Accuracy of Physical Examination in the Detection of Arteriovenous Fistula Stenosis

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Background and objectives: Physical examination has been highlighted to detect vascular access stenosis; however, its accuracy in the identification of stenoses when compared with the gold standard (angiography) has not been validated in a systematic manner.

Design, setting, participants, & measurements: A prospective study was conducted of 142 consecutive patients who were referred for an arteriovenous fistula dysfunction to examine the accuracy of physical examination in the detection of stenotic lesions when compared with angiography. The findings of a preprocedure physical examination and diagnosis were recorded and secured in a sealed envelope. Angiography from the feeding artery to the right atrium was then performed. The images were reviewed by an independent interventionalist who had expertise in endovascular dialysis access procedures and was blinded to the physical examination, and the diagnosis was rendered. Cohen's κ was used as a measurement of the level of agreement beyond chance between the diagnosis made by physical examination and angiography.

Results: There was strong agreement between physical examination and angiography in the diagnosis of outflow (agreement 89.4%, $\kappa = 0.78$) and inflow stenosis (agreement 79.6%, $\kappa = 0.55$). The sensitivity and specificity for the outflow and inflow stenosis were 92 and 86% and 85 and 71%, respectively. There was strong agreement beyond chance regarding the diagnosis of coexisting inflow-outflow lesions between physical examination and angiography (agreement 79%, $\kappa = 0.54$).

Conclusions: The findings of this study demonstrate that physical examination can accurately detect and localize stenoses in a great majority of arteriovenous fistulas.

Clin J Am Soc Nephrol 2: 1191–1194, 2007. doi: 10.2215/CJN.02400607

Dialysis access stenosis is the most common cause of access dysfunction. A variety of means, including access flow determination using ultrasound dilution technique and calculation of static and dynamic venous pressures, have been used in the detection of vascular access stenosis (1). Nevertheless, these interventions are time-consuming, require frequent calibration of the machines, and have an associated cost. Physical examination is emerging as an important element in the assessment of stenotic lesions (2–7); however, its accuracy in the assessment of stenosis within an arteriovenous fistula (AVF) when compared with the gold standard (angiography) has not been evaluated in a systematic manner. The purpose of this study was to evaluate the accuracy of physical examination in the detection and location of stenosis when compared with standard angiography.

Received June 7, 2007. Accepted July 24, 2007.

Published online ahead of print. Publication date available at www.cjasn.org.

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Concise Methods

A total of 142 consecutive patients who had AVF dysfunction and were referred for angioplasty were included in this analysis. A complete physical examination was performed by an interventional nephrologist in all of the patients before any angiography was undertaken. The elements of the physical examination used in this study were based on recent information by Beathard and colleagues (2–6). Briefly, inspection (arm, shoulder, breast, neck, and face edema and presence of collaterals), palpation, and auscultation were performed in a systematic manner. Palpation was not limited only to the body of the access; it was carefully performed from anastomosis all of the way to the chest wall. Pulse (hyperpulsatile, normal, weak) and thrill/bruit (continuous, discontinuous) characteristics were ascertained. Pulse augmentation and arm elevation tests to evaluate the inflow segment and outflow tract were performed, respectively (4). Pulse augmentation was performed by complete occlusion of the access several centimeters beyond the arterial anastomosis and evaluation of the strength of the pulse. The test was considered normal when the portion of fistula upstream from the occluding finger demonstrated augmentation of pulse (4,8). Arm elevation test was performed by elevation of the extremity with the fistula and examination of the normal collapse of the access (4). The test was considered abnormal when the fistula remained plump after arm elevation. The physical examination findings and the diagnosis made were recorded and secured in a sealed envelope.

