Diagnostic Paraspinal Musculoskeletal Ultrasonography

Debate has developed with respect to the use of diagnostic musculoskeletal ultrasound for inflammatory disorders of the nerve root or spinal facets. This discussion has shifted the focus from less controversial aspects of spinal diagnostic ultrasonography including measurement of spinal canal diameter, paraspinal muscle evaluation, and monitoring of intraoperative spinal decompression. This paper will review the literature with respect to the above, and present a supporting argument for the use of diagnostic musculoskeletal ultrasonography in the evaluation of paraspinal conditions involving ligamentous or muscular strain. A clinical study will be presented where images are correlated to magnetic resonance imaging (MRI), and a case report will be presented.

Keywords: Spine, ultrasonography, muscles, ultrasonography, soft tissues, ultrasonography

1. Introduction

Diagnostic musculoskeletal ultrasonography has been in use for medical purposes since the 1940's when B-mode (brightness mode) introduction allowed for two dimensional representation of the examined tissue to occur. Shades of gray are visualized in a lin-

ear gray scale. With digitalization by computers, image quality has improved and soft tissue applications have grown in popularity (1).

There are numerous articles supporting the use of diagnostic musculoskeletal ultrasonography to evaluate and diagnose muscular pathology (2-8). When confined to muscular conditions there is no reason to believe that efficacy would be different than paraspinal assessment, and there are references that support this presumption (9-13).

Some authors have also successfully utilized ultrasonography to measure spinal canal diameter and for the monitoring of intraoperative spinal decompression (14-22). Congenital anomalies in children, extradural space depth and lumbar disc degeneration, herniation, and annular tears have also been successfully evaluated with ultrasonography (23-30).

Claims as to the ability of diagnostic musculoskeletal ultrasonography to objectively measure inflammatory disorders of the nerve root or spinal facets (31,32) have met considerable resistance, however (33,34). This is largely due to problems with artifact, high false-positive rates, and intra-operator variability (33,34). As a result of these claims, additional correlation of previously controversial paraspinal and spinal image acquisition has become needed.

While there is literature that suggests that MRI is less than perfect for assessment of incomplete paraspinal soft tissue injuries (35-38), special attention has been given in this article to the evaluation of paraspinal muscles and posterior spinous ligaments via the use of STIR (short time inversion recovery) sequence (39) imaging in an effort to correlate ultrasonographically obtained findings.

In order to further enhance the utility of diagnostic ultrasound for paraspinal musculoskeletal conditions, identification of the pitfalls in interpretation and a grading scale for the severity of finding is required. In this paper, a case report confirming the correlation of ultrasound findings to MRI are presented, some of the pitfalls encountered in interpretation will be reviewed, and a grading scale based upon echo texture is proposed.

2. Cost Considerations

Low back pain has shown high prevalence, longevity and expense. Estimated medical costs exceed $14 billion annually in the United States (40). Finding low cost alternatives to current imaging technologies is one of medical science's main thrusts toward reducing health care costs.

Since, in the hands of experienced operators, diagnostic ultrasonography has repeatedly been proven effective in the measurement of muscle and ligament mass, function and pathology associated with tears, overuse or edema (2-13), it is not surprising that it could be utilized as a cost-saving alternative for the study of muscular or ligamentous strain in paraspinal tissues.

Ultrasonography is a noninvasive procedure with one-fifth to one-tenth the cost of MRI and computerized tomography (CT) (40). It allows comparison of the opposite side, uses no radiation, and can be performed at the bedside if necessary. It is important to keep in perspective what the different imaging techniques have to offer, and if one is just as efficacious as the other, the least invasive and least expensive should be chosen whenever possible (41).

3. Literature Review

Autopsy studies, myelography, CT and MRI have all shown abnormalities in the absence of a spinal pain history (42-44,44,46,47). Studies on MRI have shown some type of disk abnormality in up to 64% of those without symptoms (48). While it is recognized for superior ability to distinguish between disk herniation, epidural fibrosis, arachnoiditis, infection, hematoma, cyst formation and other pathologies (49), other citations conclude that MRI cannot reliably identify the source(s) of discogenic pain, and that significant annular tears often escape detection (50).

