From the Southern Association for Vascular Surgery

Mesenteric artery disease in the elderly

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Purpose: **The purpose of this study was to estimate the population-based prevalence of mesenteric artery stenosis (MAS) and occlusion among independent elderly Americans.**

Method: **As part of an ancillary investigation to the Cardiovascular Health Study (CHS), participants in the Forsyth County, NC cohort had visceral duplex sonography of the celiac arteries and superior mesenteric arteries (SMAs). Critical MAS was defined by celiac peak systolic velocity ≥2.0 m/s and/or SMA peak systolic velocity ≥2.7 m/s. Occlusion of either vessel was defined by lack of a Doppler-shifted signal within the imaged artery. Demographic data, blood pressures, and blood lipid levels were collected as part of the baseline CHS examination. Participants' weights were measured at baseline and before the duplex exam. Univariate tests of association were performed with two-way contingency tables, Student *t* tests, and Fisher exact tests. Multivariate associations were examined with logistic regression analysis.**

Results: **A total of 553 CHS participants had visceral duplex sonography technically adequate to define the presence or absence of MAS. The study group had a mean age of 77.2 ± 4.9 years and comprised 63% women and 37% men. Participant race was 76% white and 23% African-American. Ninety-seven participants (17.5%) had MAS. There was no significant difference in age, race, gender, body mass index, blood pressure, cholesterol, or low-density lipoproteins for participants with or without MAS. Forward stepwise variable selection found renal artery stenosis (*P* = .008; odds ratio [OR], 2.85; 95% confidence interval [CI], 1.31, 6.21) and high-density lipoprotein >40 (*P* = .02; OR, 3.03; 95% CI, 1.17, 7.81) significantly associated with MAS in a multivariate logistic regression model. Eighty-three of the 97 participants with MAS (15.0% of the cohort) had isolated celiac stenosis. Seven participants (1.3% of the cohort) had combined celiac and SMA stenosis. Five participants (0.9% of the cohort) had isolated SMA stenosis. Two participants (0.4% of the cohort) had celiac occlusion. Considering all participants with MAS, there was no association with weight change. However, SMA stenosis and celiac occlusion demonstrated an independent association with annualized weight loss (*P* = .028; OR, 1.54; 95% CI, 1.05, 2.26) and with renal artery stenosis (*P* =.001; OR, 9.48; 95% CI, 2.62, 34.47).**

Conclusion: **This investigation provides the first population-based estimate of the prevalence of MAS among independent elderly Americans. MAS existed in 17.5% of the study cohort. The majority had isolated celiac disease. SMA stenosis and celiac artery occlusion demonstrated a significant and independent association with weight loss and concurrent renal artery disease. (J Vasc Surg 2004;40:45-52.)**

Modern concepts of mesenteric artery disease in the elderly began when Councilman[1] reported three cases of superior mesenteric artery (SMA) occlusion associated with abdominal pain over a century ago. Although he correctly suggested that gradual occlusion of major mesenteric arteries could be responsible for intestinal ischemia causing abdominal pain, his reasoning seemed flawed. Autopsy evidence demonstrated that severe mesenteric artery stenosis (MAS) or occlusion could occur without abdominal pain.[2] In fact, Osler[3] maintained that abdominal pain in conjunction with systemic atherosclerosis associated with MAS reflected coronary artery disease and myocardial ischemia.

Despite these early controversies, a relationship between multiple-vessel MAS and intestinal symptoms is now well recognized. However, the diagnosis and management of MAS remains enigmatic.[4] This is especially true in the elderly, in whom shared symptomatology with other diseases may contribute to the diagnostic dilemma. All too often, MAS associated with chronic symptoms may progress to inanition or to acute on chronic mesenteric ischemia with resultant intestinal gangrene.[5] These unacceptable outcomes reflect delayed definitive therapy, in part due to the diagnostic challenge posed by the disease. In this regard, the proportion of MAS contributing to recognizable symptoms in the elderly is poorly characterized.

Data regarding these important issues are lacking because the prevalence of MAS in the elderly population is not known. In the past, estimates of MAS were made from case-series autopsy[6-11] and angiographic[12-15] studies. Population-based estimates were not available because evaluation of the mesenteric arteries required angiography. Recently, a number of less invasive methods of evaluation have been developed and validated. Among these, visceral duplex

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sonography (VDS) has particular appeal for the population-based study of MAS.[16] This non-invasive study poses no participant risk, and requires only an overnight fast for preparation.