ISSN: 1555-9041/206–1191

Both retrograde and antegrade angiography were performed to evaluate the access from the feeding artery to the right atrium (C-arm 9800 vascular package; General Electric, Milwaukee, WI). Retrograde angiography was performed by manual occlusion of the outflow tract of the fistula. The images recorded were sent to an independent interventionalist (a separate center) with expertise in endovascular dialysis access procedures. The independent reviewer was asked to make the diagnosis of vascular access stenosis and secure the information in a sealed envelope. Stenosis was defined as luminal narrowing ≥50% compared with the normal vascular segment located adjacent to the stenosis as per Kidney Disease Outcomes Quality Initiative (K/DOQI) (1). The independent reviewer was blinded to the results of the physical examination.

Inflow segment was defined as the feeding artery, anastomosis, and the juxta-anastomotic area (first few centimeters of the fistula) (8). Body of the fistula was considered to be 8- to 10-cm cannulation segment extending downstream from the juxta-anastomotic area. Outflow was defined as the segment from the body of the fistula to the junction of cephalic arch and subclavian vein (essentially the first rib). Central veins were the veins from the first rib to the right atrium.

Local institutional review board approval was obtained for this study. All study procedures were carried out in accordance with the Declaration of Helsinki regarding research involving human subjects.

Statistical Analyses

Diagnostic variables for both the physical examination and angiography were dichotomous (presence or absence of the lesion). The Cohen's κ value was used as a measurement of the level of agreement beyond chance between the diagnoses made by physical examination and angiography (9,10). The details of the qualitative classification of κ values as degree of agreement beyond chance can be appreciated elsewhere (9,10). Briefly, it is calculated by dividing the observed agreement beyond chance by the maximum agreement beyond chance. κ values range from 0.0 to 1.0. Zero indicates no agreement beyond chance, whereas 1.0 denotes a perfect agreement. Values between 0.0 to 0.2 and 0.2 to 0.4 confer a slight and fair agreement, respectively. κ values between 0.4 and 0.6 denote a moderate agreement. Finally, κ values >0.6 denote a substantial agreement beyond chance (9). The sensitivity, specificity, positive predictive value, and negative predictive value of the physical examination in the diagnosis of AVF stenosis were also calculated. Data were recorded in Microsoft Office Access 2003 (Microsoft, Redmond, WA) and analyzed in the statistical program Stata 9 (Stata Corp., College Station, TX).

Results

A total of 142 patients who were referred for access dysfunction were examined. Ninety five (67%) of the fistulas were located in the upper arm, and 47 (33%) were located in the forearm. Twenty-one patients demonstrated a significant side branch and were excluded from the analysis.

The outflow and inflow were the most common types of lesions (61 and 64%, respectively). There was a near-perfect agreement beyond chance between the physical examination and angiography in the diagnosis of outflow stenosis (agreement 89%, κ = 0.78; Table 1). The diagnosis of outflow stenosis by physical examination had a sensitivity of 92% and a specificity of 86% (Table 2). In terms of inflow stenosis, there was a strong agreement beyond chance between the physical examination and angiography in the diagnosis of inflow stenosis (agreement 83%, κ = 0.55; Table 1). The diagnosis of inflow stenosis by physical examination had a sensitivity of 85% and a specificity of 71% (Table 2). The analysis of coexisting lesions revealed a sensitivity of 68% and a specificity of 84% for the physical examination (Table 2). There was strong agreement beyond chance regarding the diagnosis of coexisting inflow-outflow lesions between physical examination and angiography (agreement 79%, κ = 0.54; Table 1).

Table 1. κ values for physical examination in the diagnosis of various types of lesions

Location of Stenosis	κ
Outflow tract	0.78
Inflow segment	0.55
Coexisting inflow-outflow stenosis	0.54
Body of fistula	0.18
Central veins	0.17

The physical examination for central vein stenosis showed a sensitivity of 13% and a specificity of 99% (Table 2). κ = 0.17 showed only weak agreement between physical examination and angiography (Table 1). Similarly, stenosis of the body of fistula had a sensitivity of 40% and a specificity of 84% for the physical examination (Table 2). κ = 0.18 demonstrated weak agreement between physical examination and angiography (Table 1).

