92.9% ± 2.1% vs 95.6% ± 1.4%; $P = .001$). Among the controls, manual AVF compression raised the mean BDP from 114 ± 36 mm Hg to 133 ± 29 mm Hg ($P < .001$), which was still significantly lower than the contralateral side mean digital pressure of 141 ± 30 mm Hg ($P = .002$). In addition, O_2 Sat values of the two sides were different (96.7% ± 2.1% vs 97.1% ± 1.9%; $P = .01$). Comparing the cases and controls, the mean BDP (61 ± 26 mm Hg vs 114 ± 36 mm Hg; $P < .001$), DBI (0.44 ± 0.16 vs 0.82 ± 0.19; $P < .001$), and O_2 Sat (92.9% ± 2.1% vs 96.7% ± 2.1%; $P < .001$) were significantly lower and CDP (57 ± 24 mm Hg vs 19 ± 17 mm Hg; $P < .001$) was significantly higher in the cases than in the controls. The optimal discriminatory thresholds of 80 mm Hg for BDP, 0.7 for DBI, 40 mm Hg for CDP, and 94% for O_2 Sat were determined.**

Conclusions: **Digital pressure and O_2 Sat measurements are useful additional methods to assist in the clinical evaluation of hemodialysis patients with access-related hand ischemia. BDP <80 mm Hg, DBI <0.7, CDP >40 mm Hg, and O_2 Sat <94% are associated with chronic HAIDI. (J Vasc Surg 2015;62:135-42.)**

Hemodialysis access-induced distal ischemia (HAIDI), also known as steal syndrome, is a serious complication that occurs in 1% to 8% of hemodialysis patients with arteriovenous access (AVA).[1,2] After the construction of an AVA, asymptomatic retrograde flow (steal phenomenon) may occur secondary to the arterial-venous resistance difference.[3] However, this physiologic response is not necessarily associated with access-related hand ischemia. Further, HAIDI may develop in the absence of blood flow reversal. Instead, insufficient arterial remodeling in response to increased blood flow through the AVA and arterial stenotic lesions are suggested to be responsible for the pathogenesis of HAIDI.[4,5]

HAIDI may develop during the first 24 hours after access placement (acute), later but within the first postoperative month (subacute), or >1 month (chronic).[6] The ischemic manifestations of the chronic form of HAIDI are relatively milder at the onset, but if ignored, it may deteriorate and finally result in severe consequences.[7] Although the diagnosis is mainly based on clinical evidence, supplementary investigations, such as angiography,[8-10] color Doppler ultrasound imaging,[7,11] finger pressure measurements,[1,3,8,12-18] nerve conduction studies,[19] and pulse oximetry,[20] have been used to predict, confirm the clinical diagnosis, select the appropriate treatment, and monitor the therapeutic procedures.

The clinical findings may be equivocal, making it challenging to distinguish HAIDI from other differential diagnoses such as neuropathy. In these circumstances, an objective diagnostic method is needed. Excessive access flow (>1500 mL/min), reversal of blood flow, or stenotic lesions may be detected by color Doppler ultrasound imaging or angiography. However, none of these findings are diagnostic

From the Vascular and Endovascular Surgery Research Center, Imam Reza Hospital, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad[a]; and the Department of Radiology, University of Washington, Seattle.[b]

This study received financial support from Mashhad University of Medical Sciences.

Author conflict of interest: none.

This study was carried out as Dr Shahab Hafezi's medical doctorate thesis, supervised by Prof Mohammad-Hadi Saeed Modaghegh.

Correspondence: Shahab Hafezi, MD, Vascular and Endovascular Surgery Research Center, Division of Vascular Surgery, Imam Reza Hospital, Mashhad University of Medical Sciences, Mashhad, Iran (e-mail: shahab.hafezi@hotmail.com).

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

0741-5214

http://dx.doi.org/10.1016/j.jvs.2015.02.024

of HAIDI. Our hypothesis was that finger pressure measurements could be a reliable assessment of distal perfusion. The main purpose of this study was to determine the value of digital pressure and oxygen saturation (O_2 Sat) measurements in the diagnosis of chronic HAIDI.