This report uses VDS to determine the prevalence of MAS among independent, community-dwelling elderly participants in the Forsyth County cohort of the Cardiovascular Health Study (CHS).[17] Specific areas of interest include (1) prevalence of celiac and SMA stenosis or occlusion; (2) the association of MAS with demographic characteristics, atherosclerotic risk factors, and antecedent weight loss.

METHODS

The Cardiovascular Health Study. The design of the Cardiovascular Health Study (CHS) has been previously described.[17] Briefly, the CHS is a prospective, multicenter, observational cohort study of cardiovascular disease risk factors, morbidity, and mortality among Americans over the age of 65. The initial CHS cohort was recruited from a randomly selected sample of Medicare eligible individuals in four US communities (Forsyth County, NC; Sacramento County, Calif; Washington County, Md; and Allegheny County, Pa). Initial recruitment was performed between April 1989 and May 1990. A supplemental cohort of predominantly African-American participants was recruited by the same methods from June 1992 to June 1993 to allow for racial subgroup analyses.

All CHS enrollees underwent a baseline examination consisting of a detailed medical history and clinical examination. Clinical examination included physical examination and phlebotomy, which included measurement of serum creatinine levels. Annual follow-up examinations were performed to update medical history data, assess the occurrence of cardiovascular disease events, and repeat portions of the clinical examination at previously defined intervals.[17] Weights were measured on a single, calibrated eye-level physician scale (Detecto, Webb City, Mo) with participants' outer garments, shoes, and pocket contents removed. Blood pressure and weight measures were taken at each annual follow-up visit. Repeat phlebotomy was performed in 1992 and 1993, 1996 and 1997, and at the time of the visceral duplex examination.

Visceral duplex sonography. As an ancillary study funded through the National Institute of Diabetes and Digestive and Kidney Disease, CHS participants in the Forsyth County cohort received abdominal duplex sonography between January 1995 and February 1997. The primary aim of this ancillary study was to define the prevalence of renovascular disease in the Forsyth County cohort. An additional goal was to determine the presence or absence of mesenteric artery disease, defined as celiac axis and SMA stenosis or occlusion. Participants scheduled for routine annual examination were contacted by telephone and informed of this ancillary project. This study was approved by the Wake Forest University Human Subjects Review Committee.

VDS was performed with an Ultramark-9 HDI Ultrasound System (Advanced Technologies Laboratories, Bothell, Wash). All VDS was performed by two registered vascular technologists with extensive experience in abdominal duplex evaluation. Written informed consent was obtained from CHS participants on return for their annual examination. During that same visit, consenting participants were studied with VDS at the CHS Forsyth County Field Center. As part of the annual examination, CHS participants had fasted overnight.

A complete study examined both renal arteries, the celiac axis, and SMA. Renal duplex sonography was performed first followed by VDS. To minimize participant burden, the protocol design allowed 20 minutes for completion of the entire examination. With the participant supine, a 2.25-MHz or 3.0-MHz ultrasound probe was coupled to the abdominal skin with acoustic gel 3 or 4 cm inferior to the xiphoid process. Interrogation of each renal artery and kidney was performed as described previously.[18] The SMA was then scanned longitudinally for its first 5 cm. PSV was recorded at an angle of insonation $<60°$. The celiac artery was then imaged during shallow respiration to its bifurcation. PSV along the vessel's length was recorded at an angle of insonation $<60°$.

All B-mode and Doppler spectral data were collected on super VHS tape and transferred to an electronic database. This process was repeated and the data compared for agreement. A 3% discordance in electronic data was adjudicated from review of the original duplex study.