Analysis of the forearm and upper arm fistulas revealed no significant difference in the level of agreement between physical examination and angiography. The κ for forearm and upper fistulas were 0.77 and 0.79, respectively. Similarly, no significant differences were found in the analysis of inflow stenosis (κ: forearm = 0.54, upper arm = 0.56). κ for coexisting lesions also did not show a significant difference for forearm and upper arm fistulas (forearm = 0.55, upper arm = 0.53). Both forearm and upper arm fistulas had similar κ score (mentioned previously) for central and body stenoses. Sensitivity and specificity for forearm and upper arm fistulas were virtually identical to those presented in Table 2 for the two sites of fistulas.

Discussion

Although physical examination is emerging as an important tool in the assessment of vascular access dysfunction, only a few reports have evaluated its utility in the detection of stenosis when compared with the gold standard (angiography) evaluation of an AVF (5–7). Mishler *et al.* (5) performed physical examination in 59 consecutive patients before undertaking an imaging investigation. Angiography was then performed. These investigators demonstrated that the physical examination was accurate in predicting stenoses in 91% of the cases. Choi *et al.* (6) examined the accuracy of physical examination in the detection of vascular access dysfunction in 48 patients with an AVF. Physical examination was performed 1 mo after the creation of the fistula. Venography was then performed, and the findings were compared with the physical examination. Twenty of the 48 patients demonstrated a normal physical

Table 2. Sensitivity and specificity of physical examination in the diagnosis of fistula stenosis[a]

Diagnosis	TP	FP	FN	TN	SEN	SPE	PPV	NPV	PREV
Inflow stenosis	77	15	14	36	0.85	0.71	0.84	0.72	0.64
Outflow stenosis	79	8	7	48	0.92	0.86	0.91	0.87	0.61
Coexisting inflow-outflow stenosis	30	14	16	82	0.68	0.84	0.65	0.85	0.31
Central vein stenosis	4	1	28	109	0.13	0.99	0.80	0.80	0.23
Body stenosis	6	20	9	107	0.40	0.84	0.23	0.92	0.10

[a]FN, false negative; FP, false positive; NPV, negative predictive value; PPV, positive predictive value; PREV, prevalence of diagnosis by angiography; SEN, sensitivity; SPE, specificity; TN, true negative; TP, true positive.

examination. Angiography did not reveal a problem in 19 of the 20 cases ($P < 0.001$). In only one case was the angiography abnormal. In contrast, 28 cases showed an abnormal physical examination. A great majority (70%) of these patients displayed an abnormal angiography ($P < 0.001$). The authors concluded that physical examination could accurately detect vascular access dysfunction. In another study of 68 newly created fistulas, 24 were diagnosed to have early failure on physical examination (7). All were found to have positive findings on angiography. Although these reports emphasize the strength of physical examination, they are limited by multiple confounders, such as the study design, a small sample size, lack of independent assessment of the angiographic images, and bias, because the same physician who had performed the physical examination read the images. In addition, neither the objective assessment of the agreement between the physical examination and angiography nor the sensitivity and specificity of this test were examined by these studies. By comparing it with the gold standard (angiography), this study objectively assessed the accuracy of the physical examination in the diagnosis of various types of lesions. κ values to ascertain the agreement between the physical examination and angiography as well as sensitivity and specificity were investigated by this study. Using a systematic approach, the study demonstrated excellent results in the detection of stenoses by physical examination in the access system.

