Differentiation of Necrotizing Fasciitis and Cellulitis Using MR Imaging

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OBJECTIVE. This study was performed to evaluate the diagnostic value of MR imaging in differentiating necrotizing fasciitis from cellulitis.

MATERIALS AND METHODS. Spin-echo T1-weighted, T2-weighted, and contrast-enhanced T1-weighted spin-echo sequences were performed in 15 patients with clinically suspected necrotizing fasciitis. In two other patients, only unenhanced imaging was performed. The MR imaging results were correlated with the surgical findings in 11 cases, with autopsy in one case, and with the clinical outcome in five cases.

RESULTS. Cellulitis was diagnosed when subcutaneous thickening with fluid collections was revealed on T2-weighted images and when subcutaneous tissue or superficial fascia or both showed contrast enhancement. For the diagnosis of necrotizing fasciitis, imaging revealed additional involvement of deep fasciae with fluid collections, thickening, and enhancement after contrast administration. According to these criteria, we found 11 cases of necrotizing fasciitis and six of cellulitis. MR imaging identified all 11 cases of necrotizing fasciitis correctly when compared with the surgical findings. One false-positive case of cellulitis was overstaged and was thought to be necrotizing fasciitis. Contrast-enhanced T1-weighted sequences delineated abscesses and areas of necrosis more clearly than T2-weighted sequences did, but showed no additional lesions.

CONCLUSION. When no deep fascial involvement is revealed with MR imaging, necrotizing fasciitis can be excluded. However, because its sensitivity exceeds its specificity, MR imaging tends to overestimate the extent of deep fascial involvement. Therefore, the therapeutic regimen should be based on a combination of clinical findings and MR imaging.

Necrotizing fasciitis is a rare, rapidly progressing infection characterized by extensive necrosis of subcutaneous tissue and fascia and usually accompanied by severe systemic toxicity [1, 2]. In early stages, underlying muscle is often spared [3]. Early clinical recognition of necrotizing fasciitis may be difficult, and the clinical differentiation between necrotizing fasciitis and cellulitis may be particularly difficult [4–7]. Although cellulitis, which involves only subcutaneous tissue, can be treated in most cases with antibiotics alone, necrotizing fasciitis often requires an additional surgical intervention. Early and adequate surgical débridement and fasciotomy in necrotizing fasciitis have been associated with improved survival compared with delayed surgical exploration [8–12]. At present, definitive diagnosis is made only at surgery when extensive undermining of the surrounding tissues is discovered, with the fascial plane lacking resistance to a blunt instrument [13]. Because patients with cellulitis do not need surgical intervention, the ideal diagnostic tool should provide the differentiation between cellulitis and necrotizing fasciitis before surgery. Additionally, this tool should make it possible to judge the severity of necrotizing fasciitis and to delineate the extension of the infectious process. Stamenkovic and Lew [13] demonstrated that the use of frozen-section biopsy may provide the diagnosis of necrotizing fasciitis before surgery; however, this process requires immediate histopathologic evaluation around the clock and is an invasive procedure.

MR imaging may be the ideal tool to differentiate between necrotizing fasciitis and cellulitis because MR imaging does a good job of revealing contrast enhancement of soft tissues and is highly sensitive in the detection of fluid collections. Additionally, MR imaging is noninvasive. High accuracy of
MR imaging for the diagnosis of experimentally produced cellulitis has been reported by Beltran et al. [14].

Gadolinium-based contrast agents with a distribution volume in the extracellular space show an enhancement in inflamed soft tissues and bones. Animal and clinical studies have demonstrated that gadolinium is useful in evaluating infectious diseases of the musculoskeletal system by differentiating necrotic tissue from inflamed or edematous tissue [15, 16]. Nevertheless, it has not been shown yet that the use of IV contrast agents increases the sensitivity of MR imaging in regard to the diagnosis of infectious processes.