For the purposes of this report, VDS study was considered negative or positive for hemodynamically significant MAS or inadequate for interpretation according to the following criteria: (1) VDS was negative for MAS when celiac artery PSV from aortic origin to bifurcation was <2.0 m/s and SMA PSV was <2.7 m/s for its first 5 cm; (2) VDS was positive for MAS ($\geq 70\%$ diameter-reducing stenosis) when there was a focal increase in celiac artery PSV ≥ 2.0 m/s, or a focal SMA increase in PSV ≥ 2.7 m/s, or no Doppler signal obtained from an imaged artery (arterial occlusion); (3) VDS was technically inadequate for interpretation when the mesenteric vessel was not imaged or when celiac or SMA Doppler signals were not obtained from aortic origin to its first major branch. These VDS criteria for $\geq 70\%$ diameter-reducing arterial stenosis have been validated prospectively in comparison with conventional mesenteric angiography.[16] Accuracy of mesenteric sonography in the Wake Forest University clinical vascular lab was retrospectively reviewed. Over a 3-year period, 372 mesenteric duplex exams were performed. Of these, 47 patients had both mesenteric duplex and angiography available for review. Overall SMA accuracy was 94%, and celiac accuracy was 83%. Sensitivity in the SMA and celiac were 100% and 82%, respectively. Specificity in the SMA and celiac were 95% and 86%, respectively.

Statistical analysis. After ancillary study data were keyed and verified, results of duplex sonography exams were matched with participant data provided by the CHS coordinating center. Statistical comparison of CHS partic-

Table I. Demographics and baseline atherosclerotic risk factors among CHS participants (N = 1245)

Variable	*Definition*	*Recruited (n = 870)*	*Non-recruited (n = 375)*	P
Age* (y)	Mean, SD	77.3 ± 4.9	79.7 ± 5.9	<.001
Gender				.753
	Male (%)	37.5	36.5	–
	Female (%)	62.5	63.5	–
Systolic blood pressure	mm Hg (mean, SD)	135 ± 21	139 ± 23	<.001
Diastolic blood pressure	mm Hg (mean, SD)	72 ± 10	73 ± 12	.209
Clinical hypertension	Systolic blood pressure >160 mm Hg *or* diastolic blood pressure >95 mm Hg *or* taking antihypertensive medication (%)	41.4	46.1	.126
Diabetes mellitus	Fasting glucose >140 mg/dL *or* 2-h post glucose load >200 mg/dL *or* taking insulin or oral hypoglycemic agent (%)	20.8	24.8	.121
Renal insufficiency	serum Cr ≥1.5 mg/dL (male), ≥1.3 (female)	7.1	14.0	<.001
Cigarette smoking	Current or former smoker (%)	46.4	56.1	.002
Hypercholesterolemia	Total cholesterol >240 mg/dL (%)	18.3	18.8	.859
Elevated LDL-C	LDL-C >130 mg/dL (%)	16.6	18.1	.502
Decreased HDL-C	HDL-C <40 mg/dL (%)	16.2	15.2	.655
Obesity	Greater than 130% ideal body weight (%)	30.2	24	.025

CHS, Cardiovascular Health Study; *LDL-C,* low-density lipoprotein; *HDL-C,* high-density lipoprotein.
*Age at the time of visceral duplex sonography.

ipants included and not included in the VDS study were evaluated by examining differences in baseline characteristics (χ^2 tests for categorical factors, *t* tests for continuous factors) between the two groups. In addition, change in weight was defined as the participant's baseline weight minus the weight at the time of VDS study in pounds. Annualized weight loss is the change in weight divided by the number of years between measurements. These are continuous variables in the univariate analysis and dichotomous variables at 1 standard deviation change in the multivariate model. For each, a positive number signifies weight loss over time. Estimates of MAS prevalence were computed for the group as a whole, and by gender and age strata.

Description of baseline characteristics by MAS status was examined by using means and standard deviations (for continuous factors) or relative frequencies (for categorical factors). Prevalence odds ratios (OR) of MAS were estimated for each factor via univariate logistic regression models. A "best" multivariate logistic regression model to predict MAS was constructed by using a forward stepwise variable selection procedure where, beginning with the most significant, candidate variables with a *P* value <0.10 were selected one by one for model inclusion. All variables remaining significant at a 0.05 α level were included in the final model.[19]

Analysis was performed for the group with any hemodynamically significant stenosis of the celiac or SMA as defined previously. In addition, the same analysis was repeated for the subgroup with SMA disease, either alone or in combination with the celiac, or with complete occlusion of the celiac axis (SMA/CeO).

This subgroup analysis was performed to minimize the presence of extrinsic celiac compression. The SMA/CeO subgroup was considered to represent a conservative estimate of MAS or occlusion due to atherosclerosis.

