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Duplex Ultrasonography in the Detection of Celiac Axis Stenosis: A Validation Study[1]

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Purpose: To assess the predictive value of duplex ultrasonography in the detection of celiac axis (CA) stenosis.

Materials and Methods: In 127 patients designated for coronary artery bypass graft surgery (CABG), lateral aortography for the evaluation of CA stenosis was performed between January and October 2001. Thirty-nine of these patients [M:F = 30:9; age, 44 - 75 (mean, 62) years] underwent CA duplex scanning in the supine position using 2 - 4 MHz convex probes. CA diameters obtained at lateral aortography were subsequently measured by two radiologists, unaware of the duplex results, and the original duplex velocity values were determined using velocity criteria such as peak systolic velocity (PSV), peak diastolic velocity (PDV) and end diastolic velocity (EDV).

Results: CA stenosis was confirmed at lateral aortography in 13 patients (M:F = 10:3), in all of whom CA stenosis was greater than 50%. PSV in the CA stenosis group ($n = 13$) was 283±96 cm/sec, PDV was 85±49 cm/sec, and EDV was 55±33 cm/sec, while the corresponding values in the normal CA group were 161±55 cm/sec, 59±21 cm/sec, and 32±9 cm/sec, respectively. PSV was significantly different between the normal and stenosis groups ($p < 0.01$). A threshold of PSV > 250 cm/sec provided high diagnostic accuracy in terms of sensitivity (77%), specificity (85%), positive predictive valve (71%), negative predictive value (88%) and accuracy (82%). EDV > 50 cm/sec provided lower sensitivity (46%), but higher specificity (96%).

Conclusion: The most accurate predictive factor for celiac axis (CA) stenosis was increased PSV. Duplex ultrasonography can be used prior to angiographic evaluation as a screening test for patients in whom CA stenosis is suspected.

Index words : Arteries, stenosis or obstruction
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Celiac axis (CA) stenosis or occlusion is not an uncommon clinical situation in asymptomatic individuals, and its overall incidence in Korea is 7.3% (1). Other investigators have reported that its incidence in the West ranges from 12.5 to 24% (2 - 4). The detection of CA stenosis is very important and in certain clinical situations can be critical. The right gastroepiploic artery has been proven reliable in arterial grafting during coronary artery bypass graft surgery (CABG), and to determine the hemodynamic and anatomic status of the CA, its evaluation is mandatory if this procedure is to be successful (5). In addition, severe CA stenosis accompanied with vascular compromise of the other splanchnic arteries can cause abdominal angina, although this is not a common occurrence (6). Angiographic examination has been considered the gold standard for the evaluation and diagnosis of CA stenosis, but because of its invasiveness, most physicians are reluctant to use it an early stage.

Since Jager et al. (7) suggested that duplex ultrasonography (US) might serve as a screening test for chronic mesenteric ischemia, several investigators (8 - 15) have suggested that duplex US could also be used as a screening tool to help detect high-grade stenosis of the CA and superior mesenteric artery (SMA).

In 1993, Moneta et al. (8) published the first prospective validation of their mesenteric diagnostic criteria, using duplex US for evaluation of the splanchnic arteries.

A B

C

Fig. 1. True positive duplex US in a 64-year-old woman with high grade CA stenosis.
A, B. The PSV of the proximal CA (arrow) on the abdominal Doppler US is 340 cm/sec.
C. Lateral projection of aortography shows a greater than 90% stenosis at the proximal CA (arrow).

In 1991, Moneta et al. (9) determined Doppler velocity thresholds for SMA and CA stenosis on the basis of a retrospective comparison of duplex ultrasound data obtained in 34 patients, who were diagnosed as splanchnic artery stenosis at lateral aortographies. They insisted that PSV or the absence of flow signals in an identified artery is accurate parameter for the diagnosis of splanchnic arterial stenosis of greater than 70% or its occlusion. In contrast to Moneta's findings, however, Bowersox et al. insisted that end diastolic velocity (EDV) is more accurate than PSV in the diagnosis of SMA stenosis (10).

The purpose of this study was to evaluate the predictive value of duplex scanning in the detection of CA stenosis of greater than 50%, using duplex US criteria such as PSV, peak diastolic velocity (PDV), and EDV.

Materials and Methods

Patient selection

In 127 consecutive patients about to undergo CABG between January and October 2001, the CA was evaluated by means of lateral aortography. Of the 127, 39 patients [M:F = 30:9;age, 44 - 75 (mean, 62) years] underwent CA duplex US prior to the aortography, and these comprised the study group on whom this report was based.