Rupture of the supportive ligaments of the spine following trauma can be directly visualized with MRI (51); sagital T2-weighted images are most useful for depicting injury to the anterior and posterior longitudinal ligaments, ligamentum flavum, and interspinous ligaments (52). Hypertrophy and ossification of the ligamentum flavum is also identifiable with MRI (53).

Spinal ultrasonography has been compared with CT scans, discography, MRI, and myelography (12,23,27). Tervonen compared transabdominal ultrasound images with CT/discography to determine the ultrasonographic effectiveness in screening for generalized disc lesions. The sensitivity of recognizing a discographically painful and deteriorated disc for ultrasound was 0.95, and its specificity was 0.38.

The predictive value was 1.53 for positive findings and 0.13 for negative findings (27).

Naidich retrospectively evaluated spinal sonography with myelograms and intraoperative photographs to determine how effectively sonography could display the major features of congenital anomalies in children. Sonography proved useful for confirming the presence of tethered cord, simple meningocele, lipomyelomeningocele, sacrococcygeal teratoma, and pilonodal sinus (23).

Hides has done extensive evaluation of the paraspinal multifidus muscle utilizing ultrasonography (9-12). If a strict protocol for ultrasound imaging is adhered to, comparison with MRI demonstrated that real-time ultrasound imaging effectively documented muscle size (12). Findings of atrophy have led to implementation of rehabilitative strengthening techniques and have been offered as an explanation for recurrent low back pain (9,10).

Nazarin computed Receiver-Operating-Characteristic (ROC) curves generated by data from blinded reading of images to conclude that paraspinal ultrasonography is neither a sensitive nor specific modality for evaluating back pain. Despite this rather broad conclusion, the study was directed toward the use of diagnostic ultrasound for the evaluation of paraspinal inflammation only (34). Due to the blinded nature of the ROC analysis, the ultrasonographically important feature of real-time interpretation was lost.

Proper anatomical structure identification is a necessary component to correct documentation of what was done. Kamei has described soft tissue and bony surface anatomical landmarks for paraspinal ultrasound studies (fig.1) (28) and cadaver studies have been done utilizing ultrasonography to study osseous structures versus paraspinal soft tissue structures (61).

In cases with incomplete spinal ligamentous disruption, MRI is not as sensitive as when complete tear occurs. In patients with severe enough acute traumatic spinal injury to merit immediate investigation, all MRIs were normal if there was no evidence of
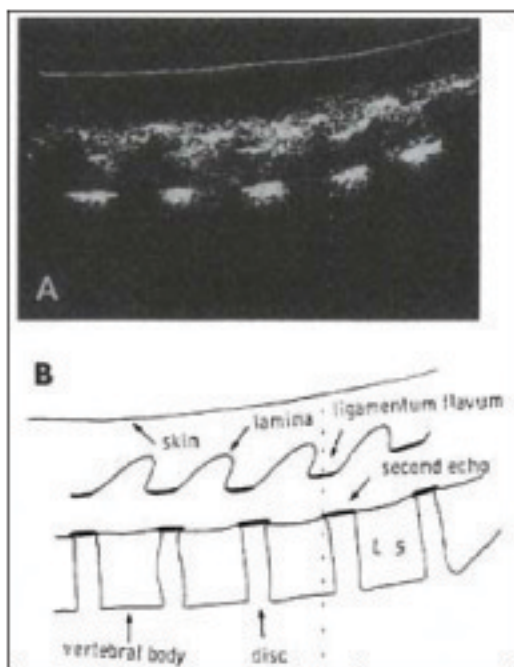
Figure 1. Spinal ultrasound image as viewed from a longitudinal plane, 15d transversely to the sagittal plane.

spinal instability on clinical exam (54). In the past, radiologists have been cautioned to be judiciously careful in reporting anterior or posterior longitudinal ligament tears, emphasizing a bias toward minimizing false positives (55). Presently, even with enhancements in MRI, the diagnosis of ligamentous instability still relies upon multiple factors, including X-Ray findings and clinical assessment.