RESULTS

Between January 1995 and February 1997, 1245 Forsyth County participants returned to the CHS Field Center for annual examination. Among returning participants, 870 gave consent for duplex sonography, providing 69.9% recruitment efficiency. Table I defines the atherosclerotic risk factors examined and compares the CHS participants who accepted and declined VDS. Compared with participants studied with VDS, participants not evaluated were significantly older, had higher systolic blood pressures, were more likely to have renal insufficiency, and had a greater rate of tobacco use. They had a lower prevalence of obesity.

A total of 870 participants consented to VDS examination. This group consisted of 544 women (63%) and 326 men (37%), with a mean age of 77.3 ± 4.9 years. Participant race was 76% Caucasian and 23% African-American. The average time for abdominal duplex examination was 18.3 ± 3.9 minutes.

Of these 870 abdominal duplex examinations, 553 (62%) were technically satisfactory to define the presence or absence of MAS. Table II compares demographic characteristics and atherosclerotic risk factors between the 553 participants with technically satisfactory VDS and the 317 participants who had technically inadequate studies. Compared with technically satisfactory examinations, participants with inadequate VDS were more likely male, had higher rates of tobacco abuse, and demonstrated significantly higher body mass indexes at baseline.

Overall, 97 of 553 participants (17.5%) with technically adequate VDS demonstrated MAS (Table III). Of the 97 participants with MAS, 83 (86%) had isolated celiac steno-

Table II. Summary statistics for CHS participants studied by visceral duplex sonography (N = 870)

Variable	*Technically satisfactory (n = 553)*	*Technically incomplete (n = 317)*	P
Age (mean, SD)*	77.3 ± 4.9	77.5 ± 5.0	.576
Gender			
Male (%)	31.1	48.6	
Female (%)	68.9	51.4	<.001
Systolic blood pressure (mean, SD)	135 ± 21	135 ± 20	.762
Diastolic blood pressure (mean, SD)	72 ± 11	73 ± 10	.305
Clinical hypertension (%)	40.8	42.6	.600
Diabetes mellitus (%)	18.4	23.9	.078
Renal insufficiency (mean, SD)	7.2	6.8	.801
Smoking (%)	43.5	51.3	.028
Hypercholesterolemia (%)	19.9	15.6	.111
Elevated LDL-C (%)	17.6	14.8	.294
Decreased HDL-C (%)	14.4	19.4	.058
Body mass index (mean, SD)	26 ± 4.4	27 ± 4.6	<.001
Obesity (%)	28.4	33.4	.119

CHS, Cardiovascular Health Study; *LDL-C,* low-density lipoprotein; *HDL-C,* high-density lipoprotein.
*Age at time of renal duplex sonography all other variables assessed at baseline.

Table III. Prevalence of MAS by anatomic location

Category (participants)	*Prevalence within cohort*
All mesenteric stenosis (n = 97)	17.5%
Isolated celiac stenosis (n = 83)	15.0%
Combined celiac and SMA stenosis (n = 7)	1.3%
Isolated SMA stenosis (n = 5)	0.9%
Celiac occlusion (n = 2)	0.4%

MAS, Mesenteric artery stenosis; *SMA,* superior mesenteric artery.

Table IV. Prevalence of MAS among participants with technically satisfactory VDS

Category (participants)	*Prevalence of MAS*†	*Prevalence of SMA/CeO*‡
Overall (n = 553)	17.5%	2.5%
Age strata*		
65 to 69 years (n = 19)	21.1%	5.3%
70 to 74 years (n = 197)	14.2%	2.0%
75 to 79 years (n = 213)	19.7%	2.4%
≥80 years (n = 124)	18.6%	3.2%
Gender		
Female (n = 381)	18.9%	3.2%
Male (n = 172)	14.5%	1.2%

VDS, Visceral duplex sonography; *MAS,* mesenteric artery stenosis.
*Age at time of VDS.
†SMA stenosis, SMA and celiac stenosis, celiac occlusion, or celiac stenosis.
‡SMA stenosis, SMA and celiac stenosis, or celiac occlusion.

sis, 7 (7%) had combined celiac and SMA stenosis, 5 (5%) had isolated SMA stenosis, and 2 (2%) had celiac occlusion. The prevalence of each of these anatomic subgroups of MAS within the entire study cohort was 15.0%, 1.3%, 0.9%, and 0.4%, respectively.