The purpose of this study was to evaluate the accuracy of unenhanced and contrast-enhanced MR imaging for differentiating necrotizing fasciitis from cellulitis and for defining the extent of the infectious process.

Materials and Methods

Materials

MR imaging examinations performed from August 1993 to February 1997 of 17 patients (eight women and nine men with a mean age of 41 years [range, 22–76 years]) with clinically suspected necrotizing fasciitis were reviewed retrospectively. The final diagnoses, proven surgically in 11 cases and by autopsy in one, were necrotizing fasciitis in 11 patients and cellulitis in six patients. In seven patients, the infectious process involved only a single leg, in five patients only a single arm, and in one woman only the right shoulder. In four severe cases, besides the involvement of extremities, infectious findings could also be seen in pelvic fasciae; one of these patients additionally showed necrotizing fasciitis of the abdominal and thoracic wall. Nine patients had predisposing factors such as small skin lesions, surgery, injections, or blunt trauma. Associated diseases such as leukemia, alcohol abuse, HIV infection, or renal insufficiency could be found in four patients with necrotizing fasciitis and in one patient with cellulitis. The patients underwent MR imaging examination within 2–7 days (mean, 3.3 days) after the onset of symptoms but less than 24 hr before surgery when necessary. One of 11 patients with necrotizing fasciitis died within 24 hr after the MR examination; and a second patient, a woman, survived after the amputation of her left calf. All patients with cellulitis survived. Only one patient with cellulitis underwent surgery because of a subcutaneous abscess.

Examination Technique

MR imaging was performed on a 1.5-T Signa Advantage system (General Electric Medical Systems, Milwaukuee, WI). The best fitting RF-coil arrangement for the expected area of involvement was used. Variation in matrix size and field of view for different infection sites ranged from 192 × 256 to 256 × 256 and from 26 × 19 cm to 40 × 40 cm, respectively. T1-weighted spin-echo sequences (TR/range/TE range, 300–540/8–21 msec) without fat saturation and T2-weighted (3000–5000/100–114 msec) spin-echo sequences with fat saturation (spectral selective suppression pulse technique) were performed of all patients. In 15 patients, additional T1-weighted spin-echo sequences (300–540/15–35 msec) with fat saturation after IV injection of 0.2 mM/kg of gadolinium tetraazacyclododecane-tetraacetic acid (Dotarem; Laboratoire Guerbet, Aulnay-sous-Bois, France) were acquired. In two patients with necrotizing fasciitis, the examinations had to be terminated before IV contrast injection because massive signs of systemic toxicity and their poor physical condition required immediate therapeutic intervention. In general, examinations were optimized to minimize the overall scan time. Therefore, using smaller matrix sizes and decreased averaging, the examination time was shortened at the cost of suboptimal image quality.

Data Analysis

All MR images were analyzed by two radiologists who were unaware of the surgical, autopsy, or clinical findings. Cellulitis was diagnosed when thickening of the subcutaneous tissues and contrast enhancement with or without fluid collections within the subcutis and the superficial fascia could be seen on T2-weighted images and deeper structures were normal. Necrotizing fasciitis was diagnosed in all cases in which, in addition to the subcutaneous changes, involvement of the deep fasciae was visible, which was defined as thickening of the fascia, high signal intensity on T2-weighted images, and contrast enhancement. Necrosis or abscesses were identified in areas with high signal intensity on T2-weighted images but with no enhancement on T1-weighted images after gadoteric meglumine injection in the center of the process and additional enhancement at the rim. The results of the MR analysis were compared with the surgical findings in 11 cases, with autopsy in one case, and with the clinical outcome in five cases of cellulitis.

