Combined Use of Power Doppler and Gray-Scale Sonography: A New Technique for the Assessment of Inflammatory Myopathy

CHARIS MENG, RONALD ADLER, MARGARET PETERSON, and LAWRENCE KAGEN

ABSTRACT. ***Objective.*** Ultrasonography (US) is a utilitarian approach to the assessment of inflammatory myopathy (IM). Power Doppler sonography (PDS), a newer technique, enables detection of muscle vascularity and inflammation. We describe the combined use of PDS and gray-scale US in patients with IM.

Methods. We studied 37 IM subjects and 6 control subjects. Clinical scores of muscle strength and function were obtained. The maximum score, 31, represented normal function and strength. Ultrasonographic gray-scale and vascularity results were scored 0–4. Nine subjects had serial assessments.

Results. Subjects ranged from 16 to 83 years of age and were predominantly female. IM subjects had significantly abnormal lower clinical scores than controls, 23.0 ± 5.8 vs 29.8 ± 2.0 ($p < 0.001$). Mean peak gray-scale score was 2.1 ± 0.96 compared to 0.5 ± 0.84 for controls ($p = 0.001$), indicating atrophy in the IM group. Similar results were found for average gray-scale scores. Peak vascularity scores were higher in IM, 2.7 ± 0.8 vs 2.2 ± 0.3 ($p = 0.007$). Disease of longer duration was significantly associated with more abnormal gray-scale scores and lower creatine phosphokinase (CPK) levels. PDS scores were more abnormal in disease of shorter duration. There was a negative association between functional scores and inflammatory scores on serial assessment.

Conclusion. Sonography is a valuable tool in the assessment of IM. Gray-scale and PDS findings were significantly different between IM and control subjects. Abnormal gray-scale US scores were associated with disease of longer duration and lower CPK levels. In contrast, increased vascularity on PDS detected disease of shorter duration and varied with the clinical course more than did gray-scale findings. (J Rheumatol 2001;28:1271–82)

Key Indexing Terms:
ULTRASOUND
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The lack of precise measures of disease activity may complicate the care of patients with inflammatory myopathies (IM)[1]. Assessment of disease activity is an important factor in measuring the effectiveness of therapy and the course of illness. The techniques currently available to physicians in practice rely upon measurement of function, strength, laboratory indices, muscle biopsy, and imaging techniques.

Several scales for assessing muscle function have been developed that rely upon patient reporting of ability to perform activities of daily living. These have had good correlations with disease activity, in both adults and children[2-4]. Variations, however, may not be distinguishable in individuals who are either extremely weak, or who, conversely, are doing well.

Quantification of muscle strength with manual muscle strength testing, timed function tests[5], and biomechanical techniques have proved utility[6,7]. These tests depend on the ability of the patient to cooperate, may not be applicable to profoundly weak patients, and may be affected by interobserver variability. Finally, biomechanical apparatus may not always be readily available.

Serial biopsy and/or electromyography have generally not been used because of cost and invasiveness[1]. Laboratory markers such as the muscle enzymes [creatine phosphokinase (CPK), aldolase, lactate dehydrogenase, and the transaminases] as well as serum myoglobin have also been found useful, but close correlation with clinical status has not been achieved in all cases[8].

Many studies have documented the diagnostic sensitivity and specificity of magnetic resonance imaging (MRI) in IM[9-13]. However, it is expensive and difficult for some patients to tolerate, and is contraindicated in those with

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pacemakers, aneurysm clips, and other ferromagnetic biomedical implants[14]. Ultrasonography (US) represents a utilitarian approach to the examination of the muscular system. It is a noninvasive, relatively inexpensive, and simple examination to perform serially. Traditional gray-scale US has found increasing application in the diagnosis of muscle diseases, including polymyositis (PM) and dermatomyositis (DM)[15], pyomyositis, Lyme myositis, sarcoid myositis, and myositis secondary to polyarteritis nodosa[16].

Power Doppler sonography (PDS) is a newer technique that increases the sensitivity for detecting soft tissue blood flow compared to conventional color Doppler sonography[17]. It has been used to depict soft tissue hyperemia[18] in synovitis, tendinitis, bursitis, joint effusions, and reflex sympathetic dystrophy[19].

We used gray-scale US in combination with PDS to prospectively study patients with IM. We describe the use of PDS in conjunction with gray-scale US in patients with IM and the correlations with clinical status, disease duration, and laboratory indices.

MATERIALS AND METHODS

Patients. Thirty-seven subjects with IM were studied (Table 1). All subjects gave informed consent for the study protocol, which was approved by the Institutional Review Board. Twenty-seven had PM or DM according to the Bohan and Peter criteria[20]. The other 10 had inclusion body myositis, myositis associated with systemic lupus erythematosus (SLE), sarcoid myositis, and focal myositis. Six subjects without myositis or any other form of myopathy were studied as a comparison group.

There were 27 women and 10 men in the IM group. All were receiving medications at the time of assessment. Thirty-one were taking corticosteroids, 4 methotrexate, and 4 azathioprine. Cyclosporine and cyclophosphamide were being administered to one patient each. In addition, 12 subjects had received intravenous immunoglobulin. The control group had one subject with cryoglobulinemia who had received a one week course of low dose corticosteroid 8 months prior to study entry. No control subject was being treated with an immunosuppressive agent at the time of assessment.

Clinical testing. Clinical scores were derived from muscle strength assessment, based on the Medical Research Council scale[21], and function, based on an activities-specific questionnaire (Table 2). The maximum total score, 31, represented normal function and strength. Two rheumatologist investigators administered the questionnaire and physical examinations.

Ultrasound. The radiologist, who was blinded to the clinical findings, examined the patients using both gray-scale and PDS. US examinations were performed using a linear phased array transducer (variable center frequency, 7.5–9 megaherz) and Logic 700 scanner (GE Medical Systems, Milwaukee, WI, USA). Gray-scale and PDS data were recorded on super VHS tape and upon review, the degree of muscle atrophy and vascularity were scored on numerical scales ranging from 0 to 4, with the higher score indicating more severe atrophy or vascularity. For the quadriceps femoris muscles, each muscle (the vastus medialis, vastus intermedius, vastus lateralis, and rectus femoris muscles) was individually scored. Similarly, individual muscles of the biceps and triceps humerus were scored. Average (mean) and peak (highest) scores were determined for the muscle groups overall.

Thirty-five subjects with IM had US evaluation of the quadriceps femoris in this manner, as did all the control subjects. Three subjects with IM had severe upper extremity weakness and US assessment was made in the biceps/triceps humerus for them. Extremities to be assessed were requested by the examining rheumatologist (upper, lower, or both).

Gray-scale evaluation of muscle was based on the relative echogenicity of muscle fascicles and surrounding fibroadipose septa. Muscles were individually graded according to the scheme listed below. With normal muscle volume, muscle fascicles appear anechoic or hypoechoic relative to these septa, while an isoechoic appearance was extremely abnormal, reflecting diminished fascicle size and closer spacing between fibroadipose septa[22]. The gray-scale grading scheme was as follows: 0 = No atrophy; 1 = Mild atrophy; 2 = Moderate atrophy; 3 = Severe atrophy.