Ultrasonography is sensitive in the detection of incomplete soft tissue injuries (56-60). Bonica states, "Because CT scans and myelograms are usually negative they should not be considered unless evidence of a neurologic problem is found" (62). While intravenous Godolinium contrasted STIR MRI offers a sensitive method of evaluating soft tissue injuries (63), this option is not always a suitable tool for the clinician who wishes to evaluate paraspinal soft tissue pain; ultrasonography is a reasonable alternative.

4. Pitfalls

As with other imaging procedures, proper instrumentation must be utilized for diagnostic musculoskeletal ultrasonography. Echoes are produced at the junction or interface of tissues of different acoustic impedances. These echoes return to the transducer only if the sound beam strikes the interface perpendicularly; otherwise they are reflected away from the transducer and are not recorded on the face of the cathode ray tube (64,65).

Experienced sonographers should continually attempt to direct the sound beam at an angle perpendicular to the structures being examined. In the case of diagnostic musculoskeletal ultrasonography for paraspinal structures, deeper structures are frequently of interest. The signals reflected from the posterior interfaces of the body are of low amplitude in comparison to more anterior echoes. This is due to signal attenuation secondary to reflection, absorption and dissipation (64,65).

Time gain control mechanisms are incorporated into all ultrasound equipment to provide progressive amplification of echoes in the depth of the interface. As greater emphasis is upon deeper structures,

these control knobs should be adjusted accordingly (66,67). Transducer sound frequency is another important parameter in determining resolution. In musculoskeletal ultrasonography, 5 and 7.5 MHz transducers are often used as they allow for both adequate depth of penetration and resolution (10,65).

Shadowing is the reduction in reflection amplitude from reflectors that lie behind a strongly reflecting or attenuating structure. Enhancement is an increase in reflection from reflectors that lie behind a weakly attenuating structure (65). Both are considered artifacts. One would certainly expect to see this in paraspinal studies due to the presence of boney structures such as the spinous processes, lamina, and zygapophyseal joints.

In fact, shadowing and enhancement that result due to these structures have been documented, both in the transverse and parasagittal planes, and are easy to locate (Fig. 2 & 3) (10). While a more strongly reflecting echo does not necessarily mean facet inflammation, it does clearly produce an obvious shadow and enhancement artifact. These have been confirmed with both cadaver studies and with in vivo needle localization (60,66).

The presence of shadows and artifacts have played an important role in the controversy surrounding paraspinal ultrasound studies. For example, claims have been made concerning facet and nerve root inflammation that seem to contradict established methods of dealing with these pitfalls (31). This problem may have been
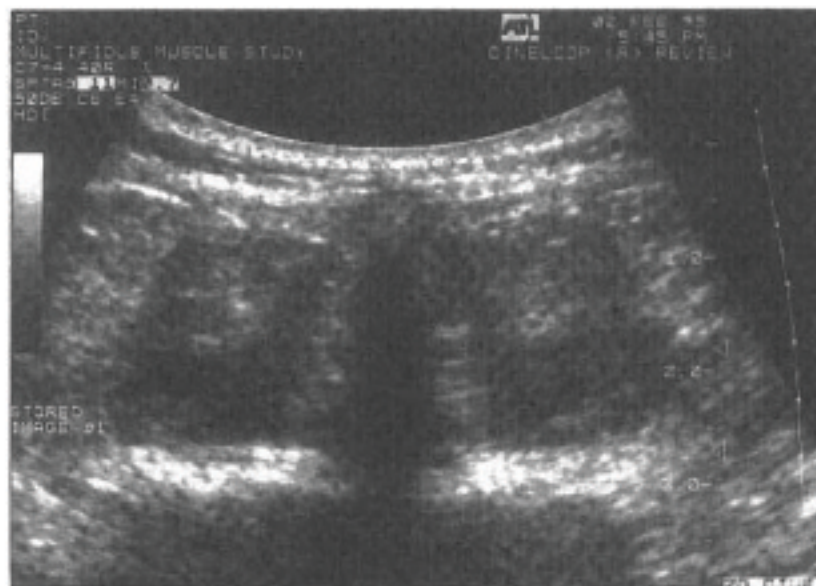

