Dysbaric osteonecrosis by X-ray and CT scan in Chinese divers.

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Jiang C, Bing B, Yu C, Xiao L, Liu W, Jiao S, Liu Y, Lam X, Lam TH. Dysbaric osteonecrosis by X-ray and CT scan in Chinese divers. Undersea Hyperb Med 2005; (32)3:169-174. Objective: To compare the results of X-ray and CT scan for dysbaric osteonecrosis in Chinese divers. Methods: Both shoulders, hips and knees of 66 asymptomatic divers with diving duration of more than one year were examined by X-ray and CT scan. Results: The most frequent locations of dysbaric osteonecrosis were the upper femurs, followed by the upper humerus, lower femurs and upper tibias, and the most frequent radiographic lesions were calcification spots and cystic changes. Of the lesions detected, 38% (27/71) and 42% (95/229) were juxta-articular of the femoral and humeral heads by X-ray and CT respectively. The detection rates of dysbaric necrosis (juxta- and/or other lesions) of X-ray and CT scan were 42.4% (95% confidence interval: 30.5%-54.3%) and 81.8% (95% CI: 72.4%-91.2%) respectively (p<0.05). If CT scan was used as the gold standard, the sensitivity of X-ray was 100% and the specificity was 31.6%. Conclusion: CT scan showed a higher detection rate of dysbaric necrosis than X-ray. We recommend that CT scan be used for early diagnosis of dysbaric osteonecrosis.

INTRODUCTION

Dysbaric osteonecrosis (DON) is an important occupational disease that occurs in compressed air workers and professional divers. Early lesions are usually silent and a major limitation of X-ray examination is the difficulty to detect small or early lesions. Failure to make an early diagnosis would result in delay in prevention and treatment. There have been a few reports on using MRI and scintigraphy for the diagnosis of DON (1,2). Kuang reported that the detection rate of DON in divers by CT scan was higher (73.5%) than MRI (67.7%) and X-ray (30.0%) (3). We performed both X-ray and CT scan on 66 male asymptomatic Chinese divers and compared the results on dysbaric osteonecrosis.

METHODS

General Data

All professional divers in Guangzhou were required to take a periodic occupational health examination according to the related regulations. During October to December 2002, we examined 66 divers, all were men, and 50 of them came from the Guangzhou Salvage Administration, the Ministry of Communication of the People’s Republic of China, and the rest were from a private salvage company. The diving work took place mostly along the shore of South China Sea and in some tropical areas abroad all year round since 1974. All were asymptomatic. Ten of the divers had a history of acute attacks of decompression sickness within 36 hours of diving with headache, joint pain, paresis, skin itch, skin bleeding, skin papules or macules and were treated by recompression immediately.

Apart from a medical examination, X-ray and CT scan, we completed a questionnaire for each diver to collect information on occupational diving history, medical history, and history of smoking and alcohol drinking.

Radiological Examination

Four radiographs and four tomographs were performed on each of the 66 divers of the shoulders, hips and knee joints. We took images of each shoulder separately, plus one for both hips and one for both knees, i.e. four images of X-ray and four images of CT. The total is 264 radiographs and 264 tomograms. A radiographer performed the X-ray examination...
using Toshiba 500mA X-ray machine and two CT doctors performed the CT scan using Toshiba X vision GX CT scan machine (Table 1).

**Procedures for diagnosis**

The study was a national collaborative project between Shanghai and Guangzhou. The first photographic evaluation was carried out by a research team in Guangzhou, which included one CT scan doctor, one radiologist, one orthopedic and two occupational physicians. Secondly, three experts of our research team, who were from Shanghai Yangpu District Central Hospital, read the films again. The final diagnosis was based on the consensus of the Guangzhou and Shanghai teams.

**Statistical analysis**

Statistical analysis was performed using SPSS for \( \chi^2 \) test and kappa test for agreement between the two methods of imaging.