Muscle vascularity, as a surrogate for hyperemia and inflammation, was assessed during a continuous sweep over each muscle group scanned in cross section. Doppler sensitivity was maximized at the lowest permissible pulse repetition frequency and wall filter with Doppler imaging performed at 7 mHz. Color gain was first lowered to eliminate any noise and then increased (typically between 50 and 52 decibels) to a point where low noise level could be appreciated during continuous data acquisition. Data were recorded on sVHS tape and reviewed at the end of the procedure[23]. Scores were based on a composite impression of each muscle seen in cross section[24].

If there was spotty appearance of a higher level of vascularity, the muscle was scored one-half point higher to reflect this. The PDS vascularity grading scheme was as follows: 0 =No vessels seen; 1 = At least one intramuscular vessel seen; 2 = ≥ 5 small vessels seen in a 2 dimensional frame or a single large intramuscular vessel seen with cross section > 5 mm or segment length > 1.5 cm; 3 = Vascularity rating of 2 with small clusters (≥ 3) of vessels; 4 = Appearance of frank blush, or vessel boundaries not distinguishable.

Serial sonographic examinations were also obtained in 9 of the 37 subjects.

Analysis. Correlations between the clinical variables and the US variables, and also between the US measured at 2 different time points, were measured using Spearman's rho. Differences between groups for clinical variables were assessed using the independent t test or Mann-Whitney test. Differences between repeated values, different time points, for the clinical variables were assessed using the paired t test. Differences between groups for US data were estimated using the Mann-Whitney test and between time points using the Wilcoxon signed-ranks test.

The statistical significance of the differences in the clinical variables for different values of the peak gray were analyzed using one-way ANOVA or Kruskal-Wallis test, with post hoc comparisons.

RESULTS

Thirty-seven subjects with IM and 6 control subjects underwent muscle US and clinical scoring (Table 1). The subjects ranged from 16 to 83 years of age, and were predominantly female. Sonographic imaging revealed marked abnormalities in muscle of patients with IM that were not seen in any control sample. Figures 1 and 2 illustrate examples of the range of US findings.

Comparison of IM and control subjects. Patients with IM had significantly lower clinical (both function and physical examination) scores, indicating more impairment, than the control group (Figure 3): average functional score 11.1 ± 3.6 vs 15 ± 1.7 ($p = 0.01$), examination score 11.8 ± 3.0 vs 14.8 ± 0.4 ($p < 0.001$), and total clinical score 23.0 ± 5.8 vs 29.8 ± 2.0 ($p < 0.001$). On sonography shown in Figure 4, the mean peak gray-scale score for the IM group was 2.1 ± 0.95 compared to 0.5 ± 0.8 for the control group ($p = 0.001$), indicating atrophy in the IM group. Similarly, the mean average gray-scale score for the myositis group was 1.43 ± 1.1 vs 0.25 ± 0.7 ($p = 0.003$).

Table 1. Demographics of study participants.

	Myositis	Control
n	37	6
Mean age, yrs*	52.1 ± 15.6	40.7 ± 8.7
Female	27	6
Male	10	0
Disease duration, mo**	65 ± 108	38 ± 14.18
Muscle biopsy obtained	35	0
Number of subjects treated with		
Corticosteroids	31	1***
Other immunosuppressives	22	0
Diagnoses (n)	Dermatomyositis (17)	Tendinitis (3)
	Polymyositis (10)	Fibromyalgia (1)
	Associated SLE (5)	Sjögren's syndrome (1)
	Inclusion body myositis (3)	Cryoglobulinemia (1)
	Focal myositis (1)	
	Sarcoidosis myositis (1)	

*Differences did not reach statistical significance, p = 0.09. **Differences did not reach statistical significance, p = 0.4. ***Subject with cryoglobulinemia was treated with 1 week course of low dose corticosteroid 8 mo before study entry.

Table 2. Clinical scores.

I. Muscle Function Score	
1. Transfer from supine to sitting	_____
2. Transfer from sitting to standing	_____
3. Stair climbing	_____
4. Hair combing - tooth brushing	_____
5. Donning jacket or shirt	_____
6. Donning trousers	_____
7. Lifting objects (e.g. groceries)	_____
8. Household maintenance	_____
Total	_____
Score (maximum 16)	
0 — cannot do	
1 — can do partially or with aid	
2 — can do alone	
II. Examination Score	
Neck flexors	_____
Proximal upper extremities	_____
Proximal lower extremities	_____
Total	_____
Score (maximum 15)	
0 — No muscle contraction	
1 — Flicker or trace of contraction	
2 — Active movement possible with gravity eliminated	
3 — Active movement possible against gravity	
4 — Active movement possible against gravity and resistance	
5 — Normal muscle power	
Total Clinical Score	_____
(Sum of I and II = maximum 31)*	

*Maximum score of 31 reflects normal clinical score.

Peak vascularity scores indicating muscle inflammation were higher in IM versus controls, 2.7 ± 0.8 vs 2.2 ± 0.3 (p = 0.007), although the difference was less marked than that seen with gray-scale US scores. Average vascularity scores were also higher in IM subjects compared to controls, but these values were not statistically different.

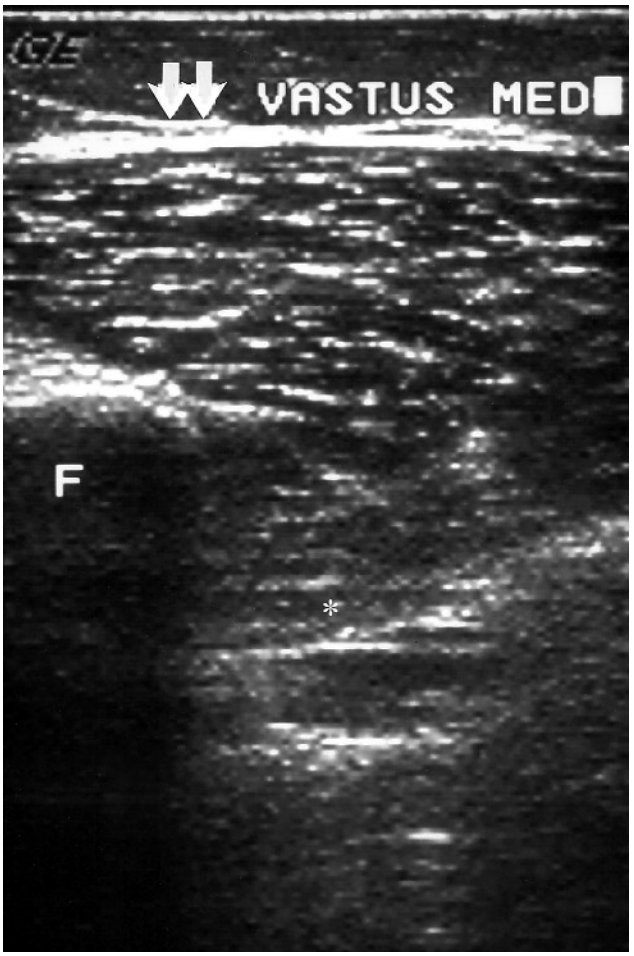

Figure 1A. Normal muscle, grade 0. Transverse sonogram of the vastus medialis muscle of a control subject. The muscle is normally hypoechoic (dark), containing thin echogenic (bright) lines corresponding to the perimysial connective tissue. Arrows denote the anterior border of the muscle. F: femur; *: the neurovascular bundle.