CA duplex US

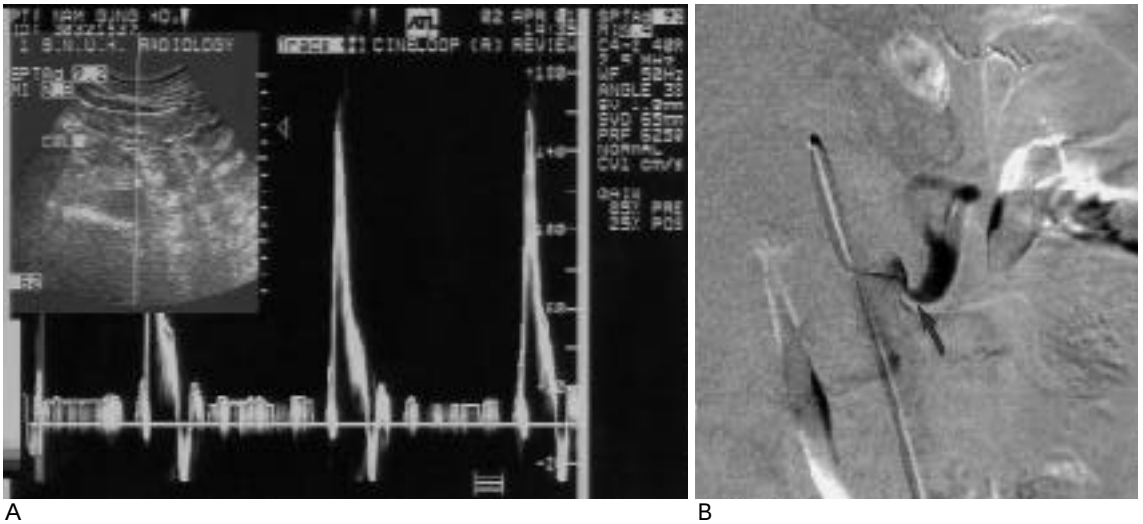
Duplex scanning was performed by one radiologist unaware of the results of angiography. Since food intake is known to substantially alter mesenteric velocities and waveform characteristics, the patients were examined following overnight fasting (11, 12).

For all studies, we used an Ultramark-9 scanner with a C4-2 probe (Advanced Technology Laboratories, Inc., Bothell, Washington, U.S.A.); its imaging frequency is 4.0 to 2.0 MHz and its Doppler frequency, 2.5 MHz. All patients were required to assume the supine position.

At duplex US, an effort was made to identify the origin of the CA along the anterior surface of the aorta in a single view, and a sagittal approach was thus used. Most cases of CA stenosis occur at the point where the CA originates from the aorta, and velocity was thus measured in the proximal CA, adjacent to its point of origin. Doppler flow spectral data, including PSV, PDV, and EDV were obtained. Close attention should be paid to sample volume angle correction during the determination of velocities, which should be measured only at Doppler angles of 30 - 60 degrees, and during the procedure, this protocol was observed. If the sample volume, flowing within a well-imaged vessel, does not provide a Doppler signal, total arterial occlusion is indicated.

Angiography

For cardiovascular imaging, lateral projection aortography was performed using an Integris BH 5000 system (Philips Medical Systems, Best, The Netherlands). The images obtained were evaluated by two radiologists, and percentage CA stenosis was thus determined. This



A B

Fig. 2. False negative duplex US stenosis in a 60-year-old man with CA stenosis.
A. The PSV of the proximal CA on the abdominal Doppler US is less than 180 cm/sec.
B. Lateral projection of aortography shows a greater than 75% stenosis at the proximal CA (arrow). In this patient, the tortuous course of the proximal CA may contribute to the erroneous velocity recording in the proximal CA.

was deemed significant if luminal narrowing exceeded 50%.

Data analysis

The diagnostic criteria used at duplex scanning to indicate CA stenosis were as follows: the lesion was considered significant (stenosis (50%) when PSV was greater than 250 cm/sec, PDV greater than 100 cm/sec, and EDV greater than 50 cm /sec.

According to the findings of duplex scanning, patients were assigned to one of two groups: "CA stenosis or occlusion" or " insignificant stenosis". Using the Mann-Whitney test, we considered that the difference was statistically insignificant if the p was greater than 0.05.

For each of the three possible sources of information, PSV, PDV and RDV, sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy were evaluated.

Results

Among the 39 patients examined by aortography and duplex US, 13 had CA stenosis greater than 50% and the other 26 had a normal CA. In the CA stenosis group, the findings were as follows: PSV, 283±96 cm/sec; PDV, 85 ±49 cm/sec; and EDV, 55±33 cm/sec. In the normal CA group, however, the corresponding findings were 161±55 cm/sec, 59±21 cm/sec, 32±9 cm/sec. Only when the velocity criteria of PSV were used, was there only found to be a significant statistical difference between the CA stenosis group and the normal CA group ($p < 0.01$). The findings of PDV ($p = 0.196$) and EDV ($p = 0.101$), indicated no statistically significant difference between the two groups.