Figure 2A. Transverse ultrasound image of the lumbar multifidus muscle at the fourth lumbar level.
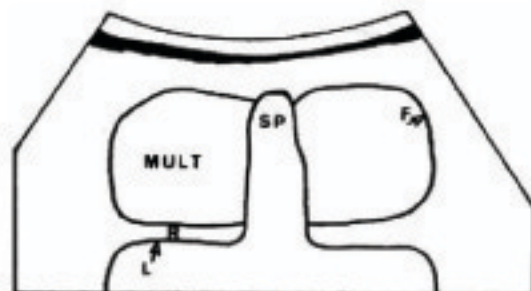

Figure 2B. The multifidus muscle (MULT) is bordered by the vertebral lamina/ zygapophyseal joint (L) inferiorly, the spinous process (SP) medially, fascia, fat and skin superiorly, and the fascia between multifidus and the lumbar longissimus and iliocostalis muscles laterally. (F). The brightness seen at the inferior border of the multifidus muscle is reflection (R) of sound waves from the vertebral lamina and zygapophyseal joints. Acoustic shadowing is seen inferior to landmark, as the ultrasound waves are unable to penetrate the bone.
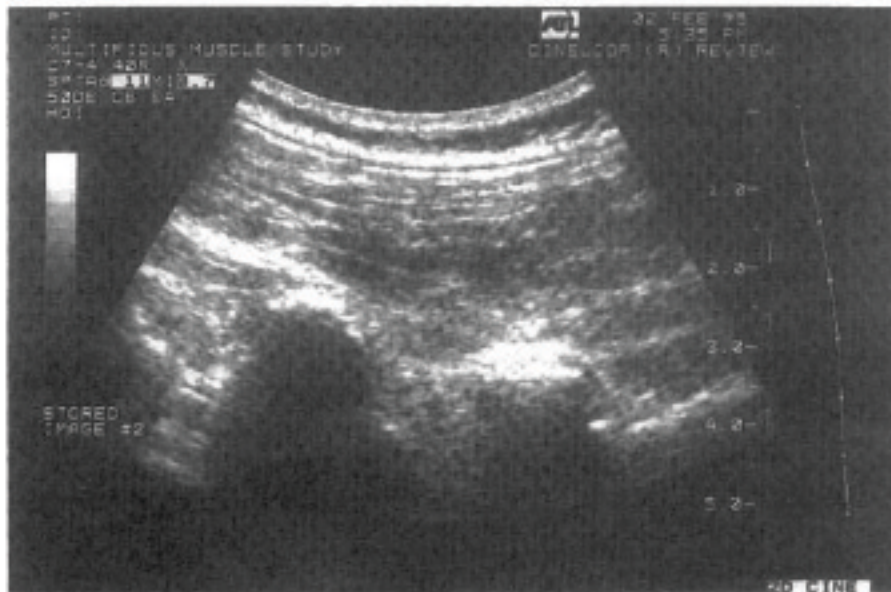
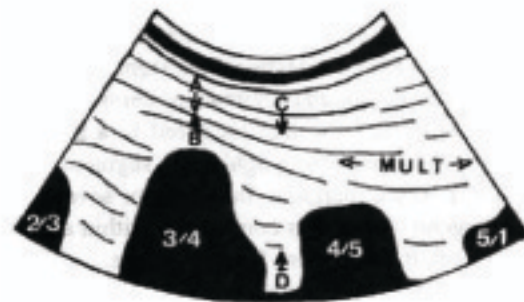*Figure 3A. Parasagittal ultrasound of the lumbar multifidus muscle.*

Figure 3B. Superiorly are the skin line and subcutaneous tissue. The multifidus fibres are seen running in a longitudinal direction in this image (<— MULT —>), as indicated by the direction of the arrows. Actual muscle fasciales are visible in this plane. Inferiorly are the zygapophyseal joints, from the L2/3 joint to the deep L5/S1 joint as indicated. The letters A —> B represent the depth of the multifidus muscle superior to the L3/4 zygapophyseal joint. The depth of the multifidus muscle increases considerably in the area between the zygapophyseal joints, indicated by C —> D.

further compounded by an incomplete effort to correlate the radiologist's interpretation of the study to findings present on physical exam (33). Fortunately, however, parameters that correctly address shadows and artifacts have been established (10,-13,61,65,66).