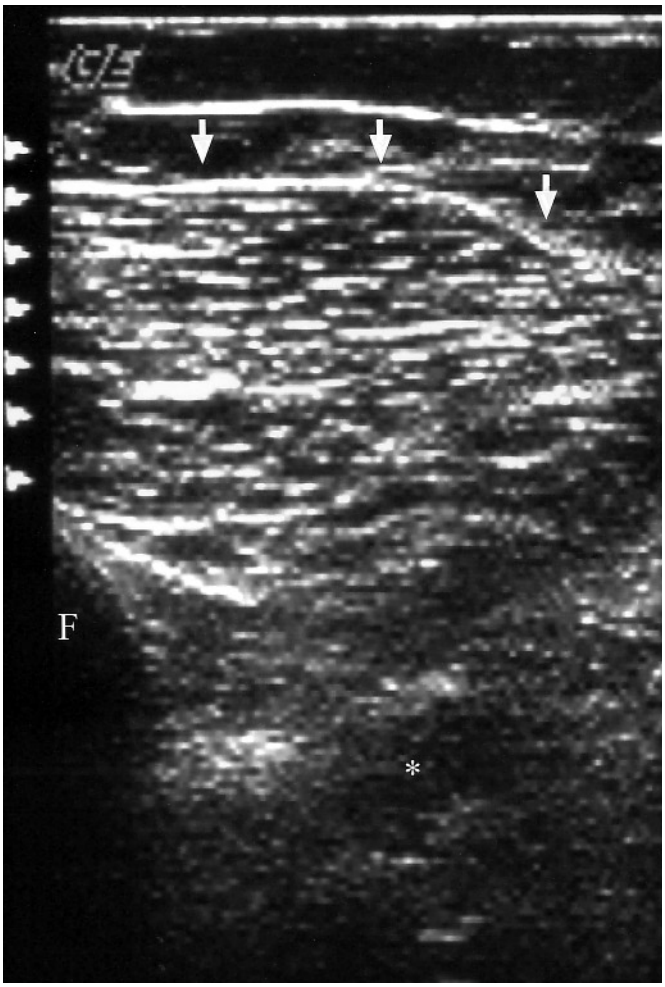

Figure 1B. Mild atrophy, grade 1. Transverse sonogram of the vastus medialis muscle of a subject with DM. In contrast to Figure 1A, there is overall greater echogenicity and diminished size of the hypoechoic muscle fascicles separating the perimysial connective tissue. Arrows denote the border of the muscle. F: femur; *: the neurovascular bundle.

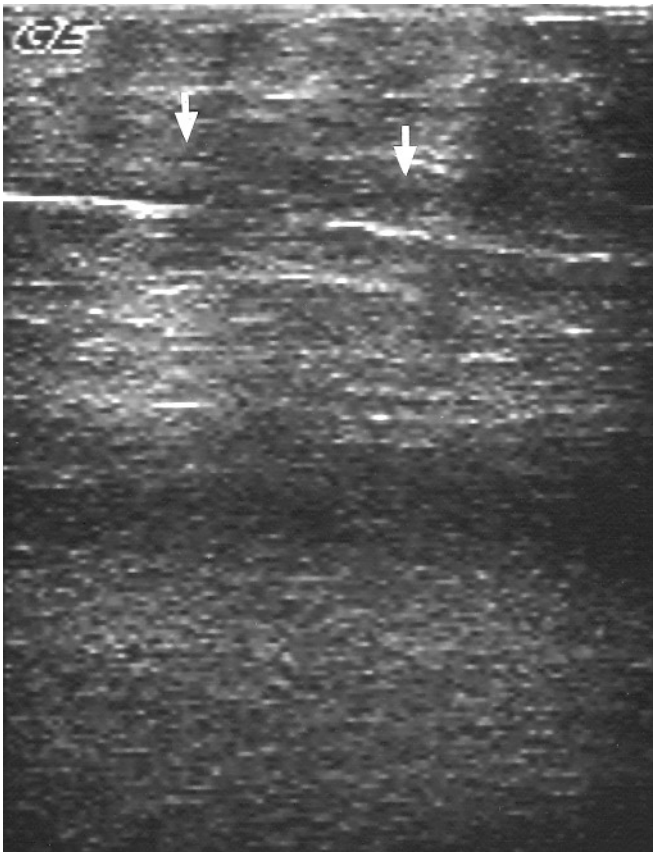

Figure 1C. Severe atrophy, grade 3. Transverse sonogram of the vastus medialis muscle of a subject with PM. The hypoechoic muscle fascicles are no longer evident. The muscle is diffusely echogenic with loss of normal architecture. Posterior muscle boundaries are no longer evident due to marked acoustic attenuation from diffuse atrophy. Arrows denote the superficial fascial plane of the muscle.

When analyzed separately, the 17 patients with DM and the 10 with PM were significantly different from the controls on US imaging. The DM patients had a higher mean average gray-scale US score of 1.0 ± 0.9 vs 0.25 ± 0.7 in the control group ($p = 0.02$) and a higher peak gray-scale US score of 1.8 ± 1.0 vs 0.5 ± 0.8 in controls ($p = 0.01$). Peak vascularity scores were slightly higher in the DM group compared to controls, 2.8 ± 0.7 vs 2.2 ± 0.3 ($p = 0.044$). The PM patients also had significantly more abnormal gray-scale US scores compared to controls: average scores were 2.0 ± 1.0 vs 0.25 ± 0.7 ($p = 0.002$) and peak scores were 2.7 ± 0.5 vs 0.5 ± 0.8 ($p < 0.001$). The rest of the comparisons were not statistically significant. Further analyses on disease subsets are discussed below.

Comparison of disease duration with US findings. Disease duration was recorded from time of first appearance of disease symptoms (muscle weakness and/or characteristic rash in DM), not time of diagnosis. Figure 5 shows the relationship of disease duration and gray-scale US findings. Disease of longer duration was associated with more abnormal gray-scale US scores, i.e., greater atrophy. Peak gray-scale US score in Group 4 (subjects with disease duration > 5 years), which had a mean of 2.77 ± 0.4, were significantly higher than those of Group 1 (subjects with disease duration < 6 months), whose mean was 1.50 ± 1.0 ($p = 0.003$). Similarly, average gray-scale US scores were significantly more abnormal in Group 4 compared to Group 1, 1.9 ± 1.0 vs 0.8 ± 0.8 ($p = 0.03$).

In contrast, differences in PDS scores between the groups with different duration of disease did not reach statistical significance (Figure 6). However, there was an opposite trend to that seen in the gray-scale US scores; that is, the

PDS scores tended to be more abnormal, showing higher vascularity, in the shorter duration disease subgroups. When a correlation for a linear relationship was performed, peak gray-scale scores increased with duration of disease (Spearman's rho 0.49, p = 0.002), i.e., greater atrophy was associated with longer duration of disease. Conversely, average vascularity scores were inversely related to disease duration (Spearman's rho –0.34, p = 0.04), i.e., greater vascularity was associated with shorter duration of disease. Average gray-scale scores approached significance (Spearman's rho 0.33, p = 0.053) and peak vascularity scores did not reach statistical significance (Spearman's rho –0.24, p = 0.2).