Results

Eleven cases of necrotizing fasciitis and five of six cases of cellulitis were correctly identified. MR imaging therefore showed a sensitivity of 100%, a specificity of 86%, and an accuracy of 94% for the detection of necrotizing fasciitis. A single case of cellulitis was overstaged as necrotizing fasciitis in a 29-year-old woman who had blunt trauma to her right shoulder. She received two intramuscular injections of corticosteroids in her right deltoid muscle, one 1 day and one 3 days before MR imaging examination. These injections were unknown to the interpreters of the imaging. The MR examination of this patient showed a thickening of the superficial and deep fascia of the deltoid muscle, with contrast enhancement of the fascia and of the muscle itself.

The signal characteristics of all cases with necrotizing fasciitis (n = 11; with gadolinium diglumine administration, n = 9) were evaluated. Generally, necrotizing fasciitis showed a high signal intensity on T2-weighted and a low signal intensity on T1-weighted images of the subcutaneous tissue (comparable to cellulitis); contrast enhancement of the subcutaneous tissue was found in all cases. Involvement superficial and deep fasciae had a high signal intensity on T2-weighted images and showed contrast enhancement after gadolinium administration in all cases (Fig. 1). In six of nine cases of necrotizing fasciitis, small abscesses could be identified (Fig. 2). The massive increase in signal intensity of deep fascia on the T2-weighted scans of the patients who did not receive gadolinium diglumine led to the diagnosis of necrotizing fasciitis (Fig. 3). The intramuscular signal intensity on T2-weighted sequences increased diffusely in 10 of 11 cases (Fig. 1A). Circumscribed intramuscular fluid collections corresponding to intramuscular abscesses were seen in three patients (Fig. 2A). Two of these abscesses showed contrast enhancement of the abscess wall (Fig. 2B); the third patient did not receive gadolinium diglumine. A discrete, diffuse intramuscular contrast enhancement could be seen in seven of nine cases with necrotizing fasciitis (Fig. 1B). No alterations of the signal intensity in the bone marrow could be detected except in two patients, one with a hairy cell leukemia and one after previous osteosynthesis of a fracture of the femoral diaphysis.

In all cases of necrotizing fasciitis, a total of 42 deep fasciae showed signs of involvement on T2-weighted MR images. Surgical and autopsy findings could prove only 34 involved deep fasciae, all of them seen on T2-weighted MR images. Six of these eight fasciae that showed fluid collections along deep fasciae on T2-weighted scans but were not involved at surgery also showed a signal increase after IV contrast injection.

The signal characteristics of all cases with cellulitis showed high signal intensity of the subcutaneous tissue on T2-weighted images and a moderate to high contrast enhancement of the subcutaneous fat in all patients. Thickening of the superficial fascia with signal intensity increase on T2-weighted and T1-weighted images after contrast administration was recognized in four cases, and one case also showed a large subcutaneous abscess (Fig. 4). Except for one patient, all pa-
MR Imaging of Necrotizing Fasciitis and Cellulitis

Fig. 1.—Necrotizing fasciitis of right calf in 34-year-old man. 
A, T2-weighted fat-saturated spin-echo MR image shows signal enhancement of subcutaneous tissue (arrows) and fascia between gastrocnemius muscles and soleus muscle (arrowheads). Note increased signal intensity in medial part of soleus muscle. 
B, Enhanced T1-weighted fat-saturated spin-echo MR image shows signal enhancement of subcutis (white arrows) and deep fasciae (arrowheads) is less prominent than in A, especially along lateral part of fascia between soleus and gastrocnemius muscles (black arrows). Note muscular edema in medial part of soleus muscle, which shows only limited enhancement.

tients with cellulitis showed no involvement of deep fasciae and muscles. No osseous abnormalities were found.

