Diagnosis of Necrotizing Soft Tissue Infections by Computed Tomography

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Hypothesis: In contrast to previous beliefs, we hypothesize that computed tomography (CT) scanning is sensitive and specific for the diagnosis of necrotizing soft tissue infections (NSTIs).

Design: Retrospective and prospective case series.

Setting: Academic medical center.

Patients: Patients who were clinically suspected of having NSTIs from January 1, 2003, through April 30, 2009, and who underwent imaging with a 16- or 64-section helical CT scanner were studied. The CT result was considered positive if inflamed and necrotic tissue with or without gas or fluid collections across tissue planes was found. The disease (NSTI) was considered present if surgical exploration revealed elements of infection and necrosis of the soft tissues and pathological analysis confirmed the findings. The disease was considered absent if surgical exploration and pathological analysis failed to identify any of these findings or the patient was successfully treated without surgical exploration.

Main Outcome Measures: Sensitivity and specificity of CT for diagnosing NSTI.

Results: Of 67 patients with study inclusion criteria, 58 underwent surgical exploration, and NSTI was confirmed in 25 (43%). The remaining 42 patients had either nonnecrotizing infections during surgical exploration (n=33) or were treated nonoperatively with successful resolution of the symptoms (n=9). The sensitivity of CT to identify NSTI was 100%, specificity was 81%, positive predictive value was 76%, and negative predictive value was 100%. No differences were found in demographics, white blood cell count on admission, symptoms, or site of infection between those with a false- or true-positive CT result.

Conclusions: A negative CT result reliably excludes the diagnosis of NSTI. A positive CT result correctly identifies the disease with a high likelihood.

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Patients with necrotizing soft tissue infections (NSTIs) have mortality rates that range from 25% to 75%; therefore, this disease remains a therapeutic challenge.1,2 Treatment delays are frequent and in part owing to inadequate diagnostic tests. Computed tomography (CT) scanning has been considered inaccurate for the diagnosis of NSTI based on studies with small sample sizes and old CT technology.2,7,8

See Invited Critique at end of article

Magnetic resonance imaging (MRI) has a higher sensitivity but still low specificity and is not always available around the clock.9-12 Liberal surgical exploration has been recommended to prevent treatment delays but results in unnecessary interventions, pain, inconvenience, and expenses. The evolution of CT technology has allowed better definition of tissues and interpretation of images. Our hypothesis is that the new 16- and 64-section CT scanners can accurately diagnose NSTI and identify patients who require surgical intervention. The objective of this study is to calculate the sensitivity and specificity of 16- and 64-section CT for diagnosing NSTI.

Methods

Patients who were admitted to the Massachusetts General Hospital from January 1, 2003, through April 30, 2009, with a diagnosis of soft tissue infection and who underwent CT scanning because of clinical suspicion for NSTI were included in the study. Patients who had obvious NSTI on presentation and were directly taken to the operating room without first undergoing CT were excluded. Similarly, patients with unclear symptoms who were taken to the operating room without undergoing CT and who had undergone surgical exploration that revealed no NSTI were excluded. The following data were collected retrospectively for January 1, 2003, through July 30, 2008, and prospectively for August 1, 2008, through April 30, 2009: demographics; site of infection; white blood cell count on admission; systolic blood pressure, temperature, and white blood cell count on admission; time from be-
The mean (SD) interval from the onset of symptoms to admission was 3.5 (4.0) days (range, 0-15 days). The mortality for the entire group was 7.5% (5 patients), and the mean (SD) hospital stay for the survivors was 15 (16) days.

Fifty-eight patients (87%) underwent surgical exploration, and NSTI was confirmed in 25 (37% of all patients and 43% of patients who underwent surgical exploration). The remaining 33 patients had non-NSTIs and did not require debridement (n=28) or had isolated abscesses that required drainage (n=5). Nine more patients were treated nonoperatively with successful resolution of symptoms. In total, 42 patients (63%) who were evaluated with a CT scan did not have NSTI.

All patients had their NSTIs correctly diagnosed by CT scanning, and there were no false-negative test results. All 25 had abnormally enhanced soft tissues, indicative of inflammation and necrosis; 9 also had gas across tissue planes, and 7 had fluid collections. One patient had an initially equivocal scan result; therefore, another scan was performed 12 hours later and showed signs of NSTI. He underwent debridement and fared well. Of the 42 patients without NSTI, the CT result was false positive in 8 (19%; Table 1). The consistent finding was abnormal enhancement of soft tissues in all 8 patients and fluid collections in 3. The fluid collections were eventually found to be abscesses from pyomyositis and required drainage. One of these patients had an initially equivocal scan; therefore, another scan was performed 24 hours later and deemed to be suggestive of NSTI, but the result of the surgical exploration was negative. The sensitivity of CT was 100%, specificity was 81%, PPV was 76%, and NPV was 100%.