Comparison of US findings in disease subsets. Because there may be differences in pathogenesis between the different types of IM, we analyzed our data for differences among the subjects with DM and PM and those with associated SLE. We did not analyze the subjects with inclusion body myositis, focal myositis, and sarcoidosis, as there were too few cases of each.

The group with SLE was significantly more functionally impaired than the other 2 groups, with a mean score of 7.4 ± 2.4 compared to 12 ± 3.9 for the DM and 12.1 ± 2.9 for the PM groups (p = 0.03). The SLE group also had shorter disease duration, with a mean duration of 8.4 ± 15 months compared to 86.8 ± 151 months for the DM group and 59.3 ± 47 months for the PM group (p = 0.049).

Subjects with PM had the most abnormal peak gray-scale (p = 0.005) and average gray-scale (p = 0.04) scores, indicating the greatest atrophy (Figure 7). The SLE group had the least atrophy shown on gray-scale scores, with the DM group having values intermediate between the other groups.

In contrast, PDS scores among the 3 disease subsets were similar (Figure 8). The average vascularity scores, however, were slightly higher in the SLE group (p = 0.02), which had also been shown to have shorter disease duration. These results are consistent with our other findings.

Comparison of CPK levels and US findings. Average CPK value in the IM subjects at the time of assessment was 1328 ± 2152. Subjects with higher peak gray-scale scores, indicative of more muscle atrophy, had lower CPK levels (Figure 9; p = 0.02). In contrast to this inverse relationship between the peak gray-scale US scores and CPK level, there was no statistically significant relationship evident between average gray-scale US and PDS with enzyme values.

Serial measurements. Nine subjects had repeat sonographic measurements performed after an average interval of 4.56 ± 2.5 months. There was an association, which did not reach statistical significance (Spearman's rho –0.56, p = 0.1), between clinical change measured by functional score and average vascularity score (Figure 10). Four of these subjects improved clinically, and in 3 cases their vascularity scores also improved. One subject worsened, as did the vascularity score. One subject who showed improvement had an increase in vascularity score, however. The remaining subjects had no change in functional scores. Among these, the vascularity score was unchanged in one, improved in one, and worsened in 2 subjects.

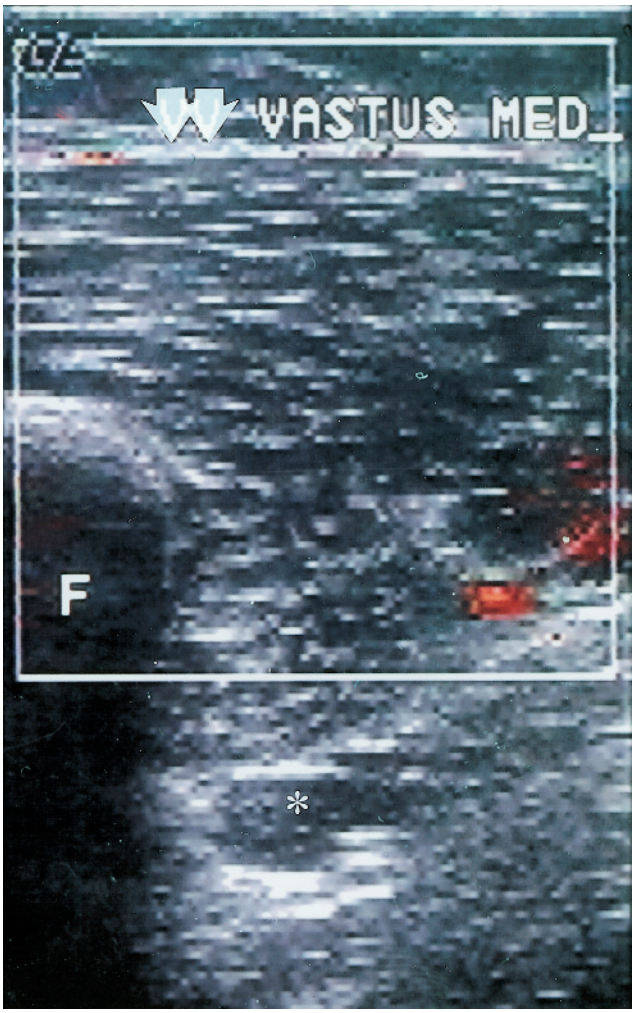

Figure 2A. Grade 1 vascularity. PDS of the vastus medialis muscle of a control subject, transverse plane. There is normal muscle architecture with hypoechoic muscle fascicles separated by echogenic perimysial connective tissue. Several tiny intramuscular vessels are apparent, resulting in a vascularity score of 1. Arrows denote the superficial fascial plane. F: femur; *: the neurovascular bundle.

The average vascularity measurements also correlated with the peak vascularity in this group. Among the 4 subjects with decrease in average vascularity, 3 also had decrease in peak vascularity. Of the 4 with increased vascularity, 3 had change in the same direction in peak vascularity. One subject had no change in average vascularity, and there was similarly no change in peak vascularity.

The gray-scale measurements largely reflected changes in atrophy on repeat measurements. Interestingly, 8 out of 9 had higher (more abnormal) average gray-scale scores on

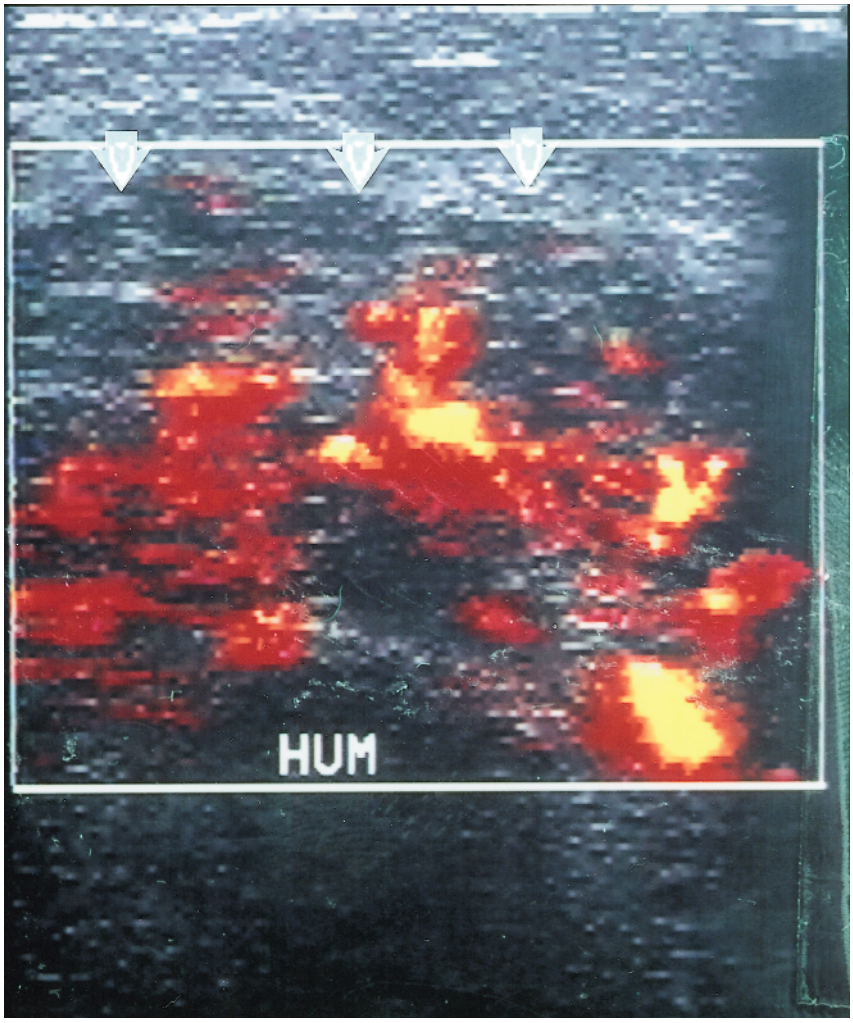

Figure 2B. Grade 3 vascularity. PDS of the biceps muscle of a subject with DM, transverse plane. Multiple small clusters of the intramuscular vessels are evident, many of which are contiguous. Arrows denote the superficial fascial plane of the biceps muscle. HUM: humerus.