Discussion

The MR imaging examinations of all 17 patients in our study showed signs of cellulitis including thickening of the subcutaneous tissue and increase of signal intensity of the subcutaneous tissue on T2-weighted and contrast enhanced T1-weighted images (Fig. 5). According to our previous definition, we judged the infectious process to be a necrotizing fasciitis only if deep fascial involvement could be identified on T2-weighted and contrast-enhanced T1-weighted images. Following these criteria, all 11 cases of necrotizing fasciitis were identified correctly, but one case of cellulitis was overstaged as necrotizing fasciitis because of the false-positive staging of deep fascial involvement. Overall, we noticed a sensitivity of 100%, a specificity of 86%, and an accuracy of 94% for the detection of necrotizing fasciitis. This high sensitivity is mainly due to the ability of MR imaging to detect fluid collections along the deep fascial sheaths. These collections are characterized by high signal intensity and thickening of the fascial planes on T2-weighted images. At surgery, these fluid collections correspond to foul perifascial fluid [17] and edema of the involved fasciae [18]. Contrast-enhanced T1-weighted images, even when acquired soon after gadolinium diplumine injection, showed an enhancement in nearly the same areas with increased signal intensity on T2-weighted sequences. Because these areas correspond at surgery to necrotic tissue rather than to highly vascularized tissue, major damage of the neighboring capillary network must be considered, resulting in early and increased extravasation of the contrast agent.

Fig. 2.—Necrotizing fasciitis with muscular abscess within right bi-ceps muscle in 40-year-old woman. 
A, T2-weighted fat-saturated fast spin-echo MR image shows thickening of subcutaneous tissue with fluid collections along superficial fascia (small arrows) and along deep fascia between biceps and triceps muscles (large arrow). Note abscess (arrowhead) and edema within bi-ceps muscle. 
B, Enhanced T1-weighted fat-saturated spin-echo MR image shows clear delineation of abscess wall. Note contrast enhancement of superficial (small arrows) and deep (large arrow) fascia.
(Fig. 5). At relatively few locations (12 locations in seven patients), an abscesslike delineation of the necrotic tissue with rim enhancement after contrast administration could be identified (Fig. 2).

By comparing MR imaging with the surgical findings, we found that the extent of infection revealed by MR imaging was usually overestimated. Several nonnecrotic deep fasciae showed slight to moderate signal increase on T2-weighted images. Of the 42 fasciae with increased signal intensity on T2-weighted images, only 34 were verified by surgery or autopsy as inflammatory fluid collections. The most likely explanation is noninfectious edema of fasciae neighboring the fasciae with infectious necrosis.

The surrounding muscles showed a slight signal intensity increase on T2-weighted sequences in 10 of 11 cases and a diffuse intramuscular contrast enhancement in seven of nine cases. This signal increase was less severe than that of the fasciae and therefore corresponds to edema (Fig. 1). Only three patients had intramuscular necrosis, represented as intramuscular abscesses (Fig. 2). This relatively rare occurrence of intramuscular necrosis is typical of necrotizing fasciitis [3].

No additional lesions could be detected using contrast agents, which is comparable to the results of other studies [15, 16, 19]. But by comparing the clinical history of the patients with the pattern of contrast enhancement after IV contrast administration, we noted that the early extravasation of the IV contrast agent in necrotic areas (Fig. 5) seems to be a parameter of the aggressiveness of the process, whereas abscess formation, shown by the typical rim enhancement after IV contrast administration, indicates a less aggressive process (Fig. 2).

The results of our study are comparable to those of Saiag et al. [20], who examined 26

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Fig. 3.—Necrotizing fasciitis in 57-year-old man who died 24 hr after MR imaging.  
A, T1-weighted spin-echo MR image shows bilateral hypointense thickening of deep fascia of latissimus dorsi muscles (arrowheads).  
B, Fluid collections, histologically verified as necrosis, can be seen on both sides of both latissimus dorsi muscles (arrowheads) on fat-saturated T2-weighted fast spin-echo MR image. Note involvement of superficial fascia of right serratus anterior muscle (arrow), additional involvement of subcutaneous brachial fascia of right arm, and pleural effusion.

