ASSESSMENT AND EVALUATION OF HIGH-SPEED DS/I HELICAL CT, CHEST RADIOGRAPH AND THERMAL TEXTURE MAPS (TTM) IN SARS DIAGNOSIS

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ABSTRACT

To assess the diagnostic value of High-speed DS/I Helical CT, Chest Radiograph and Thermal Texture Maps (TTM) for severe acute respiratory syndrome (SARS) and improve the accuracy of SARS diagnosis. Methods: 111 confirmed SARS patients were examined between the days of March 10, 2003 to June 18, 2003 by CT, Chest Radiographs, and TTM, over intervals of 2-6 days each. Overall, the Chest Radiograph, CT and TTM examinations took approximately 80-90 days. Results: About 48% (53/111 cases) of lesions in the 111 SARS patients examined were detected in the lower lung fields. During the early stages of severe acute respiratory syndrome (SARS), chest radiograph manifestations were focal or multi-focal effusion change, SCT manifestation were focal, multi-focal small patches. Most of the focal, multi-focal small patches show “cotton ball” ground-glass infiltration density. In the progress stage, most SCT manifestations were extensive patches of ground-glass-like density or solitary patched density. TTM manifestations depicted abnormally high thermal radiation as well as solitary density structures that corresponded to lesions displayed in the CT manifestations. The thermal radiation of spleen was higher than liver's. The thermal radiation of spine decreased. In recovery stage, most chest radiographs and SCT manifestations were normal. In a few serious cases, HRCT manifestations showed pulmonary interstitial fibrosis. In those same patients, TTM manifestations depicted abnormally low
thermal radiation in the lungs that corresponded to the pulmonary interstitial fibrosis displayed in the CT manifestations. In normal recovery-stage patients, the thermal radiation of the spleen decreased, and the normal heat signatures of the spine were restored. Conclusion: TTM imaging was able to depict the position, morphology, and progress of lesions with the same degree of success as CT. Chest Radiograph, CT, and TTM combined were able to improve the quality and accuracy of general differential diagnosis and SARS diagnosis in the clinical practice.

KEYWORDS

SARS, SCT, CT, Radiograph, TTM, Diagnosis

INTRODUCTION

The first SARS outbreak was recorded in south China's Guang Dong Province in November 2002 and in a few months quickly spread over East Asia, appearing also around the world in 28 countries. Largely due to limited understanding concerning the new disease as non-typical pneumonia, high infection and fatality rates (11%-15%) resulted, drawing the attention of scientists around the globe. A new type of coronavirus has been identified as the cause of the emergent disease called SARS. The genetic sequence of SARS was decoded by teams of scientists in China and other countries, and as a result, new diagnostic tests have been developed and are under clinical study. Today, the standard diagnostic procedures still depended on epidemiology, clinical, laboratory and radiology examinations.

Images from chest radiology examinations (especially the HRCT) are important for early diagnosis of SARS for monitoring disease progress, making decisions to discharge, and monitoring recovery stages for complication. Early detection, early diagnosis, and immediate isolation are the keys to preventing another outbreak of SARS. Active image monitoring and analysis of the full clinical stages of illness are important for accurate diagnosis and treatment. In order to improve the process of diagnosing and monitoring SARS, three methods of using medical imaging to display SARS-related abnormalities have been studied and compared.