Patients with a true- and false-positive CT result were compared (Table 2). None of the examined variables showed statistically significant differences. No outcome differences were found between patients who underwent imaging with the 16- vs 64-section scanner.

Our findings suggest that a negative CT result can reliably exclude NSTI in patients with soft tissue infections and thus prevent unnecessary surgical explorations with their associated complications. When the CT result is positive, it correctly identifies the disease with a likelihood of 76%.

#### RESULTS

Eighty-five patients clinically suspected of having NSTI were admitted to the hospital during the study period. Eighteen of them were taken directly to the operating room because the signs and symptoms unequivocally suggested the presence of the disease. They were all confirmed to have NSTI by surgical exploration and pathological analysis. The remaining 67 patients underwent imaging first and make up the study population. Their mean (SD) age was 46 (15) years (age range, 18-85 years), and 43 were men (64%). The mean (SD) white blood cell count on admission was 16.3 (8.6) x10^9/L. The infection was localized in the extremities in 54 patients (81%), torso in 9 (13%), and genitoperineal area in 4 (6%). The mean (SD) interval from the onset of symptoms to hospital admission was 3.5 (4.0) days (range, 0-15 days). The mortality for the entire group was 7.5% (5 patients), and the mean (SD) hospital stay for the survivors was 15 (16) days.

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#### COMMENT

Our findings suggest that a negative CT result can reliably exclude NSTI in patients with soft tissue infections and thus prevent unnecessary surgical explorations with their associated complications. When the CT result is positive, it correctly identifies the disease with a likelihood of 76%.

Standard teaching rejects CT scanning as a reliable method of diagnosing NSTI. Surgical exploration is recommended as the diagnostic standard of reference. Tissue necrosis with lack of bleeding, crepitis among tissues indicating gas-forming organisms, fluid collections...
or “dishwasher” foul-smelling fluid, and loss of resistance on digital separation of the fascia from adjacent tissues are the hallmarks of the disease during surgical exploration. However, one can argue that the new-generation CT scanners are at least as sensitive as, if not more sensitive than, the naked eye to detect tissue ischemia, gas, and fluid collections. Most of the previous studies that reported on the value of CT were performed with old-generation scanners in limited patient populations. Wysoki et al reported on the characteristics of CT in 20 patients with necrotizing fasciitis admitted to the hospital between 1992 and 1996. In their study, CT scanning identified fascial thickening and fat stranding in 80%, gas in 55%, and abscesses in 35% of the patients. Three patients had none of these findings, and 6 had only 1 finding. No information was available on false-positive results. Becker et al described 16 patients with necrotizing fasciitis of the head and neck who were admitted to 3 hospitals during a 6-year period before 1997. Nonspecific CT findings of tissue thickening and enhancement were noted. Specific CT findings, such as gas and fluid collection or tissue necrosis, were less frequent. Earlier studies report only on pathognomonic CT findings, such as gas, which are not found in all patients with NSTI. Surprisingly, the literature lacks original data on the diagnostic accuracy of new-generation scanners for NSTI.

Magnetic resonance imaging has been proposed as an optimal tool for NSTI diagnosis because of its ability to identify differences in soft tissue enhancement. However, MRI is limited by 2 issues. First, it tends to overestimate the extent of deep fascial involvement, which may result in mislabeling cellulitis as NSTI and performing unnecessary surgical explorations. Its specificity ranges from 50% to 85%. Second and most important, it may lead to therapeutic delays because MRI is not immediately available around the clock in many institutions.

Computed tomography with a 16- or 64-section scanner is the most rapid and reliable test that can be performed in patients with suspected NSTI. Distinguishing between cellulitis and NSTI is often hard on the basis of clinical signs. Early detection is crucial to achieve optimal outcomes. Findings from CT, such as asymmetrical thickening of the fascia and muscle, nonenhancing tissues indicating necrosis, fluid collections, and gas across tissue planes, can be detected in all patients with NSTI according to our study. Therefore, the absence of these findings would suggest a nonnecrotizing infection that can be managed nonoperatively. In nearly 1 of every 5 patients, the CT scanner suggested NSTI, but the diagnosis was not confirmed on surgical exploration and pathological analysis. In all these patients, the finding was abnormal enhancement of deep tissues, which might indicate NSTI. On surgical exploration there was edema but no ischemia. Also, in 3 of these patients the CT scan suggested fluid collections. The finding was confirmed at surgical exploration but was associated with pyomyositis rather than NSTI. Like MRI, the highly sensitive new-generation CT scanners may overestimate the degree of deep tissue involvement. None of the examined factors in our study was able to distinguish between patients with true- and false-positive CT results. It seems that the presence of necrotic tissue or gas on CT unequivocally indicates NSTI. However, the other 2 criteria that we used in our study (asymmetrical tissue thickening and fluid collections) are subject to interpretation and could lead to a negative surgical exploration result. Correlation with clinical symptoms is of the utmost importance for the decision to perform a surgical exploration.