Using PSV threshold of 250 cm/sec, CA stenosis was identified in ten cases (Fig. 1). Three false negative cases encountered (Fig. 2). Among the 26 patients with less than 50% stenosis, Duplex sonographic diagnosis was correct in 22 cases; there were four false-positive cases (Fig. 3). Duplex US showed a sensitivity of 77%, a specificity of 85%, a positive predictive value of 71%, a negative predictive value of 88%, and an overall accuracy of 82%; using a PDV velocity threshold of 100 cm/sec, sensitivity was 38%, specificity 96%, positive predictive value 83%, and negative predictive value of 74%. At an EDV threshold of 50 cm/sec, we found there was six true-positive cases and 25 true-negative cases. Thus, duplex US showed a sensitivity of 46%, a specificity of 96%, a positive predictive value of 86%, a negative predictive value of 78%, and an overall accuracy of 79%.

EDV was less accurate than PSV in the diagnosis of CA stenosis. A threshold of more than 50 cm/sec resulted in an attainable EDV accuracy of 79%, with low sensitivity (46%) but high specificity (96%). Reducing the EDV threshold to lower velocity values increased sensitivity, but because the number of false positives in-

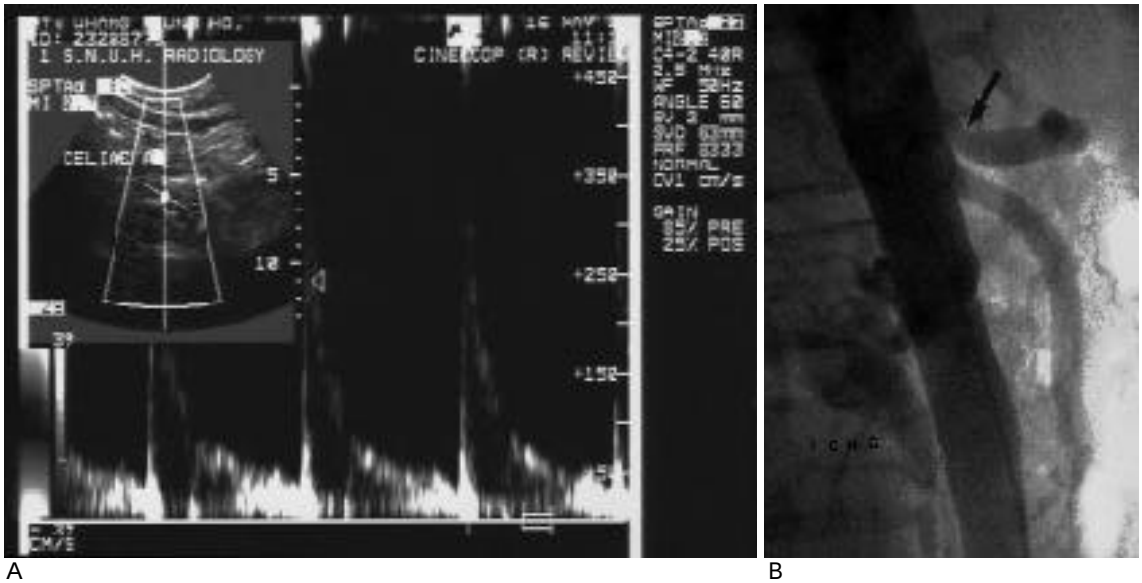


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Fig. 3. False positive duplex US in a 67 year-old man without CA stenosis.
A. The PSV of the proximal CA on the abdominal Doppler US is greater than 300 cm/sec.
B. On the lateral aortography there is no evidence of CA stenosis (arrow). In this patient, the tortuous course of the proximal CA may induce the erroneous velocity recording in the CA.

creased at a faster rate than that at which the number of false negatives decreased, this led to reduce overall accuracy.

Discussion

Since Jager et al.'s report (4), duplex US has been used by many investigators (8 - 13) for the noninvasive detection of high-grade splanchnic arterial stenosis or occlusion in patients in whom chronic intestinal ischemia is clinically suspected. Although a number of investigators (8 - 14) have insisted that duplex US is an accurate and useful screening method for the detection of CA and SMA stenosis, they have used different criteria for the diagnosis of different degrees of the stenosis, and no consensus has yet been achieved regarding diagnostic criteria nor the hemodynamically significant degree of CA or SMA stenosis.

We found a velocity threshold of PSV > 250 cm/sec, or the absence of a flow signal, to be the most accurate mesenteric duplex US diagnostic parameter for the identification of occlusion or CA stenosis of greater than 50%. Its overall accuracy was 82%, and the accuracy of PSV, at 82%, was better than that attained by means of any EDV threshold. Our observation that PSV provides substantially greater diagnostic accuracy is in agreement with previous analyses by Moneta et al. (8) and Lim et al. (12).