INFORMATION AND METHODS

Information: The 111 patients (pre-confirmed to be SARS patients by clinical and laboratory diagnosis) were examined between the days of March 10, 2003 and June 18, 2003 by Chest Radiograph, CT and TTM at the Department of Communicable Diseases, You-An Hospital, Beijing, China. All cases met the standard SARS diagnosis criteria set by the China Ministry of Health and the United States CDC. Among the 111 examined patients, 54 were male (24 cases between 12-30 years of age, 30 cases between 31-62 years of age, the average age being 34) and 57 were female (22 cases between 14-30 years, 35 cases between 31-68 years of age, the average age being 36). Out of the 111 cases, 98 claimed to have had close contact with other SARS patients; their symptoms included fever (94.4%), cough (92.7%), chest pain (83.3%), headache (55.6%) and Diarrhea (3%). Among the 111 patients, only 3 experienced no major symptoms. Laboratory tests of all the patients showed the following: a) White
blood cell count and lymphocyte count decreased during the earlier phases of the disease. b.) CD3, CD4, and CD8 T-cell counts were decreased - CD4 decreased most severely. T-cell counts were at their lowest 10-14 days after the symptoms began. The lower the T-cell count, the greater the severity of the SARS disease.

Methods of examination: Chest radiograph and CT were performed for every patient upon admission into the Hospital. Repeated follow-up examinations were performed afterwards regularly. Chest Radiographs were repeated every 2 to 3 days and CT every 4 to 6 days, for a total of 80 to 90 days. TTM examinations were performed between May 19 to June 18, 2003 for all 111 cases and a total of 164 times. The CT was performed with a High-speed DX/I helical CT unit manufactured by GE Company with slice thickness and slice interval of 10 mm. from lung apices to phrenic angles. The HRCT was performed with a 140 kV, 180mA, with a slice thickness of 2 mm, and slice interval of 2 to 4 mm and bone algorithm reconstruction. The radiograph was performed with a SHIMADZU 800 MA system. The TTM examinations were performed in three positions; anterior, dorsal, and right lateral of body with a TSI-21M system manufactured by Bioyear Group Inc. Total compatible TTM Imaging with CT are 123 case/time and chest radiographs are 152 case/time. More than 3 radiologists and scientists with senior qualifications assessed and reviewed all images.

RESULTS

A. Imaging Manifestation in Initial Stage:

Small focal or multiple and extensive patches of infiltration density showed in 28 out of 111 cases, and among those 28 cases, small focal opacity were more common in 24 cases of them (24/28, 85.7%). Radiograph showed only 14 cases. CT, particularly HRCT could show the lesion more clearly, and showed that the focal ground glass opacity was common. TTM manifestations depicted abnormally increased thermal radiation as well as solitary density structures that corresponded to lesions displayed in the HRCT, as well as an abnormal thermal radiation increase in the spleen and a decrease in the spine.

B. Imaging Manifestation of Progressive Stage

1) Uniform ground-glass-like density with ill-defined border and blood vessels (throughout the whole course of the continued follow-up observation) showed 18 cases out of 111 (16.2%).
2) Mainly ground-glass-like density with consolidation showed 85 cases out of 111 (76.6%)
3) Mainly consolidation density with air-bronchogram image showed 8 cases out of 111 (7.2%).

Again, TTM dynamic manifestation depicted abnormally increased thermal radiation as well as solitary density structures that corresponded to lesions displayed in the CT and radiograph. Abnormal thermal radiation reached its highest level in the spleen. The TTM images also show abnormality in the functions of other organs caused by SARS, or possibly by other, related or unrelated diseases. See table 1 and table 2.
C. Imaging Manifestations of Recovery Stage

Most of the patients in the recovery stage exhibited normal images. 4 of the 111 cases showed pulmonary interstitial hyperplasia with multiple linear, reticular or honey-combed patterns. Some also displayed an increase in density of the sub pleural arc line and thickened interlobular septa, or compensatory emphysema and

<table>
<thead>
<tr>
<th>Result</th>
<th>Same</th>
<th>Almost Same</th>
<th>Partially Same</th>
<th>Different</th>
<th>Determinate</th>
<th>Indeterminate</th>
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<td></td>
<td></td>
<td>123</td>
</tr>
<tr>
<td>TTM</td>
<td>106</td>
<td>11</td>
<td>6</td>
<td>0</td>
<td></td>
<td></td>
<td>123</td>
</tr>
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<td>9%</td>
<td>5%</td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 1: Comparison results of 123 cases in using CT/TTM examinations for SARS

Assessment: The same diagnosis results between CT and TTM were 106 cases out of 123 (86%), plus 11 cases of almost same diagnosis result, total up to 117 cases (95%+). The difference in the partial same diagnosis result as the residual state of illness in 5 cases of recovery stage, and 1 case of progress stage, because the functional image of TTM as more sensitive than the CT.