the second measurement, while clinical scores remained stable or improved. This trend also held for the peak gray-scale scores for 5 of the 9 subjects.

DISCUSSION

Patients with IM pose important challenges to the clinician. Disease flares can be confused with changes due to steroid myopathy, chronic atrophy, or other comorbid conditions. Examination and laboratory indices may not always reliably distinguish these important alternatives. Other approaches such as electromyography, biopsy, or MRI may be invasive, expensive, or difficult to perform serially.

Reimers, *et al* reported findings correlating gray-scale US with concurrent histology in 70 patients with IM[15]. Chronic IM yielded higher echointensities and more atrophy than acute disease. Acute IM often presented with lower echointensity and muscle edema. The sensitivity of muscle US in detecting histologically proven disease was 82.9%, with a specificity of 97.1%. The only longitudinal study to date examined 12 patients with juvenile DM and PM who had a mean duration of symptoms of 10 years[25]. Increased echogenicity on muscle US was found in 60% of the patients and there was clinical evidence of disease in 58%. Conventional color Doppler is useful for detecting large vessel flow, but is limited for evaluating regional perfusion. PDS is angle independent, extending the dynamic range over that of conventional color Doppler imaging. PDS detects vessels of roughly 40 µm size, such as venules and arterioles. While it does not differentiate between arterial and venous flow, it identifies areas of vascular recruitment and response[23,26]. Newman, *et al* performed PDS in the biceps muscles of healthy volunteers to evaluate exercise induced changes in muscle blood volume[23]. Using a subjective scoring system, as well as a semiquantitative vascularity

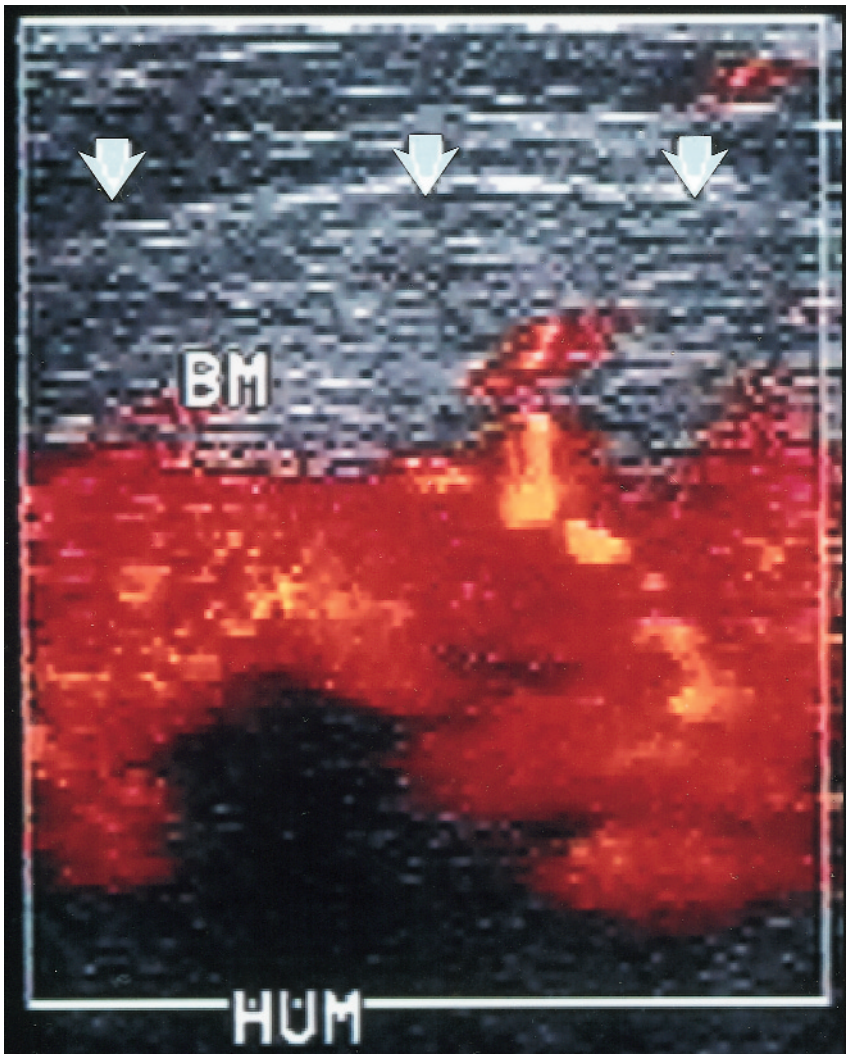

Figure 2C. Grade 4 vascularity. PDS at the level of the biceps muscle of a subject with DM, transverse plane. There is marked increase in blood flow with complete loss of vessel boundaries, resulting in a diffuse blush. Arrows denote the anterior margin of the muscle. HUM: humerus.

measure similar to that described here, they observed significant increases in intramuscular vascularity after exercise, reflecting increases in muscle perfusion. Our study presents the first data on PDS in conjunction with conventional gray-scale US in the assessment of IM.

Both gray-scale and peak PDS scores correlated with clinical scores, distinguishing between disease and control subjects. Differences between IM and control subjects on PDS were not as great as those on gray-scale. This may have been due to the presence of several large blood vessels in few of the control subjects. None of these controls had abnormal gray-scale findings, however. Thus, the appearance of increased vascularity on PDS in the setting of abnormal gray-scale findings is indicative of myopathy.

The ideal control group for setting normal standards for a new technique would consist of subjects completely free from musculoskeletal disease. Given that our population was drawn from an orthopedic and rheumatic disease referral center, this was not feasible for our study. In our control group, there was a subject with Sjögren's syndrome and a subject with cryoglobulinemia, the latter who had been treated with steroids. The subject with Sjögren's syndrome had sicca symptoms and no other signs of systemic disease. The subject with cryoglobulinemia associated with hepatitis C infection had symptoms limited to puffy hands, and had undergone a week's course of low dose prednisone finished many months before entering the study. Both subjects, as well as the other 4 in this group, had no evidence of myopathy.

Abnormal findings on gray-scale US, indicating muscle atrophy, was associated with disease of longer duration. In contrast, PDS findings of increased vascularity appeared to detect disease of shorter duration. Combining these techniques may help guide the clinician in assessing disease status.