### RESULTS

The mean age of the divers was 38.4 years (standard deviation SD: 7.92, range: 22 to 53 years), and the mean professional diving duration was 18.4 years (SD: 9.03, range: 1 to 33 years). The deepest dive was 100 meters and the shallowest was 2 meters, and the most common depth was 10 meters. The mean diving frequency in one year was 66.6 times (SD 44.45, range: 10 to 180 times), and the mean duration per dive was 1.5 hours.

264 radiographs and 264 CT scans of 66 divers were examined. Table 2 shows that 28 divers had dysbaric osteonecrosis by X-ray examination and 54 divers had so by CT scan. The detection rates of X-ray and CT scan were 42.4% (28/66) (95% confidence interval: 30.5%-54.3%) and 81.8% (54/66) (95% CI: 72.4%-91.2%) respectively (\( p<0.05 \)). If CT scan was assumed to be the gold standard, the sensitivity of X-ray for dysbaric osteonecrosis was 100% (28/28), and the specificity was only

### Table 1 Radiographic condition of X-ray and CT scan

<table>
<thead>
<tr>
<th>X-ray</th>
<th>CT scan</th>
</tr>
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<tbody>
<tr>
<td>Focus-film distance</td>
<td>Exposure status</td>
</tr>
<tr>
<td>Shoulder Joint</td>
<td>80-90cm</td>
</tr>
<tr>
<td>Knee Joint</td>
<td>80-90cm</td>
</tr>
<tr>
<td>Hip Joint</td>
<td>80-90cm</td>
</tr>
</tbody>
</table>

### Table 2 Comparison of positive detection rates for dybaric osteonecrosis between X-ray and CT

<table>
<thead>
<tr>
<th>X-Ray</th>
<th>Positive</th>
<th>Negative</th>
<th>Total (Detection rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>28</td>
<td>26</td>
<td>54 (81.8%)</td>
</tr>
<tr>
<td>Negative</td>
<td>0</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Total (Detection rate)</td>
<td>28 (42.4%)</td>
<td>38</td>
<td>66</td>
</tr>
</tbody>
</table>

\( \chi^2 =10.8, \) degree of freedom=1, \( p=0.001; \) Kappa=0.28, \( p=0.001 \)
31.6% (12/38). The Kappa test for agreement was 0.28, indicating fair agreement.

We present seven X-ray and CT images of 3 divers to illustrate. (a) normal X-ray but positive CT findings in the right head of humerus (Figs. 1-1 and 2); (b) positive X-ray and CT with the latter showing clearer lesions (Figs. 2-1, 2-2 and 2-3) in the right head of the femur; and (c) positive X-ray and CT with both showing clearly positive findings (Figs. 3-1 and 3-2) in the right head of femur.

Fig. 1. X-ray and CT abnormalities in the right humeral head of a male diver aged 37 years. Diving history 12 years, diving frequency about 60 days per year, deepest 52 m, shallowest 2 m, most common 30 m. Figure 1-1: X-ray shows no abnormalities. Figure 1-2: CT shows increased density at articular surface, and several cysts with dense surroundings.

Fig. 2. X-ray and CT abnormalities in the right femoral head of a male diver aged 40 years. Diving history 23 years, diving frequency 30 days per year, deepest 45 m, shallowest 1 m, most common 20 m. Figure 2-1: X-ray shows depression and deformities of articular surface, and cystic change with irregular and dense areas. Figure 2-2: CT shows more deformities of articular surface and several cysts with irregular and dense areas more clearly. Figure 2-3: CT of next layer shows depression of articular surface, 3 cysts and many dense areas.

Fig. 1-1

Fig. 1-2

Fig. 2-1

Fig. 2-2
Besides the lesions found in the femur, humerus and tibia, we also found lesions in uncommon locations such as the clavicle, scapular, pubis and ischium. Table 3 shows that 71 lesions were detected by X-ray, including 19 calcification spots, 22 cystic lesions and 30 other lesions, and 229 by CT scan, including 160 calcification spots, 65 cystic lesions and 4 others. The most common location of dysbaric osteonecrosis was the upper femur, 59.2% (42/71) by X-ray and 33.6% (77/229) by CT scan; followed by the upper humerus, 19.7% (14/71) and 23.1% (53/229); lower femur, 14.1% (10/71) and 18.8% (43/229) and upper tibia, 4.2% (3/71) and 10.0% (23/229) respectively. Moreover, we found that juxta-articular lesions of the femoral and humeral head from numbers bracketed in Table 3 were 38% (27/71) by X-ray and 42% (95/229) by CT scan respectively.