The diagnostic elements of the physical examination used in the evaluation of an outflow lesion included the presence of a water-hammer pulse (hyperpulsation), systolic thrill (bruit), and abnormal arm elevation test (2–4). Physical examination in the diagnosis of outflow stenosis demonstrated excellent sensitivity and specificity (92 and 86%, respectively) with an outstanding κ value (0.78; Tables 1 and 2). Such high sensitivity makes the physical examination a valuable tool to screen for the presence or absence of outflow stenosis. The decent specificity observed for this type of lesion translated into a very high probability that if the examination were negative, then 86% of the patients would not demonstrate an outflow stenosis. In addition to the detection of stenosis, pinpointing the location of the lesion on physical examination has important particle implications. A positive test will certainly alert the interventionalist to cannulate the vascular access in an antegrade manner, thereby avoiding cannulation in a wrong direction. This could potentially save time, minimize morbidity, and reduce cost. Similarly, performing the physical examination during angioplasty of the stenosis can assist in gauging the response to balloon dilation.

The diagnostic elements of the physical examination used in the assessment of inflow stenosis included the presence of a weak pulse (hypopulsation, flat access), lack of a continuous thrill, and abnormal augmentation test (2–4). The physical examination in this scenario had good sensitivity (85%) and moderate specificity (71%). The agreement between the physical examination and the angiographic images for the inflow stenosis was somewhat less than that for the outflow stenosis. The cause of this discrepancy was unclear. Perhaps grading of how well an access augments upon occlusion into various categories will detect more stenoses on physical examination. For example, an access with a 50% inflow stenosis will still augment but not as robustly as an access with no inflow stenosis. It is conceivable that some of such cases were missed on our physical examination because we categorized the test into those who augmented (even if it was a slight augmentation) and those who did not. Despite this, the κ value of 0.55 showed strong agreement beyond chance between the physical examination and angiography. Just like an outflow lesion, pinpointing the location of stenosis would allow the interventionalist to cannulate the access in a retrograde direction and gauge response to dilation of the lesion during an angioplasty procedure.

The frequency of coexisting lesions in this study was consistent with previously published information (8). Physical examination to detect a coexisting lesion presented an interesting scenario. Here, both an abnormal augmentation and arm elevation tests assisted in establishing the diagnosis of coexisting lesions. This study found strong agreement beyond chance regarding the diagnosis of coexisting inflow-outflow lesions between the physical examination and angiography. Such lesions usually are approached using an antegrade as well as a retrograde cannulation.

Clinical features that contribute to the diagnosis of central stenosis include edema of the arm and shoulder; breast, supraclavicular, neck, and face swelling; and abnormal arm elevation test. The physical examination presented excellent specificity of 99%, making it a good test to rule out the disease; however, its sensitivity was poor, rendering physical examination not useful as a screening tool. Intuitively, one would imagine that by virtue of its clinical features, the diagnosis of central stenosis would be easy to establish by physical examination. Why, then, did this study demonstrate poor agreement ($\kappa = 0.17$) between the physical examination and angiography in the diagnosis of central venous stenosis? This might be explained by the fact that a great majority (59%) of patients with central stenosis had a coexisting outflow lesion. In this context, the presence of an outflow lesion could prevent downstream flow to the degree that the symptoms of central venous stenosis might be masked. The examination of the lesions in the body of the AVF has good specificity (84%) in the context of low prevalence (10%).

This study has some limitations. The analysis did not address the variability of the interpretation of angiography because only one interventionalist read the angiographic images. In addition, the angiography was used in a restricted manner because only still images were evaluated by the independent reviewer. Cinematography runs and two independent reviewers might result in a better assessment of vascular access. Finally, analysis of cases showing accessory veins were excluded from this report because the mode of retrograde angiography used in this study could highlight veins that were not otherwise hemodynamically significant. Accessory veins should be evaluated using a technique that does not involve outflow obstruction that would tend to increase intraluminal pressure and cause insignificant side branches to be augmented. The use of a vascular catheter introduced into the artery would serve this purpose. Finally, the test was performed by an interventional nephrologist with significant experience in the physical examination of vascular access. Future studies should evaluate the role of this tool when performed by multiple examiners.

Conclusions

The findings of this study demonstrate that physical examination can be an important tool in the diagnosis and localization of an AVF stenosis. We suggest that this tool be used as common practice by nephrologists.

Disclosures

None.

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