Analysis by disease subset revealed worse functional

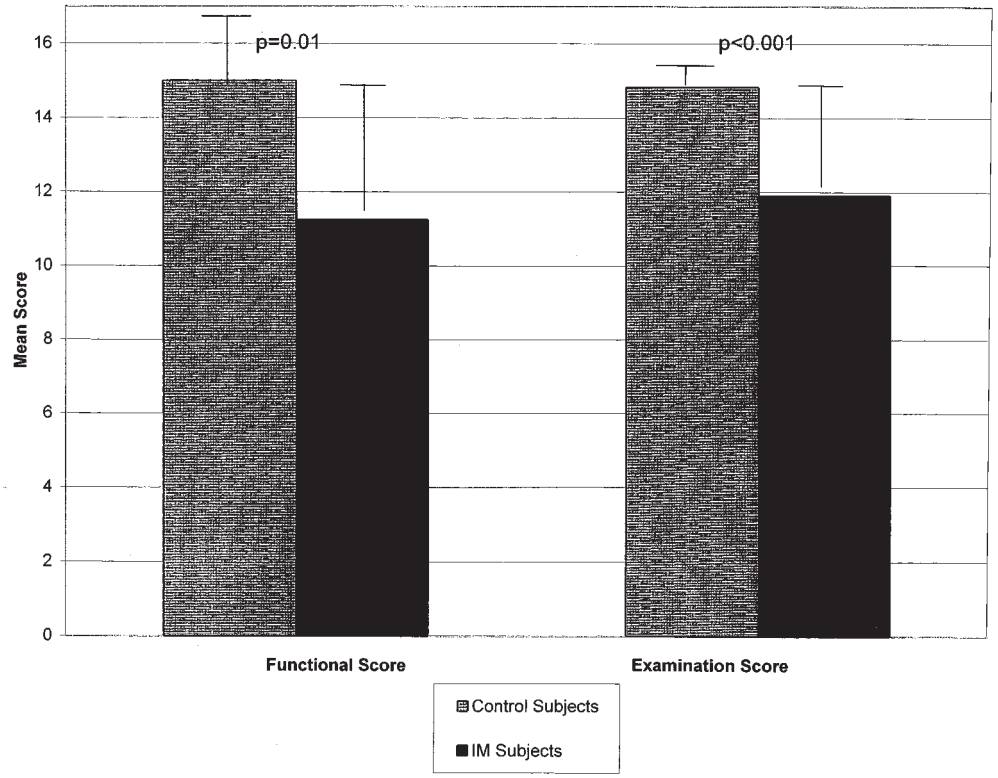

Figure 3. Comparison of clinical scores between subjects with IM and controls. Maximum for functional score is 16, for examination score 15, yielding a total maximum clinical score of 31. All error bars shown in this and subsequent figures are standard deviations. Subjects with IM, n = 37; controls, n = 6.

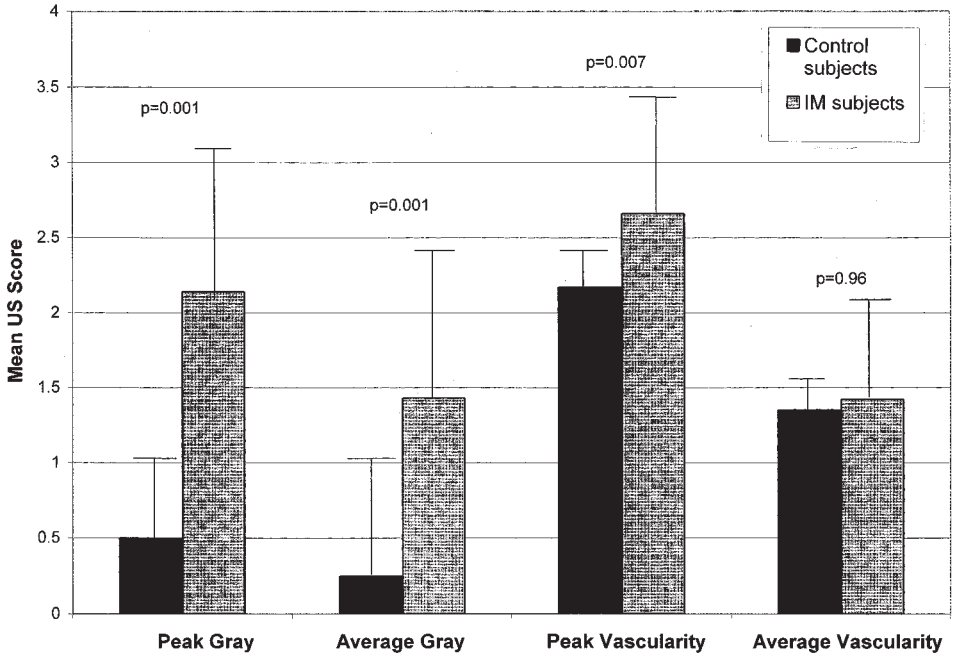

Figure 4. Comparison of US scores between subjects with IM and controls. US scores range between 0 and 4, and the peak (maximum) and average (mean) scores determined for each muscle group scanned. Subjects with IM, n = 37; controls, n = 6.

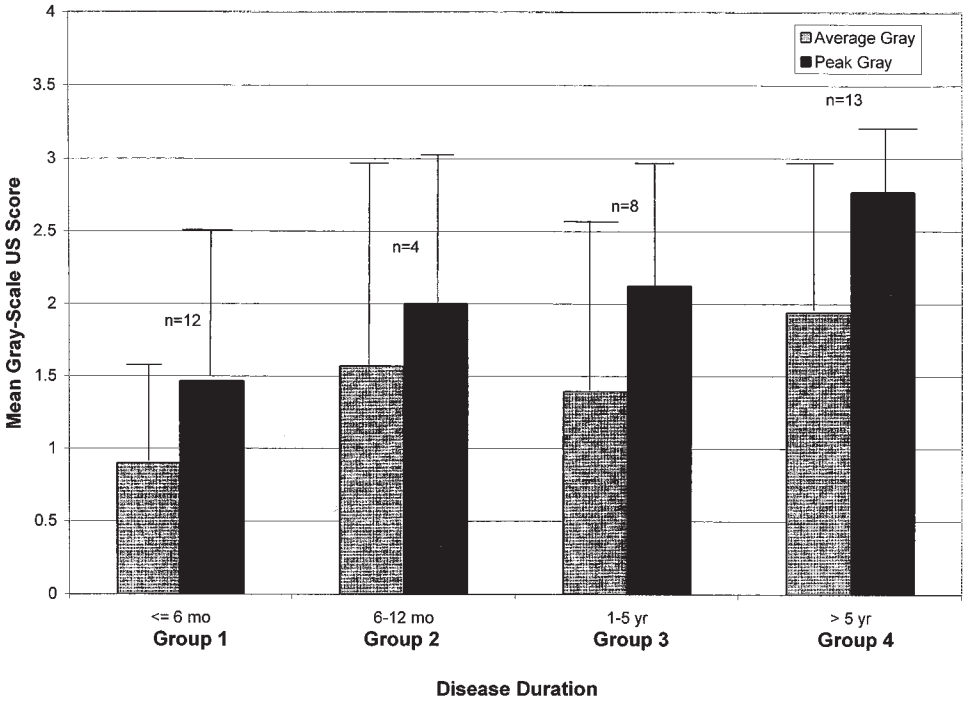

Figure 5. Gray-scale US scores are compared according to disease duration. p for average gray (Group 1 vs 4) = 0.03, p for peak gray (Group 1 vs 4) = 0.003. Other differences were not statistically significant.