<table>
<thead>
<tr>
<th>Result</th>
<th>Same</th>
<th>Almost Same</th>
<th>Partially Same</th>
<th>Different</th>
<th>Determinate</th>
<th>Indeterminate</th>
<th>Total</th>
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<td>24</td>
<td>6</td>
<td>0</td>
<td></td>
<td>19</td>
<td>152</td>
</tr>
<tr>
<td>TTM</td>
<td>103</td>
<td>24</td>
<td>6</td>
<td>0</td>
<td>19</td>
<td>0</td>
<td>152</td>
</tr>
<tr>
<td>%</td>
<td>68%</td>
<td>16%</td>
<td>4%</td>
<td>12% (TTM)</td>
<td>12% (X-ray)</td>
<td></td>
<td>100%</td>
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</tbody>
</table>

Table 2: Comparison results of 152 cases in using Chest- X-ray/TTM examinations for SARS

Assessment: Total three results of Radiography were 88%. It remains the main imaging method of lung diseases including SARS. But, CT and TTM show more details in the early stage of the disease.
<table>
<thead>
<tr>
<th>Specification Item</th>
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<th>Protection</th>
<th>Examination Time (Minutes)</th>
<th>Cost</th>
<th>Environment Risk</th>
<th>Mobility</th>
<th>Power Consumption (KW)</th>
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<td>High</td>
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<tr>
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<td>5</td>
<td>Low</td>
<td>No</td>
<td>Best</td>
<td>0.3</td>
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</tbody>
</table>

Table 3: The comparison of three image system features in SARS examinations:

The table shows that TTM imaging is one of the efficient technology for SARS examinations. It not only shows lung abnormality but also shows liver, spleen, kidney or other abnormality of patient (including breast, spine and throat) reduced thoracic cage. 5 of the 111 cases showed focal or multi-cavity with purulent. TTM manifestations depicted abnormally low thermal radiation with "cool zone" structures that corresponded to lesions that displayed interstitial hyperplasia or compensatory emphysema, or "oval cold" solitary density structures that corresponded to cavities with purulent in the CT and radiograph. TTM continued to show a decrease in thermal radiation of the spleen and an increase in the thermal radiation of the spine.

**DISCUSSION**

A. Chest Radiograph, SCT and TTM Manifestation of SARS and Its Pathologic Basis

It is generally considered that radiographic and CT indications of SARS are in the density, appearance and distribution of lesions. Density can show ground-glass opacity and/or consolidation. In this particular study, ground-glass density was seen in most cases regardless of the stage (not including recovery stage). The shape of lesion could be focal, multi-focal, nodular, patchy, segmental, lobar and in extensive conglomerated lesions. The distribution of the lesion in this study was similar to that reported in the reference papers [1]-[3] - mostly in lower lung fields and sub-pleural regions. Seen in a TTM image, SARS can be detected in the change of thermal radiation, distribution, and appearance of pulmonary lesions, as well as metabolic change displayed in other organs related with SARS. At the initial and progress stages, there was an increase in the thermal radiation of the lesions, and solid density heat structures appeared over 3 cm deep from the surface of the skin that corresponded with the lesions found in CT and Chest Radiography. At the recovery stage, there was decreased thermal radiation, with "cool zone" structures or "oval cold" solitary density structures that matched lesions that displayed interstitial hyperplasia and compensatory emphysema, or cavities with purulent in the CT and radiograph. TTM also showed decreased thermal radiation of the spleen, and increased thermal radiation of the spine.

