

Full Length Research Paper

The evaluation of the bone graft survival status in titanium cervical cages by radionuclide bone CT scan

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To find a better way to evaluate the bone graft survival status in cervical cages, forty-one patients suffering from one-level cervical spondylosis were enrolled in this study. All underwent anterior cervical decompression and fusion with titanium cage and plate. When followed up, another 21 patients were confirmed as one-level cervical spondylosis without operation and were enrolled as control group. "Bolos" injection of radioactive ^{99m}Tc methylene diphosphonate (^{99m}Tc -MDP) with a dose of 25 ~ 30 mCi was performed through cubital vein, and radionuclide distribution images of cervical spine were obtained by single photon emission computed tomography/computed tomography (SPECT/CT). In sagittal view, bone graft was positioned accurately. By "region of interest" (ROI) technique, the same regions in bone graft and thoracic vertebra with the same level of suprasternal fossa were selected. Radioactive count ratio was then obtained. In the control group, "bone graft" was chosen on the inferior vertebra of the lesion segment, and the ratio was similarly gotten. Statistical difference was shown between bone graft group and control group by t test ($t = 2.713$, $P < 0.05$). The bone graft survival rate was 100% by SPECT/CT and bony fusion rate was 92.7% by CT scan. It indicated that in all bony fusion cases, bone graft survived; however, the bone survival was not surely together with bony fusion.

Key words: Bone graft, titanium cervical cage, radionuclide bone CT.

INTRODUCTION

In recent years, cervical interbody cages have gained popularity in the treatment of degenerative spinal disorders and satisfactory clinical outcomes have been reported (Hacker, 2002; Profeta et al., 2000). However, the cage still has some disadvantages, among which is the stress shielding that decreases interbody bone matrix formation or even leads to non-bony union (Kandziora et al., 2002; Kanayama et al., 2000). Due to the cage's smaller size and X-ray shielding character, the evaluation of bone graft survival status in the titanium cage difficult becomes difficult, especially combining with the anterior plate. So it is essential to find a direct and effective way

to evaluate the bone graft status in the opaque cage. In this study, radionuclide bone computed tomography (CT) scan was performed to carry out such an evaluation.

MATERIALS AND METHODS

Patients

From October 2007 to April 2008, forty-one patients with confirmed diagnosis of one-level cervical spondylosis in our hospital were enrolled. There were twenty-one men and twenty women. The mean age was 47.3 years (37 - 62 years). All patients had taken X-ray, CT and magnetic resonance imaging (MRI) combined with careful physical examination preoperatively. Twenty-nine cases were confirmed as myelopathy type and twelve were radiculopathy type. The lesion segment distributions were 3 cases of C2/3, 7 cases of C3/4, 10 cases of C4/5, 12 cases of C5/6 and 9 cases of C6/7. They all underwent anterior cervical decompression and fusion (ACDF) with titanium cage insertion and plate fixation. Another 21 patients confirmed as one-level cervical spondylosis with conservative treatment were enrolled in the study as volunteers who were well matched with proportion of gender and age. All patients clinically show bone tumors and metabolic diseases. The mean follow-up period was 10 months post surgery,

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Abbreviations: ACDF, Anterior cervical decompression and fusion; ROI, region of interest; MDP, methylene diphosphonate; MRI, magnetic resonance imaging; SPECT/CT, single photon emission computed tomography/computed tomography.