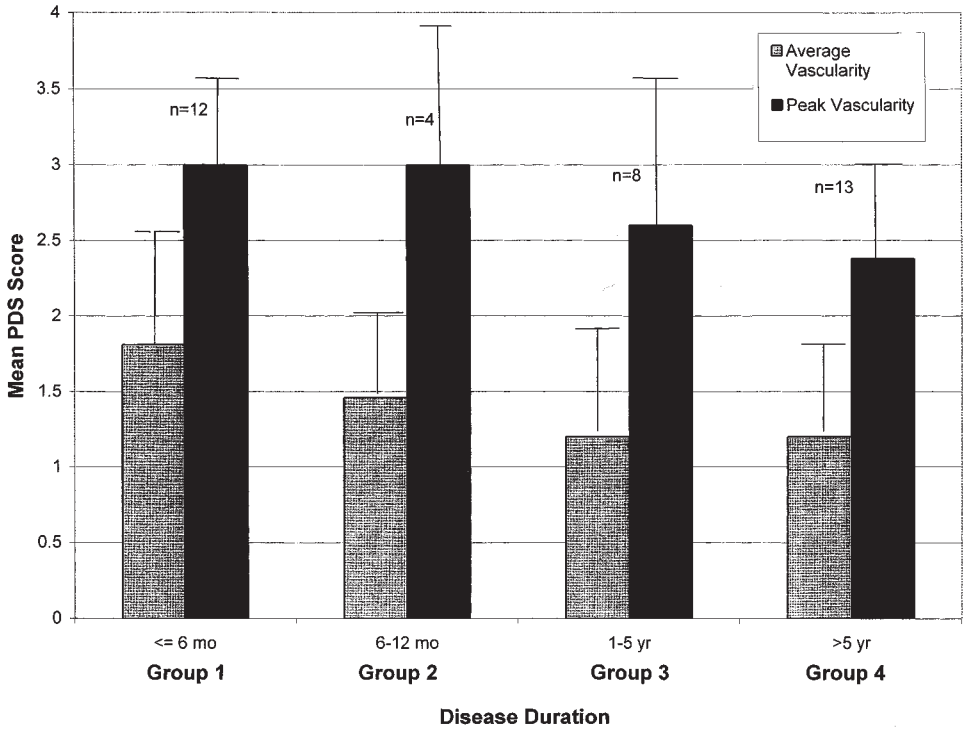

Figure 6. PDS scores are compared according to disease duration. There was a trend toward higher scores in the shorter duration disease groups but differences were not significantly different.

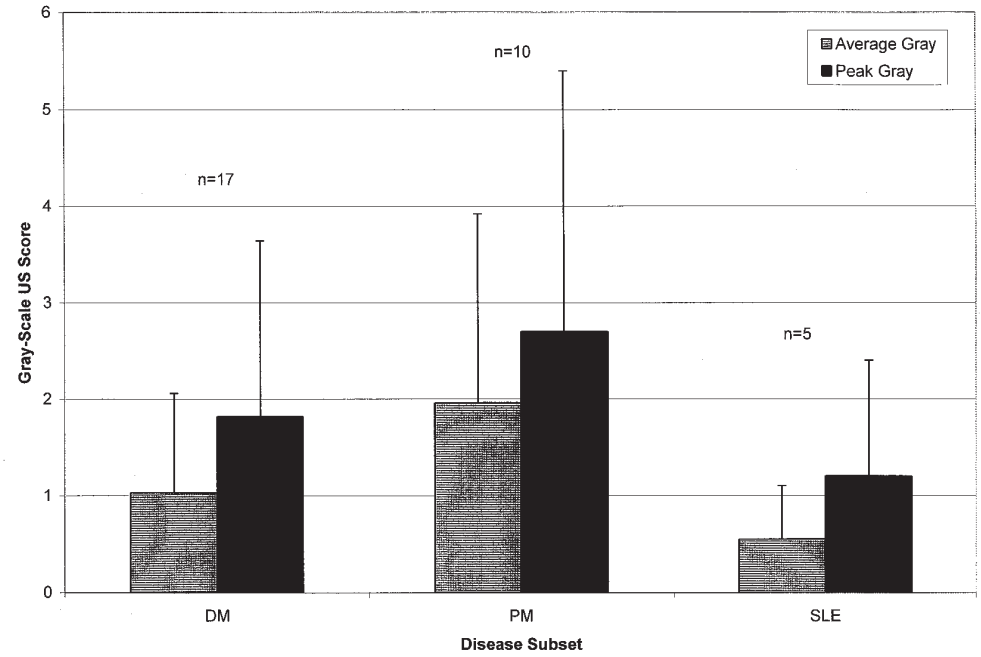

Figure 7. Comparison of gray-scale US scores across disease subsets of IM. Kruskal-Wallis test was used. P values are for comparisons across the 3 groups; p for average gray = 0.04, p for peak gray = 0.005.

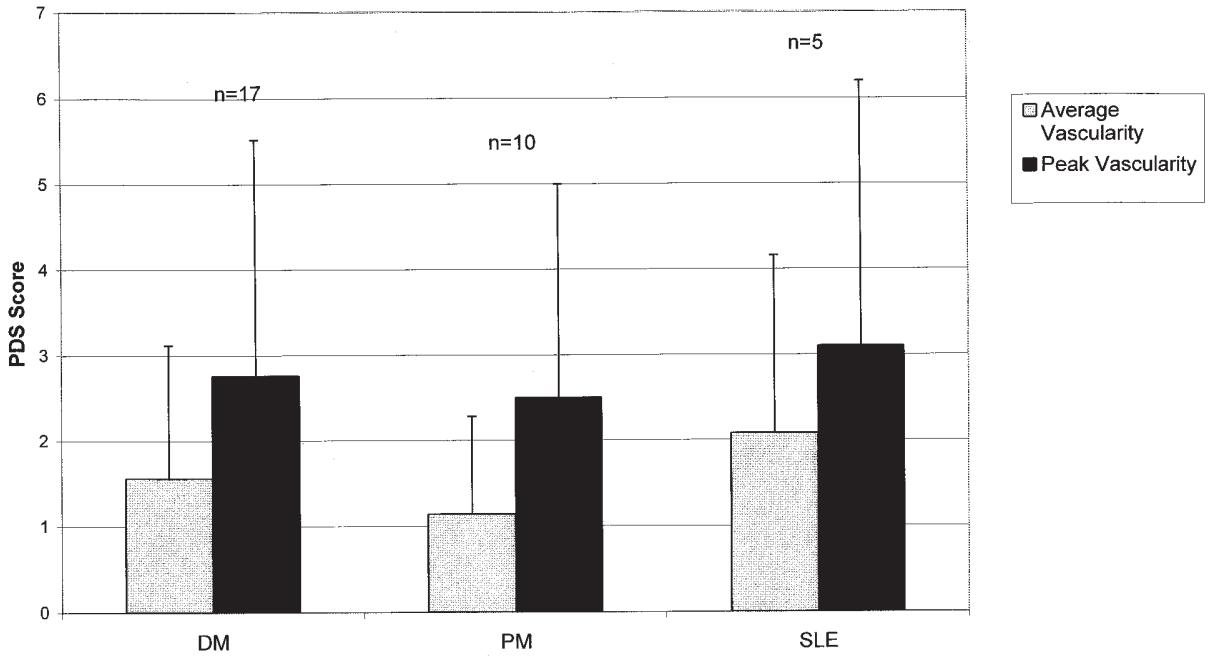

Figure 8. Comparison of PDS scores across disease subsets of IM. Kruskal-Wallis test was used. P values are for comparisons across the 3 groups; p for average vascularity = 0.02, p for peak vascularity = 0.3.

scores, higher average vascularity scores, and shorter duration of disease among the subjects with myositis secondary to SLE. The lower functional scores may be related in part to other systemic manifestations of their disease. The greater vascularity seen on PDS and shorter duration of their disease is consistent with our present findings.