The pathologic findings of SARS include parenchymal and interstitial abnormalities. If the lesion is mainly interstitial or the parenchymal lesion does not fill the alveoli completely, the lesion may show ground-glass density. Severe parenchymal infiltration results in imaging density of consolidation. Generally in the early stages, the lesions were chiefly interstitial infiltrative. However, with progression, the lesions become consolidation predominates. In
the later stages, the SARS patient may develop adult respiratory distress syndrome (ARDS), in which the main pathologic abnormality is pulmonary edema. The degree of pathologic change is almost identical to that of the imaging manifestation. The radiograph manifestation displayed mass change of opacity in lung fields. TTM manifestation showed appearance of low thermal radiation - zones and solid heat structures in lung fields, along with metabolic changes in the other organs.

B. Dynamic Evolution Imaging in SARS

Dynamic follow-up observations of changes in the images of SARS patients are indispensable, where it is not necessary in other pneumonias. Imaging changes in SARS patients were not only dependent on the inherent development of the disease itself, but also on treatment methods, treatment effects, age, previous health, etc. Among the 111 cases, some of the small patchy densities in the early stages progressed into extensive lesions in a very short time roughly 24 to 48 hours. Such a dynamic change was largely consistent with a worsening of the clinical condition. Diffusely scattered lesions in both lungs are suggestive of early ARDS. Progression from focal ground-glass-like density to extensive density with consolidation (CT & Radiograph) and appearance of low thermal radiation zone with abnormal solid density structure of heat (TTM) and signs of rapid development of the lesion are compatible with the clinical features of ARDS. The decreased opacity showed resolution of the lesion, and eventual disappearance of low thermal radiation zone, along with decreased density of lesion structures and increased appearance of spine line and liver heat. During the recovery stage, some patients displayed complicated pulmonary interstitial fibrosis or multiple abscess-like cavities. HRCT showed linear, reticular and honey-comb-like densities. Radiographs cannot demonstrate detailed interstitial changes. Radiographic changes of lung markings are nonspecific for interstitial fibrosis. The low thermal radiation zone of TTM was suggestions of the possibility of interstitial fibrosis.

C. Comparison and Usage of Three Imaging Examinations for SARS

Radiography remains the main imaging method of lung diseases including SARS. A patient suspected of having SARS must undergo chest radiography or TTM at first. But, in early stages of the disease, there are certain limitations to radiographic imaging. If the radiograph shows no abnormality, but TTM does, then an SCT should be performed at once. HRCT may demonstrate subtle focal lesions in early stage of the disease, especially ground-glass-like density; corresponding TTM images may show solid density structures of lesions as well as other functional image information related with SARS. During treatment of SARS, it is necessary to monitor the chest condition, such as the distribution and extent of the lesion and the effect of treatment. Following the initial stage of the disease, radiography and TTM become the main methods of imaging examination of SARS, which can show the general manifestation of the disease. In addition, it is convenient, less expensive, and requires less exposure to potentially harmful radiation. It is suggested that TTM and Radiography be employed together to monitor the dynamic evolution of SARS. During the recovery stage, if there is any change towards possible pulmonary interstitial hyperplasia, HRCT and TTM should be used to reveal details of the interstitial and functional low-thermal radiation zone.
Although HRCT demonstrates some favorable advantages concerning early diagnosis, in the case of critically ill patients, or patients with ARDS, bedside radiography and TTM are the only imaging modalities of choice.

TTM-manifestations such as functional imaging was able to quickly examine and assess the position, morphology, and progress of SARS lesions, in the meantime effectively monitoring treatment and patient recovery by providing information regarding the functional condition of the liver, spleen, kidney and other organs.

Chest Radiograph and TTM will be used as first line image systems for SARS screening, followed by CT and TTM to carry out further differential diagnosis, including full-course treatment monitoring. This combination of the three imaging systems should be the most beneficial for future prevention and treatment of SARS.

REFERENCES