Table IV summarizes the prevalence of MAS relative to age strata at the time of duplex examination. The distribution of MAS by age strata was 65 to 69 years (4/19; 21.1%), 70 to 74 years (28/197; 14.2%), 75 to 79 years (42/213; 19.7%), and ≥80 years (23/124; 18.6%). In addition, the prevalence of MAS in the SMA/CeO subgroup is described. For those participants with either SMA stenosis or celiac occlusion, the distribution of disease by age strata was 65 to 69 years (1/19; 5.3%), 70 to 74 years (4/197; 2.0%), 75 to 79 years (5/213; 2.4%), and ≥80 years (4/124; 3.2%).

Table V summarizes the univariate analysis of demographic features and atherosclerotic risk factors and the presence of MAS. HDL-C >40 mg/dL and the presence of renal artery stenosis demonstrated univariate associations with MAS. None of the atherosclerotic risk factors defined in Table I had a statistically significant association with MAS. Hypertension, tobacco use, diabetes mellitus, obesity, hypercholesterolemia, and elevated low-density lipoprotein–C had no apparent association with MAS when considered as either categorical or continuous variables by univariate analyses. Multivariate analysis confirmed significant associations between high-density lipoprotein >40 mg/dL (P = .022; OR, 0.33; 95% confidence interval [CI], 0.13, 0.85) and the presence of renal artery stenosis (P =.008; OR, 2.85; 95% CI, 1.31, 6.19) with MAS.

Overall, 32 of 539 participants (6%) lost ≥10% of their baseline body weight over the study interval. Of the participants with weight data, 423 had no evidence of mesenteric stenosis and a mean weight gain of 0.1 pound. The 86 participants with MAS who had weight data lost an average of 1.7 pounds. The 12 participants in the SMA/CeO subgroup with baseline and follow-up weight measurements lost an average of 7.0 pounds.

Table VI summarizes a univariate analysis of participants with SMA stenosis, isolated or in combination with celiac stenosis, or celiac occlusion (SMA/CeO) compared with participants with either no MAS or with isolated celiac stenosis only. In this analysis, weight loss (P = .018; OR, 1.92; 95% CI, 1.12, 3.30) and the presence of renal artery steno-

Table V. Results of univariate analysis for MAS and associated risk factors*

Variable	*Participants with MAS (n = 86)*	*Participants without MAS (n = 423)*	*Odds ratio*	*95% CI*	P
Age†	78.0 ± 5.2	77.1 ± 4.7	1.23	0.98, 1.53	.075
Gender (male)			0.78	0.46, 1.31	.346
Male (%)	23 (26.7)	135 (31.9)			
Female (%)	63 (73.3)	288 (68.1)			
Renal artery stenosis (%)‡	11 (12.8)	22 (5.2)	2.67	1.24, 5.74	.012
Clinical hypertension (%)	42 (48.8)	159 (37.6)	1.59	0.99, 2.53	.053
Diabetes	17 (19.8)	80 (18.9)	1.06	0.59, 1.89	.854
Smoking	38 (44.2)	185 (43.7)	1.02	0.64, 1.63	.939
Hypercholesterolemia (%)	20 (23.3)	85 (20.1)	1.21	0.69, 2.10	.509
Elevated LDL-C (%)	21 (24.4)	72 (17.0)	1.58	0.91, 2.74	.108
Decreased HDL-C (%)	5 (5.8)	64 (15.1)	0.35	0.14, 0.89	.027
Systolic blood pressure§	137.6 ± 22.8	133.1 ± 20.3	1.24	0.98, 1.57	.072
Diastolic blood pressure§	71.9 ± 10.0	71.8 ± 10.8	1.01	0.80, 1.78	.941
Body mass index§	25.6 ± 4.1	26.1 ± 4.4	0.87	0.68, 1.12	.281
Weight loss§	1.7 ± 11.2	0.1 ± 9.7	1.13	0.91, 1.39	.237
Annualized weight loss§	0.3 ± 2.7	0.0 ± 2.6	1.14	0.91, 1.41	.245

MAS, Mesenteric artery stenosis; *CI,* confidence interval; *LDL-C,* low-density lipoprotein; *HDL-C,* high-density lipoprotein.
*Analysis for participants with data for all factors only.
†Odds ratio per 5-y increase.
‡Renal artery peak systolic velocity ≥1.8 m/s.
§Odds ratio per standard deviation change.