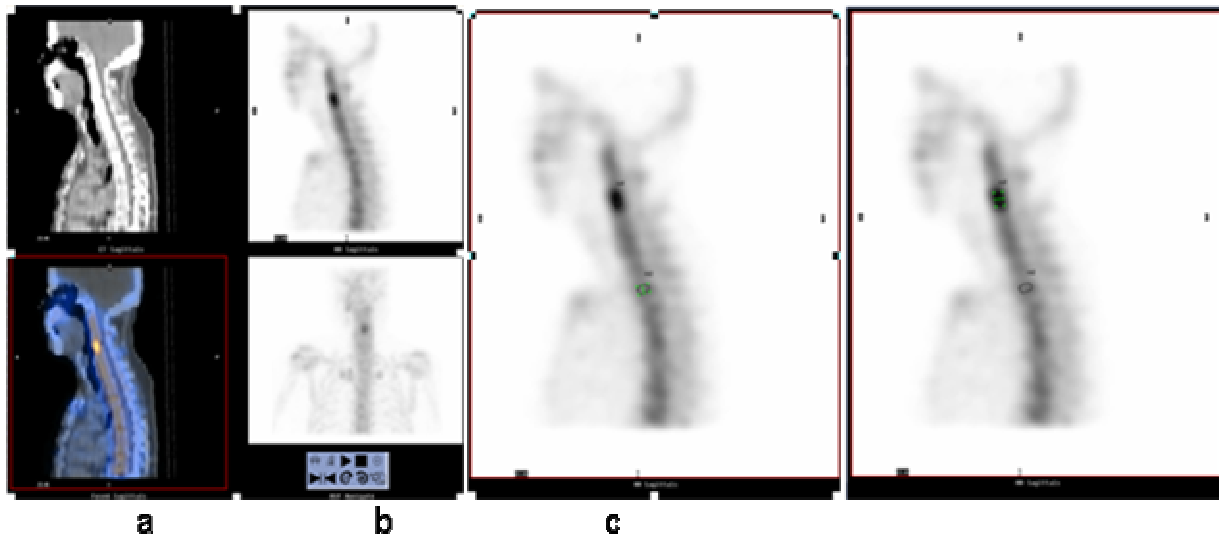


Figure 1. A 42-year-old male that underwent ACDF with cage was reexamined by SPECT/CT to evaluate the bone graft survival status. A: Location of bone graft in the sagittal reconstruction fused images; B: selection of ROI in the bone graft and obtaining of the radioactive count in the sagittal view; C: selection of ROI on the vertebra with the level of the suprasternal fossa with the same size of that in (b) and obtaining the radioactive count.

with a range of 3 to 15 months.

Radionuclide bone CT scan evaluation

The "bolus" injection of radioactive ^{99m}Tc methylene diphosphonate (^{99m}Tc -MDP) with a dose of 25 ~ 30 mCi was performed through the cubital vein. Three hours later, radionuclide bone CT scan for cervical spine was carried out by Hawkeye single photon emission computed tomography (SPECT)/CT (GE, United States). Images of radionuclide distribution in cervical spine were routinely obtained and automatically fused to locate the cage position for postoperative patients. Another spot was selected on thoracic spine, with the same level of suprasternal fossa. By region of interest (ROI) technique, the radioactive counting was performed in the cage location in the fused sagittal multiplanar image. With the same size, the radioactive counting of the thoracic vertebra was recorded correspondingly as contrast. Then, the radioactive counting ratio of cage insertion site to control site could be acquired. For the patients who have not undergone ACDF with cage insertion and anterior plating, the inferior cervical vertebra adjacent to the lesion segment was chosen to get the radioactive counting by ROI technology. Using the same method, the radioactive count of ROI in the thoracic vertebra with the level of suprasternal fossa was gotten. This is shown in Figure 1. For the two groups, the results are presented as the mean \pm standard deviation, respectively.

2-D CT reconstruction evaluation

All patients having undergone the cervical cage insertion and anterior plate fixation were reexamined by the 16-slice spiral CT (Toshiba Aquillion, Japan) when followed-up. The coronal and sagittal multiplanar reconstruction images were routinely obtained. The bone graft growth status within the titanium cage could be observed. Whether bridging bony trabecula has formed with the cage between the adjacent vertebrae and bony fusion has formed through the cages, it could be visually judged and it may indirectly reflect the bone survival status. This is shown in Figure 2.

RESULTS

Radionuclide bone CT scan

The radioactive count ratio of "region of interest" was 1.880 ± 0.293 in the bone graft group, and 1.084 ± 0.016 in the control group. The Statistical Package for the Social Sciences (SPSS) 11.0 software package was used to analyze the result by t test, and t value equaled to 2.713, $P < 0.05$, indicated statistically significant difference between both groups. The radioactive count ratio in the follow-up group was higher than that in the control group, which presented that the bone metabolism in the follow-up group was more active. The bone graft survival rate was 100%.

2-D CT reconstruction

Among all the patients who underwent ACDF with cage and plate instrumentation, thirty-eight were observed with bridging bony trabecula formation through the cage between the fixed adjacent cervical vertebrae. The other 3 cases were presented with a bit of bone defect in the bone graft, and bone graft in the cage was discontinuous. Thus the bony fusion rate was 92.7%.