A limitation of CT and our study is that the distinction between NSTI and pyomyositis may be difficult because both show necrotic tissues and infectious collections. In later stages, pyomyositis demonstrates more focal muscle swelling and well-delineated areas of fluid attenuation, whereas NSTI is associated with asymmetrical and diffuse tissue involvement. However, in the early stages of pyomyositis the differentiating characteristics are less distinct. In most patients, both diseases require surgical debridement, and, therefore, the imaging differences are only of academic interest. Ultrasonography may be an alternative imaging method with contraindications to CT, but our experience is limited and published evidence is lacking.

We pursued surgical exploration in 33 patients even when the CT findings were not consistent with NSTI. This practice stemmed from the old belief that CT scanning was unreliable to make the diagnosis. The value of additional CT scans has been previously emphasized. An initially negative CT result does not preclude eventual progression of the disease. A patient with unresolved or worsening symptoms despite appropriate antibiotic treatment should undergo imaging again. Similarly, a follow-up CT scan after surgical debridement may reveal clinically unsuspected progression of the disease.

To our knowledge, this is the only study that reports on the value of 16- and 64-section CT in patients with suspected NSTI and estimates the false-positive and false-negative rates. With a sensitivity of 100% and specificity of 81%, CT is a reliable test to rule out NSTI or establish the need for urgent surgical intervention. In all cases, the clinical evaluation should be carefully correlated with the radiographic images.

### Table 2. Comparison of Patients With True- and False-Positive CT Results

<table>
<thead>
<tr>
<th>CT Result</th>
<th>False-Positive CT Result (n=8)</th>
<th>True-Positive CT Result (n=25)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex, No. (%)</td>
<td>5 (62)</td>
<td>17 (68)</td>
<td>&gt; .99</td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>41 (17)</td>
<td>51 (15)</td>
<td>.16</td>
</tr>
<tr>
<td>White blood cell count on admission, mean (SD), /µL</td>
<td>13 (7)</td>
<td>15 (8)</td>
<td>.43</td>
</tr>
<tr>
<td>Time from onset of symptoms to admission, mean (SD), d</td>
<td>2.2 (1.7)</td>
<td>2.1 (1.5)</td>
<td>.97</td>
</tr>
<tr>
<td>Time from admission to CT, mean (SD), h</td>
<td>14.9 (12.7)</td>
<td>15.3 (31.8)</td>
<td>.91</td>
</tr>
<tr>
<td>Site of infection in extremities, No. (%)</td>
<td>7 (88)</td>
<td>17 (68)</td>
<td>.39</td>
</tr>
</tbody>
</table>

Abbreviation: CT, computed tomography.

SI conversion factor: To convert white blood cell count to ×10⁹/L, multiply by 0.001.
INVITED CRITIQUE

Computed Tomography to Exclude Necrotizing Soft Tissue Infection

Not Quite Ready for Prime Time?

Dr Zacharias and colleagues have proposed that a negative CT result can reliably exclude the presence of NSTI, providing that a 16- or 64-section helical CT is used and intravenous contrast given. Although they report no false-negative CT results, 1 scan in a patient with a surgically confirmed NSTI was “equivocal” and CT needed to be repeated within 12 hours. Such an event might be considered a false-negative result in the purest sense and therefore could have altered the reported results. Although it has been described that repeat CT imaging may have a role in the diagnosis of NSTI in select patients, the need for an additional contrast load in the face of infection and end-organ dysfunction needs to be carefully weighed against any potential benefits.

Two of the 4 criteria that the authors used to reliably identify NSTI, asymmetrical tissue thickening and fluid collections, were more common in patients who had negative surgical explorations and are therefore of questionable value. Only the presence of nonenhancing tissue consistent with necrosis and gas traversing tissue planes appeared truly diagnostic. Therefore, although these findings may reliably identify muscle and fascial necrosis, CT is less likely to clearly identify those infections confined to the skin and subcutaneous tissues because these tissues are less vascular and less likely to contain gas. These infections, often with manifestations similar to their deeper counterparts, also require early identification and aggressive surgical debridement.

In summary, as CT technology continues to improve, it will continue to serve as an important adjunct in the diagnosis of most NSTIs. However, it is likely not perfect and should continue to be judiciously used in conjunction with good clinical judgment and a high index of suspicion.

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