Table VI. Results of univariate analysis for SMA stenosis/celiac occlusion group and associated risk factors*

*Variable**	*SMA/CeO present (n = 12)*	*SMA/CeO absent (n = 497)*	*Odds ratio*	*95% CI*	P
Age†	77.6 ± 4.7	77.2 ± 4.8	1.09	0.62, 1.91	.760
Gender (male)			0.44	0.10, 2.02	.289
Male (%)	2 (16.7)	156 (31.4)			
Female (%)	10 (83.3)	341 (68.6)			
Renal artery stenosis (%)‡	4 (33.3)	29 (5.8)	8.09	2.30, 28.43	.005
Clinical hypertension (%)	4 (33.3)	197 (39.6)	0.76	0.23, 2.56	.660
Diabetes	3 (25.0)	94 (18.9)	1.43	0.38, 5.38	.598
Smoking	6 (50.0)	217 (43.7)	1.29	0.41, 4.06	.663
Hypercholesterolemia (%)	4 (33.3)	101 (20.3)	1.96	0.58, 6.64	.280
Elevated LDL-C (%)	4 (33.3)	89 (17.9)	2.29	0.62, 1.77	.183
Decreased HDL-C (%)	1 (8.3)	68 (13.7)	0.57	0.28, 4.51	.597
Systolic blood pressure§	130.6 ± 21.1	133.9 ± 20.8	0.84	0.46, 1.55	.579
Diastolic blood pressure§	71.3 ± 10.4	71.9 ± 10.6	0.94	0.53, 1.69	.841
Body mass index§	26.6 ± 5.1	25.9 ± 4.3	1.16	0.66, 2.02	.615
Weight loss (lbs)§	7.0 ± 6.8	0.1 ± 10.0	1.92	1.12, 3.30	.018
Annualized weight loss§	1.5 ± 1.3	0.1 ± 2.7	1.44	0.99, 2.11	.057

SMA, Superior mesenteric artery; *CeO,* celiac occlusion; *CI,* confidence interval; *LDL-C,* low-density lipoprotein; *HDL-C,* high-density lipoprotein.
*Analysis for participants with data for all factors only.
†Odds ratio per 5-y increase.
‡Renal artery peak systolic velocity ≥1.8 m/s.
§Odds ratio per standard deviation change.

sis (P = .001; OR, 8.07; 95% CI, 2.30, 28.4) had significant associations with SMA stenosis or celiac occlusion.

A multivariate analysis after forward step-wise variable selection was performed for the SMA/CeO subgroup. An annualized standard deviation decrease in body weight (P =.028; OR, 1.54; 95% CI, 1.05, 2.26) and the presence of renal artery stenosis ((P =.001; OR, 9.48; 95% CI, 2.62, 34.37) had significant and independent associations with SMA stenosis or celiac occlusion.

DISCUSSION

This study represents the first population-based estimate of MAS in the elderly. Overall, 17.5% of this cohort demonstrated celiac and/or SMA stenosis or occlusion. The majority of MAS was defined by isolated celiac artery stenosis, and MAS had a significant association with concomitant renovascular disease. Considering only CHS participants with SMA stenosis, isolated or in combination with celiac stenosis, or celiac occlusion, MAS demonstrated a significant and independent association with annualized weight loss.

Early autopsy and angiographic case series demonstrated some degree of MAS in 12% to 60% of subjects; however intestinal ischemia associated with MAS was exceedingly rare.[6-8,12,13] Although these reports drew attention to MAS, the early case series shared a number of common limitations. Numbers of mesenteric arteries examined in each series were small and subjects were generally selected on the basis of the presence of advanced atherosclerosis. Methods to estimate the presence and severity of disease were variable and MAS was not related to intestinal ischemia. In contrast to these limitations, the present study provides an estimate of >70% celiac and SMA stenosis or occlusion in a population-based cohort and relates this anatomic disease to one of the hallmark signs of chronic intestinal ischemia—decrease in body weight over time.

In the current report, the prevalence of MAS is lower than that observed in many earlier case series, but closely approximates the more recent report of Valentine and coworkers.[20] These investigators reported a case series of consecutive angiographic studies in men evaluated for aortic aneurysm and occlusive disease or lower extremity ischemia. A >75% diameter-reducing stenosis or occlusion was noted in 11.7% of celiac and 2.9% of SMAs. Overall, 2.9% of patients had significant stenoses of both celiac and SMAs. No patient demonstrated symptoms of intestinal ischemia, but a significant association was observed between unsuspected renovascular disease and MAS—an observation also demonstrated in this CHS cohort.