Gray-scale US findings were more abnormal in those with lower CPK levels. These results probably reflect the association of chronic IM, lower CPK values, and more atrophic muscles. Of note, our data are consistent with other studies showing lack of strict correlation between CPK levels and clinically assessed weakness. Several studies

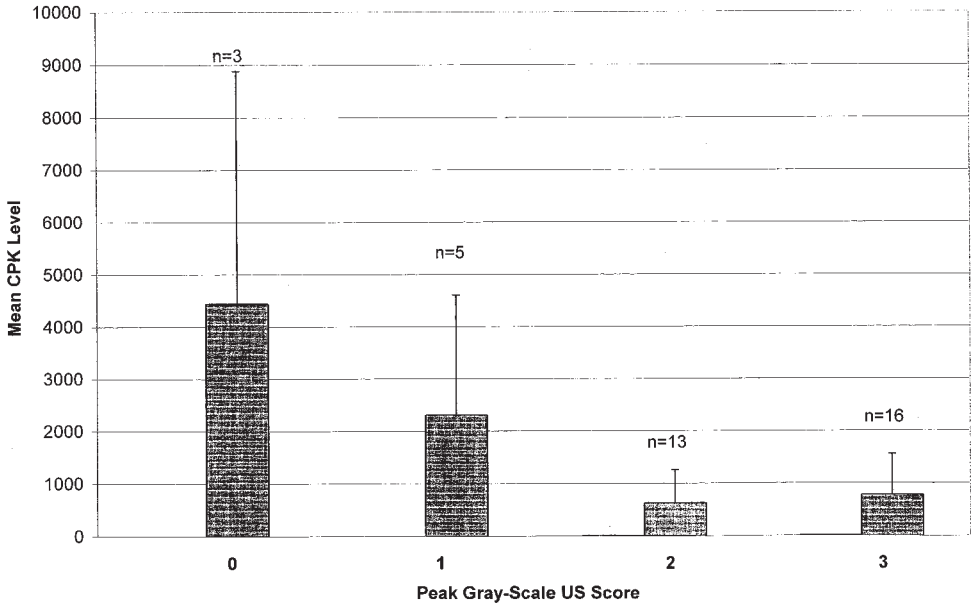

Figure 9. Average CPK levels were determined for all subjects with a given peak gray-scale US score (in the IM group only). There was a statistically significant relationship between US score and CPK levels, in which subjects with higher scores (more atrophy) had lower CPK levels (p = 0.02).

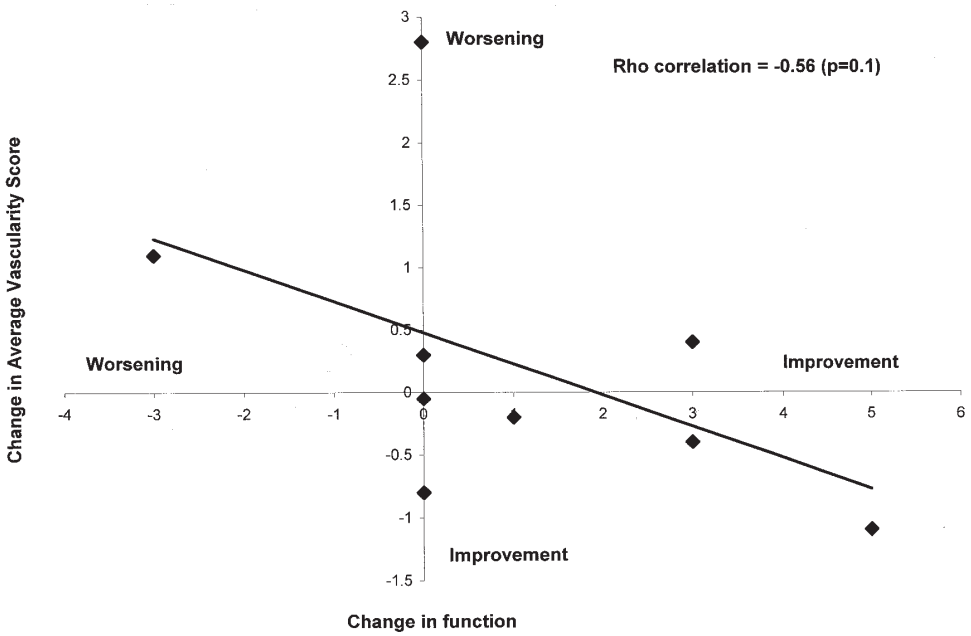

Figure 10. Scatter plot of repeat data of function and vascularity scores with trend line. Although the association did not reach statistical significance, there was a trend toward improvement in function and vascularity scores on serial assessment.

have shown that CPK levels may not reflect muscle strength, often when myositis was secondary to another connective tissue disease[8]. The presence of a circulating inhibitor of CPK activity may also lead to underestimation of the CPK level in patients with IM[27].

Overall, the vascularity score was most responsive to clinical changes in the time frame measured. There was a trend, shown by gray-scale US, to suggest increasing muscular atrophy with time, as indicated by serial assessment. However, function and strength did not decline in parallel. It is possible that learned adaptive mechanisms and response to physical therapy or drug treatment may have preserved function, even in the face of atrophic change. The persistence of structural abnormalities after clinical

improvement has also been seen by MRI in patients with IM[28,29].

Currently, MRI is the gold standard for imaging in IM[10,11]. Acute disease presents as muscle edema on MRI, characterized by normal appearance on T1 weighted images and increased signal intensity on T2 weighted images, whereas chronic disease with fatty infiltration of muscle shows increased signal intensity on T1 weighted images. Added sensitivity can be achieved in assessing these patients using fat suppression techniques, such as inversion recovery. The change of imaging findings may be delayed relative to clinical change, and stable MRI results may occur despite significant clinical change[28,29]. MRI also offers the possibility of assessing biochemical energy characteristics during disease[12,30,31].

Our data indicate that PDS in conjunction with gray-scale US is valuable in the assessment of IM. The use of US may allow effective assessment with greater cost savings. However, because MRI offers more quantitative data than US, we do not recommend replacing MRI with US for the assessment of IM at this time. If the patient is unable to undergo MRI, or if cost issues are prohibitive, US may offer a reasonable alternative. Future studies comparing serial US and histological data will be of interest.

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