Paraspinal diagnostic musculoskeletal ultrasonography has also received criticism for considerable variance from one area to another, depending upon the gain setting and angulation of the transducer (33,66). It is well known that transducer angulation artifacts such as reverberations (multiple reflections) can occur with an ultrasound study of any body part (65). As discussed above, gain settings affect all ultrasonographic studies. There is no particular reason why these problems are more severe or difficult to recognize in the paraspinal musculature than elsewhere.

There is a lack of an accepted grading system for the severity of findings. Even if a simple grading scale of zero (no hypoechogenicity) to three (most hypoechogenicity) is utilized, and only non-artifact, hypoechogenicity is read, it has little utility unless the problems with variance are first addressed. Therefore, hypoechogenic areas should be read only if they are significantly different from the surrounding tissue.

Ideally, the gain should be adjusted so as to obtain the greatest clarity and depth of image production, while not sacrificing reasonable contrast.

Naturally, every effort should be made to eliminate the possibility of a poor transducer angle or suboptimal gain setting so as to minimize variance.

5. Materials And Methods

Patients in a clinical setting who presented with diagnosis including cervical or lumbar sprain, ligamentous strain and myofascial pain were studied with diagnostic musculoskeletal ultrasonography of the paraspinal tissue. All patients were subject to a clinical physical exam, and an impression reached prior to the study.

With a standard diagnostic ultrasound machine (ALOKA, Model 500, Wallingford, Connecticut) and a 7.5 MHz linear transducer, a bilateral, split screen parasagittal approach was used. The transducer was constantly directed back and forth between a plane directly perpendicular to the multifidus and slightly angled toward the midline. Gain and focus were adjusted so as to provide the maximal amount of clarity/resolution without sacrificing depth of penetration. Shadows and artifacts were not read, with parameters for identification of the same adopted from previously described citations (10-13,61,65,66).

An entire spinal section (cervical, thoracic or lumbosacral) was studied whenever the clinical impression confirmed evidence of pathology at a particular spinal level (i.e., C2, T8, L5). Hypoechoic signals, when localized within a particular segment, as compared to the surrounding tissue, or when localized to a particular segment, as

Figure 4A. Transverse ultrasound image of the cervical multifidus muscle at the C3, 4 level (long arrow points to the multifidus on right.
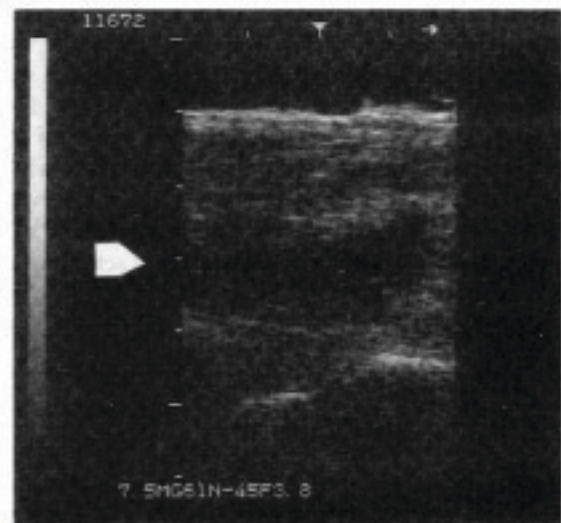
Figure 4B. Paraspinal ultrasound image of the cervical multifidus muscle at the C3, 4 level (short arrow points to the hypoechoic signal). The dense, hyperechoic white signals at the bottom of the figure of this cervical study correspond to the zygapophyseal joints (the dense, hyperechoic white signals at the bottom of Figure 3A, in the lumbar spine).

compared to neighboring segments, were graded as normal, marginal, moderate or severe. If a hypoechogenic signal was confined to within a particular segment, it was read as focal in nature.

Positive findings were then correlated to MRI (normal studies were not). The reading radiologists were requested to pay attention to paraspinal structures, with emphasis on the multifidus. Clinical impressions on the referral for the MRI were labeled: "Include paraspinal musculature. Hypoechogenic lesion at...". STIR sequences were utilized. The ultrasound studies were done at one facility, and the MRIs were done at a two other facilities. The time interval between the ultrasound study and MRI was variable, depending on scheduling the clinical course, but generally within a period of several weeks. Results were tabulated after fifteen studies had been completed.