Few data are available that correlate MAS with the risk of intestinal ischemia. Dunphy's[21] classic observations relating intestinal symptoms with death from intestinal gangrene have not been replicated in a prospective series. In an attempt to define the clinical course of MAS, Thomas and colleagues[22] reviewed 980 consecutive angiograms to identify 82 patients with >50% stenosis of at least one mesenteric artery. Seventy-two patients were interviewed for symptoms of intestinal ischemia every 6 months. Overall, four patients developed symptoms of chronic intestinal ischemia before follow-up of 2.6 years. In each instance, patients with follow-up intestinal symptoms had significant stenosis of all 3 mesenteric arteries (ie, celiac, superior, and inferior). This study demonstrates the diagnostic dilemma associated with MAS. Multiple mesenteric artery disease, which is generally considered necessary for symptomatic intestinal ischemia, was observed in only 1.5% of patients. Even when multiple mesenteric arteries were diseased, only one in four patients developed intestinal symptoms.

The current study demonstrated a number of features similar to the Thomas et al findings. Even though 17.5% of this population had MAS, SMA stenosis or celiac occlusion was present in only 2.5%. Despite the fact that the intestinal risk of MAS would be presumed low, the finding of a significant and independent association between this pattern of MAS and annualized weight loss in a population-based study is a concern. Data gathered as part of the CHS do not allow assessment of intestinal symptoms in the cohort; however, follow-up of this subgroup may provide important estimates of intestinal risk associated with MAS.

A number of unique data are provided by this study, but a number of study limitations deserve comment. Indexed subjects from the CHS were collected through a two-step random process; however, eligible members from the sampled individual's household were also recruited.[23] This strategy was intended to enhance recruitment and retention of the elderly cohort for longitudinal observation. As a result, the final CHS cohort consisted of 70% of those initially sampled and 30% who were recruited because they shared the same household. This recruitment strategy may have introduced an important source of bias, since significant differences existed between randomly selected participants and those who chose not to participate in the CHS. The refusal rate was higher among women than men and enrolled participants were younger, more highly educated, more likely to be married, and less likely to be smokers.[23] In addition to this "healthy cohort" effect, the recruitment for VDS may have introduced other sources of bias. Compared with the 870 CHS participants recruited for duplex study, the 375 participants who declined study were older, had a greater history of tobacco use, and had a significantly lower instance of obesity. Each of these characteristics may have contributed to an underestimation of MAS.

In addition, requirements of the duplex protocol may have introduced unintended bias. VDS was performed in this cohort as part of an ancillary study that included renal duplex sonography. The specific aim of the duplex examination was to determine the presence or absence of hemodynamically significant renal artery stenosis or occlusion. The evaluation for MAS or occlusion was a secondary aim. To minimize the study burden on this elderly cohort, the duplex protocol limited the entire examination to 20 minutes. Ninety-six percent of renal duplex examinations were technically satisfactory; however, study time was inadequate for simultaneous VDS in one third of participants.[18] Compared with participants with adequate VDS, participants with inadequate studies were more likely men with a history of tobacco use.

Despite these study limitations, the Forsyth County CHS cohort provided a large, diverse group of community-dwelling men and women for VDS.[17,23] The results from VDS in combination with data already collected or being collected as part of CHS will provide important information regarding mesenteric artery disease. Continued follow-up of this cohort may provide important estimates of intestinal risk associated with MAS.

In summary, MAS was present in 17.5% of independent, community-dwelling elderly men and women. MAS demonstrated no association with age, race, gender, or hypertension. The presence of SMA stenosis or celiac artery occlusion had significant and independent associations with both annualized weight loss and concomitant renovascular disease. Continued follow-up of this cohort may provide unique estimates regarding the intestinal risk of MAS and provide rationale for management of mesenteric artery disease in the elderly.

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DISCUSSION

Dr Raymond S. Martin (Nashville, Tenn). This interesting report prompted me to review the incidental finding of unsuspected MAS in our office laboratory. Though we have not screened the general elderly population, I selected 100 consecutive abdominal arterial duplex scans done for aortic aneurysm surveillance in patients over 65 years of age.