Our results are comparable to those of Moneta et al. (8) (sensitivity of 87%, specificity of 80%, and accuracy of 82% for CA stenosis or occlusion) and Lim et al. (corresponding figures of 100%, 87%, and 89% for the diagnosis of 70% or greater CA stenosis or occlusion). Using PSV criteria, we encountered four false-positive and three false-negative cases of either CA stenosis or occlusion. Moneta et al. (8), recorded 12 false-positive and three false-negative cases in the detection of CA stenosis or occlusion, and Lim et al. (12) made nine false-positive diagnoses of CA stenosis or occlusion but found no false negative cases of CA stenosis. The difference between Lim et al.'s report and ours in terms of the number of false-positive and false-negative cases could be due to factors such as diagnostic criteria and inter-observer variability (14).

The false-negative cases in our study may have arisen because of the complexity of the CA anatomy, and technical problems such as Doppler angle correlation. The CA orifice is located deep in the abdomen, and the course of the proximal CA is usually tortuous, thus perhaps disturbing the precise location of the Doppler sample volume in the stenotic segment. Improper placement of this sample volume, involving an incorrect or improper Doppler angle, is the most common cause of erroneous spectral waveforms, which result in incorrect velocity measurements. The false-positive cases encountered may be due not only to extrinsic compression caused by the sonographic probe, but also the effect of respiration: the CA is located just below the median arcuate ligament, which can compress it, especially during expiration.

Another limitation of mesenteric duplex scanning that may give rise to false-negative or false-positive diagnosis is inter-observer variability in the administration of duplex US examination, as described by Zoli et al. (14). They found that PSV of the SMA, as recorded by different operators, were significantly different.

In conclusion, our data suggest that despite certain limitations, an analysis of duplex US criteria based on PSV measurements constitutes a useful and accurate approach to the diagnosis of CA stenosis.

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이중초음파검사를 이용한 복강동맥협착 진단의 유효성[1]

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박창민 · 박재형[1, 2, 3] · 최영호 · 성낙종 · 윤창진 · 정진욱[1, 2, 3]

목적: 복강동맥(celiac axis, 이하 CA)의 협착을 진단하는데 있어서, 이중초음파검사의 진단적 추정도(predictive value) 를알아보고자하였다.

대상과 방법: 2001년 1월에서 10월 사이에 관상동맥 우회로 수술(CABG)을 위한 수술 전 CA 협착 평가를 위해, 대동맥 조영술을 시행한 127명의 환자들 중에서, CA 이중 초음파검사를 시행한 39명의 환자들(남: 30명, 여: 9명, 나이: 44 - 75세, 평균 나이 62세)를 대상으로 하였다. 이중 초음파검사는 앙와위(supine)로 2 - 4 MHz의 초음파 탐촉자를 이용하여 한명의 방사선과 의사가 시행하였다. CA 이중 초음파검사를 통해, 최고 수축기 속도(peak systolic velocity, 이하 PSV), 최고 이완기 속도(peak diastolic velocity, 이하 PDV), 확장기말 속도(end diastolic velocity, 이하 EDV)를 분석하였다. CA 이중 초음파검사 결과를 모르는 2명의 방사선과 의사가 대동맥 조영술의 측면 투사영상(lateral aortography)을 통해 CA의 협착여부및그정도를평가하였다.

결과: 대동맥조영술에서 13명의 환자(남 10명, 여 3명, 나이 44세 - 75세)가 적어도 50%이상의 CA 협착이 있는 것으로 진단되었다. 이들 환자들(n=13)에서, 측정한 PSV는 283±96 cm/sec; PDV는 85±49 cm/sec; EDV는 55±33 cm/sec 이었고, 반면, CA 협착이 없는 환자군(n=26) 에서는 각각 161±55 cm/sec; 59±21 cm/sec; 32±9 cm/sec로 측정 되었다. CA 협착이 있는 환자군과 협착이 없는 환자 군에서 PSV가 통계적으로 유의한 차이를 보였다(p < 0.01). CA 협착의 이중초음파진단의기준을 PSV > 250 cm/sec으로하였을때, 높은진단적정확도를보였는데, 민감도(sensitivity) 77%, 특이도(specificity) 85%, 양성 예측도(positive predictive valve) 71%, 음성 예측도(negative predictive value) 88% 그리고 정확도(accuracy) 82%로 나타났다. 진단적 기준을 EDV > 50 cm/sec 했을 경우에는 낮은민감도(46%), 및높은특이도(96%)를보였다.

결론: 복강동맥 협착을 진단하는데 있어 가장 정확한 추정인자는 PSV이며, 복강 동맥 협착이 의심되는 환자에서 혈관조영술전에유용한선별검사로사용될수있다.