METHODS

This case-control study was conducted during a 43-month period, from June 2010 to December 2013, and was approved by the Mashhad University of Medical Sciences Institutional Review Board. A total of 20 clinically diagnosed patients with chronic HAIDI (cases) and 40 asymptomatic hemodialysis patients (controls) were matched for age, sex, etiology of end-stage renal disease, and type of AVA. Written informed consent was obtained from all participants. Chronic HAIDI patients were diagnosed based on ischemic signs and symptoms, including cold sensation, paresthesia, numbness, hand pain, cold extremity, delayed capillary refill time, pallor or cyanosis, weakness, ischemic ulcer, and gangrene. The clinical diagnosis was confirmed by partial or complete resolution of ischemic symptoms during manual compression of the AVA. Functioning AVAs of the controls had never been complicated. The severity of ischemia was used to classify HAIDI as mild (grade 1: cool extremity and mild symptoms without pain; no treatment needed), moderate (grade 2: ischemic pain only during dialysis; intervention sometimes needed), and severe (grade 3: ischemic pain at rest or tissue loss; intervention mandatory).[21]

Basal digital pressure (BDP), digital pressure during manual compression of access, digital brachial index (DBI), change in digital pressure with access compression (CDP), digital pressure of the contralateral side, and bilateral O_2 Sat were measured in all patients. DBI was calculated as the ratio of BDP to contralateral brachial systolic blood pressure. CDP was defined as the difference between digital pressure with the access manually compressed and BDP.[13] All systolic digital pressures, expressed in mm Hg, were obtained from the third finger using the SysToe automated portable device (Atys Medical, Soucieu-en-Jarrest, France). An inflatable cuff was wrapped around the proximal phalanx, and the photoplethysmographic sensor was placed on the distal phalanx. O_2 Sat of the index finger was recorded. Because finger pressures and O_2 Sat may decrease significantly during hemodialysis,[22,23] all measurements were performed before a dialysis session.

Statistical analysis. Data are expressed as mean ± standard deviation or as frequency and percentage. Continuous variables were compared using the independent sample *t*-test or Mann-Whitney *U* test. Categoric variables were evaluated by the χ^2 test or the Fisher exact test. The paired samples *t*-test or Wilcoxon signed rank test were used to compare the results of fistula side and contralateral side measurements in the same group (cases or controls), as well as finger pressure measurements before and during access compression. Optimal test thresholds were determined by evaluation of receiver operating characteristic curves. A $P < .05$ was considered statistically significant.

Table I. Characteristics of chronic hemodialysis access-induced distal ischemia (*HAIDI*) patients and asymptomatic controls

Variable[a]	*Chronic HAIDI patients (n = 20)*	*Asymptomatic controls (n = 40)*	P
Age, years	45.6 ± 15.1	48.7 ± 14.1	.448
Gender			
Male	13 (65)	22 (55)	.459
Female	7 (35)	18 (45)	
Etiology of ESRD			
Diabetes mellitus	9 (45)	17 (42.5)	.854
Hypertension	6 (30)	11 (27.5)	.839
Other	5 (25)	12 (30.0)	.685
Type of access			
Proximal (brachial artery-based)	17 (85)	33 (82.5)	1.0
Distal (radial artery-based)	3 (15)	7 (17.5)	
Duration of hemodialysis, month	34.5 ± 29.3	55.6 ± 57.7	.215
Current access age, month	21.5 ± 21.4	32.5 ± 40.6	.118
Prior AVA(s), No.	0.60 ± 1.04	0.33 ± 0.57	.43
Patients with previous AVA(s)	7 (35)	11 (27.5)	.55

AVA, Arteriovenous access; *ESRD,* end-stage renal disease.
[a]Continuous data are shown as mean ± standard deviation and categoric data as number (%).

Analyses were performed using SPSS 18 software (IBM Corp, Armonk, NY).

RESULTS

Of 20 patients with chronic HAIDI, 15 patients had grade 1 HAIDI, 2 patients were in grade 2, and 3 patients experienced rest pain (grade 3), one of whom also had ischemic ulcer. Cold sensation, paresthesia, numbness, and ischemic hand pain were reported by 17, 11, 9, and 5 patients, respectively. Cold extremity, delayed capillary refill time, pallor or cyanosis, weakness, and ischemic ulcer were found in 16, 14, 12, 3, and 1 patient, respectively. No gangrene was found. The 20 patients with chronic HAIDI had an autogenous arteriovenous fistula (AVF). As summarized in Table I, the characteristics of cases and controls were not significantly different.

In the case group, the mean BDP increased by manual AVF compression from 61 ± 26 mm Hg to 118 ± 28 mm Hg ($P < .001$). However, this improved pressure did not reach the mean contralateral digital pressure (118 ± 28 mm Hg vs 151 ± 25 mm Hg; $P < .001$). Also, O_2 Sat of the AVF side was lower than the non-AVF side (92.9% ± 2.1% vs 95.6% ± 1.4%; $P = .001$). In the control group, the mean digital pressure during manual compression of AVF was significantly higher than BDP (133 ± 29 mm Hg vs 114 ± 36 mm Hg; $P < .001$) but was still lower than digital pressure of the contralateral side (133 ± 29 mm Hg vs 141 ± 30 mm Hg; $P = .002$). Also, there was a clinically negligible but statistically significant difference between O_2 Sat of the two sides (96.7% ± 2.1% vs 97.1% ± 1.9 %; $P = .01$).