Fig. 4.—38-year-old man with cellulitis of left forearm.  
A, T2-weighted fat-saturated spin-echo MR image shows massive thickening of subcutaneous tissue with large fluid collection within subcutaneous fat (arrows).  
B, Enhanced T1-weighted spin-echo MR image delineates large subcutaneous abscess with hypointense center and rim enhancement (arrows).
MR Imaging of Necrotizing Fasciitis and Cellulitis

Fig. 5.—32-year-old man with necrotizing fasciitis of left leg. 
A, Enhanced T1-weighted spin-echo MR image shows thickening and contrast enhancement of subcutaneous tissue (as seen in cases of cellulitis) (white arrows); additionally, thickening and contrast enhancement involve deep fascia between vastus lateralis muscle and biceps femoris muscle (black arrow). No abscess formation is seen. 
B, T2-weighted fast spin-echo MR image shows corresponding fluid collections within deep fascia (arrow) that were surgically verified as necrotic fascia.

patients with severe acute soft-tissue infections, but only three patients in his series had signs of necrotizing fasciitis on MR images. All of these three cases were confirmed at surgery. Hopkins et al. [19] also reported a high sensitivity (89–100%) for MR imaging in the detection of soft-tissue infections, whereas their specificity of 46% was low. They compared cases of osteomyelitis, pyarthrosis, abscesses, and myositis and cellulitis (total, n = 22) with 12 cases of noninfectious soft-tissue processes. Using MR imaging, Rahmouni et al. [6] analyzed 36 cases of acute soft-tissue infections, 11 of which had deep fascial necrosis at surgery. They concluded that T2-weighted MR images are reliable for detecting deep fascial fluid collections. Comparable to our results, they diagnosed necrotizing fasciitis when fluid collections along deep fasciae could be detected. However, they injected gadolinium diethylene only in cases with suspected abscesses.

Different radiologic methods have been evaluated for the detection of necrotizing fasciitis. Conventional radiography gives nondetailed information, such as soft-tissue thickening, gas formation, and possible foreign bodies [21]. Detection of soft-tissue gas by conventional radiography is more sensitive than by physical examination [9]; however, plain radiography shows no specific abnormality until the necrotizing process is well advanced, with the development of considerable gas in the subcutaneous tissue in cases of anaerobic infections [21]. Otherwise, only soft-tissue swelling can be detected. Foreign bodies (e.g., wooden foreign bodies), abscesses, and fluid collections can be found using sonography [22–24]. CT allows detection of subcutaneous and fascial edema, gas formation, abscesses, and foreign bodies [21]. In cases of massive fluid collections along fasciae seen on CT or sonography, necrotizing fasciitis can be suspected. Compared with MR imaging studies [6, 20], sonography and CT do not have as high accuracy for differentiation between cellulitis and necrotizing fasciitis because of their lower sensitivity in detecting deep fascial fluid.

Even if our study and those we have discussed show that MR imaging is probably the best radiologic tool for diagnosing necrotizing fasciitis, this method is limited because of its suboptimal specificity. Many other disorders, such as myositis, rheumatic diseases, phlebodem, and lymphedema or neoplastic disease, may result in an increased water content of the soft tissue [25–27]. Nevertheless, most of these entities can be diagnosed from their specific clinical findings and history.

Because necrotizing fasciitis has a fatal outcome if diagnosis is not made immediately and the clinical differentiation from cellulitis is difficult, it is important to establish an early and reliable diagnosis. Our results show that MR imaging has high sensitivity in the diagnosis of necrotizing fasciitis, with its characteristic findings of thickening and fluid collections along deep fascial sheaths. Therefore, MR imaging should be performed early in every case of suspected necrotizing fasciitis. If MR imaging does not exclude the presence of necrotizing fasciitis, further examinations, such as frozen-section biopsy, should be performed. In those cases, MR imaging can help to find the ideal location for these biopsies. The administration of IV gadolinium diethylene helps to delineate abscesses, and this study seems to indicate that the immediate extravasation of gadolinium in necrotic tissue is a marker for the aggressiveness of the infection.

MR imaging appears to be the method of choice to differentiate necrotizing fasciitis from cellulitis.

References
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