5.1 Case Report:

W.W. is a 43 year old female with a chief complaint of neck pain, associated complaints of numbness and weakness radiating into the upper extremity. Symptoms began two months earlier after a rear-end motor vehicle accident. Physical exam showed no sensory motor deficit. Spurling's compression test for radiculopathy was subjectively positive to the left, with palpable spasm at C7 bilaterally and C4 on right. Electromyographic examination with nerve conduction studies were normal.

Diagnostic paraspinal ultrasonography demonstrated the presence of a focal, segmental hypoechoic signal at C3,4 (fig. 4), with MRI STIR sequence demonstrating paraspinal muscular atrophy on the right (fig. 5). Paravertebral block at C3,4 relieved the patient's pain.

5.2 Findings

Of the fifteen patients that were studied with both paraspinal ultrasonography and STIR MRI, eight of the MRIs were read as having evidence of either multifidus atrophy, a fluid signal deep to the multifidus, or an increased signal in the interspinous ligament at the corresponding segment. An additional three
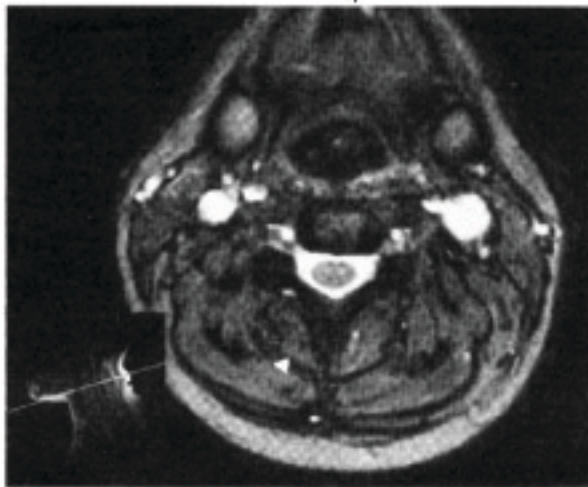

Figure 5. Cervical MRI STIR sequence including paraspinal musculature with section at C3, 4 (the arrow head points to the multifidus).

studies showed evidence of discal disorders, and one study showed structural change consistent with vertebral subluxation at the same segment as the ultrasound studies. The ultrasound finding did not seem to demonstrate any correlation with the different positive MRI results obtained.

Three out of fifteen of the ultrasounds that were read as abnormal could not be confirmed with MRI. Two of these studies had minimal hypoechoic findings on ultrasonography. One additional study showed minimal evidence of a discal bulge at a level that did not correlate with the ultrasound findings, and two additional MRIs were read as completely normal.

If MRI is used as the gold standard, then paraspinal ultrasound had an 80 percent true positive and 20 percent false positive rate in this series.

6. Discussion

The objectification of abnormality in soft tissue injury can be of significant clinical relevance. If simple palpation techniques were only required, then the treatment of people with these complaints should be relatively simple. Unfortunately, many individuals with soft tissue injury develop chronic pain syndromes, and local treatment at the site of perceived pain is not always effective (67-69).

It is clear that referred pain is an established clinical entity (70-72). Without dismissing psychological factors, the management of those whose soft tissue injuries do not heal within the expected period of time can be greatly enhanced if the generator of the symptoms can be correctly identified (73-75). When used properly, diagnostic paraspinal ultrasound offers a good clinical tool toward this end.

If STIR sequence MRI of the paraspinal musculature is used for comparison purposes, diagnostic paraspinal ultrasonography demonstrates a high sensitivity for pathology, but this does not translate into specificity for the type of abnormality uncovered. Hypoechoic areas may represent only edema associated with the underlying pathology. Reimers et al. (3) found that hyperechogenicity correlated with atrophy. This finding may be explained by atrophy without associated edema.

Diagnostic ultrasonography is far less expensive then other imaging modalities, and when established protocols are followed to account for pitfalls such as echo artifacts and shadows, operator dependant variations can be minimized and reproducibility enhanced so as to increase the effectiveness of diagnostic paraspinal ultrasonography.

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