As in other studies of patients with established advanced atherosclerosis, the overall prevalence of MAS was much higher, at 47%, than in Dr Hansen's study. Using the same systolic velocity criteria, 22 patients had renal artery stenosis, 42 had celiac stenosis, 20 had SMA stenosis, and 13 had stenosis of both major mesenteric vessels. Though these two cohorts are certainly not comparable, both demonstrate that celiac stenosis is far more common than SMA stenosis in asymptomatic patients.

My review of the paper raised the following 3 questions for discussion.

First, your study and others confirm a prevalence of mesenteric vascular disease far higher than the incidence of clinically symptomatic mesenteric ischemia. Does the use of the single simplistic criterion of peak systolic velocity overestimate this disease as compared with the estimates given by arteriography? Would the use of diastolic velocities, wave form analysis, or other criteria commonly employed in carotid evaluation give a more accurate picture?

Second, impingement of the median arcuate ligament on the celiac trunk is commonly seen on lateral aortograms. Do you know whether some patients you identified with celiac stenosis might have this phenomenon, resulting in overestimation of the prevalence of this lesion? It certainly does affect the overall estimate if you really don't know how many of these had atherosclerotic plaque versus median arcuate ligament syndrome.

Finally, you noted a significant fall in body weight in individuals with SMA stenosis or celiac occlusion as compared with those with celiac stenosis alone or no mesenteric artery stenosis. Were these patients otherwise symptomatic, and did any of them have infarction or clinical incidence during the course of follow-up? Your discovery of these patients with mesenteric artery stenosis and weight loss raises the question, is intervention indicated in patients with mesenteric artery stenosis and weight loss but no abdominal pain?

Dr David B. Wilson. We base the revascularization of the mesenterics on symptoms of postprandial pain and food fear and not just on weight loss. The finding of weight loss in a population we found interesting. What makes this study unique is that it wasn't performed on patients. While duplex exam isn't being advocated to screen for mesenteric stenosis in the general population, it is useful for patients selected through clinical criteria to have a high likelihood of disease.

You asked about the follow-up of our subgroup with SMA disease or celiac occlusion. We have taken a preliminary look at the outcomes and overall events in that group, and with a first look at the data through 2001 we did not see an association between the presence of disease and all-cause mortality or cardiac events. Unfortunately, the CHS is very well characterized in certain areas, such as whether a patient likes to eat his chicken with the skin on or the skin off, but it doesn't address whether or not he has pain after eating, so we don't have a lot of information about gastrointestinal symptoms.

The relevance of the median arcuate ligament compression isn't addressed in our data. Unfortunately duplex sonography is unable to distinguish between intrinsic arterial disease and extrinsic compression. We performed the subgroup analysis to exclude those patients most likely to have extrinsic compression, and this does make a conservative estimate of the impact of atherosclerosis in the population overall.

The first question was does peak systolic velocity alone overestimate the presence of stenoses and would diastolic velocities or other measurements add to the accuracy? In our pilot study we did not find that to be the case. In a population of 30 patients with about 20% disease prevalence, we found that the peak systolic velocity alone at 2.7 m/s for the SMA or 2.0 m/s for the celiac had the highest accuracy—positive and negative predictive values to correlate with a 70% angiographic stenosis.

Dr Mitchell Goldman (Knoxville, Tenn). Does inspiration and expiration affect the velocity in your median arcuate syndrome patients, number one? And how about feeding them and checking them again, especially in the combined patients where you have celiac and SMA disease, to see if you actually have an outcome effect or a functional effect. Since you are only dealing with 80-odd patients, it might be worthwhile to go back and grab that cohort and chase them a little bit.

Dr Wilson. Inspiration/expiration duplex views can help differentiate between diaphragmatic compression and intrinsic disease with accelerated velocities in end expiration consistent with compression. For our protocol the participants were breathing at a slow normal comfortable rate and so we don't have that information. It is useful in a clinical setting.

The food trial has been described in a clinical setting, but these patients were all fasting and so that might be a very useful adjunct for patients with a clinical suspicion.

The patients in follow-up are now quite elderly, and it's difficult to get them into the clinic. But in those few who are still coming back for visits, a food trial would be interesting. Thank you.