DISCUSSION

DON was first reported in compressed air workers (4) and was subsequently observed in divers. At present, DON is still an important occupational disease of compressed air workers and divers (5,6). The primary method of detecting DON lesions is bone and joint radiography (7). Because more than 8 weeks are needed before bone lesions can be detected even in animal experiments, delayed diagnosis is common. Our literature review showed that the earliest reported DON diagnosis was at 7 months after diving work (8,9).

The prevalence of the DON range from 10% to 70% by X-ray examination (2,9,10) and the differences depended on the exposure and duration of follow up. Several studies showed that the detection rates for DON by CT scan
and MRI were much higher than that by X-ray (1,2,3). Kuang’s detection rate by CT scan was more than double that of X-ray (73.5% versus 30.0%) (3). Our CT scan prevalence was also nearly twice that of X-ray (81.8% versus 42.4%). DON lesions usually affect long bone with fatty marrow, especially the humerus, femur and tibia. Pathological features are characterized by intramedially venous stasis, ischemia and necrosis of bone and radiographic features characterized by increased denseness, calcification, cystic changes, damage or transmutation of joint surface. Davidson et al. reported that the most frequent radiographic and tomographic features were calcification, cystic changes and others such as lesions of joints surface (narrowed space or transmutation) (6).

The most frequent location by X-ray or CT was the upper femur, followed by the upper humerus, lower femur and tibia. However, Xue reported (9) that long bone lesions by X-ray examination were most frequently found in upper humerus (46%), followed by upper femur (37.7%), lower femur (8.3%) and tibia (8.0%). Future study should be performed comparing X-ray, CT scan, and MRI.

In defining a cystic lesion, there should be a circle of osteosclerosis around the cystic area. However, some of the cysts in our subjects did not have a typical circle of osteosclerosis while no bone trabecules were visible in the center of the cysts. We hypothesize that this is likely to be an early cystic change as also reported by Zhang (11). Follow-up of these cases in the future would clarify the hypothesis.

Besides lesions of the femur, humerus and tibia, we also found bony lesions by CT in some locations which were seldom reported in the literature, such as the clavicle, scapular, pubis and ischium.

CT scan has been confirmed to have higher sensitivity and specificity in the
diagnosis of bone and joint diseases than X-ray, and our results showed that it can be used for early diagnosis of dysbaric osteonecrosis. X-ray had high sensitivity but low specificity. The radiographic appearance in X-ray and CT scan were similar, but CT scan is superior because it can detect smaller lesions. We found some lesions in bones other than the humerus and femur. These could be unrelated to dysbaric disease.

Previously, we had admitted a patient (not among the 66 in the present study) who first got acute decompression sickness in December 2001 after diving work. He had recompression treatment immediately until the symptoms disappeared. The patient was followed-up regularly for three months with no abnormal findings. X-ray was normal but CT scan was not done. He continued diving until October 2002 when he felt pain again in his right hip. X-ray examination showed a typical severe osteonecrosis in the head of the right femur. Had CT scan been done earlier, the lesion could have been detected earlier, and its progression could have been prevented or retarded by suspension of diving work.

We recommend that CT scan should be used for early diagnosis of dysbaric osteonecrosis when X-ray does not reveal any lesions, especially for those who had a history of decompression sickness and/or joint symptoms, missed decompression or use of decompression tables that are known to have produced DON. Symptomatic subjects with osteonecrotic lesions should not be further exposed to compressed air work and diving. However, the cost of the screening method must also be taken into account when screening large group of subjects.

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REFERENCES