DISCUSSION

Compared to the ACDF procedure only, ACDF with cage and plate instrumentation can obviate the need for allograft use or iliac autograft harvest and provide initial

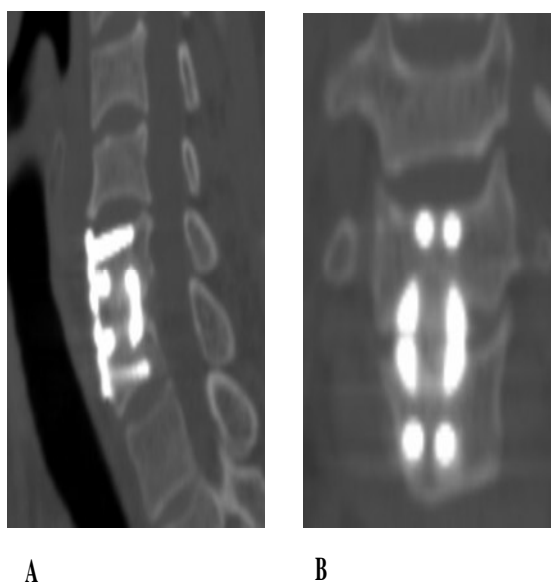


Figure 2. The same patient mentioned in Figure 1 was examined by CT scan and sagittal/coronal multiplanar images were reconstructed to observe the bony fusion status. A: In sagittal view, the bridging bony trabecula has formed and indicated exactly bony fusion; B: in coronal view, the bony fusion was also shown through the titanium cage between the adjacent vertebrae.

stability before fusion. The intraoperative complications, blood loss and operative time showed no significant difference (Hacker et al., 2000). It has gained more popularity in clinical treatment of cervical spondylosis. But there still exists some disadvantages, such as migration, subsidence or pseudoarthrosis because of the non-fusion which is connected with bone graft survival status (Zdeblick and Phillips, 2003). Traditionally, the monitoring of bone graft survival status was dependent on X-ray. However, the cervical titanium interbody cage with small internal space for graft and character of X-ray shielding increases the difficulty in evaluating bone graft survival.

Radionuclide bone CT scan can directly reflect the functional status of bone metabolism. For the bone graft, it may reflect the bone graft survival status earlier with higher sensitivity. Only when the amount of local calcium varies over 30 ~ 50% can X-ray demonstrate the difference (Papier, 1978). The amount of ^{99m}Tc -labeled bisphosphonates deposited in bone depends on the local blood flow, mineral metabolism and bone activity. When blood flow and metabolism of the bone increases strongly and new bone forms, more ^{99m}Tc labeled phosphonates will gather in the bone and deposit than that of normal bone. Yet there are few reports of the use of radionuclide bone CT scan to monitor bone graft survival in the cervical titanium cage.

SPECT/CT scan using image fusion technique combined with radionuclide imaging and CT scans make up for the defects of bone graft's small size and difficulty in locating on images and thus enhance the accuracy of radio-

nuclide bone scan. This study showed that in most of the cases, ^{99m}Tc -MDP gathered and its γ -ray radioactivity could get through the metal cage wall and be detected. The ratio of radioactivity count reflected the bone graft survival status.

In this study, the cage was filled with local autogenous bone resected from the vertebra in the surgery. Mainly, it was cancellous bone from the vertebra body. "Creeping substitution" will proceed after bone grafting. The porous structure of bone graft determines the "creeping substitution" speed (Hoppens, 1980). Compared to cortical bone, cancellous bone is more conducive for angiogenesis. More nutrients could be delivered to participate in metabolism and ossification, which makes the process of creeping substitution easier. The amount of viable cells in cancellous bone is larger than in cortical bone of the same volume (Burchardt, 1983, 1987; Springfield, 1987). Theoretically speaking, the radio-nuclide ^{99m}Tc -MDP should gather more in cancellous bone than in cortical bone. Thus, the image will develop fully and radionuclide concentration zone will be easily distinguished from the surrounding bone graft bed. In this study, it is shown that radionuclide uptake in the bone graft was significantly more than that in control group, which indicated that bone graft metabolism was active postoperatively, 3 to 15 months. The concentration of radionuclide indicated that sub-MDP exchanging with hydroxyapatite greystone deposited more in delayed phase. One case with minimum 3-month followed-up period postoperatively showed a radioactive count ratio of 1.634, which was higher than

the maximum value (1.100) of the control group (0.084 ± 0.016). It suggested that the bone graft had survived in the cage. The radioactive count ratio of the cases was 1.853 with 6-month follow-up period, and 1.502 with 9-month follow-up period. All were higher than the result of early postoperative stage. One case with the maximum 15-month follow-up period had radioactive count ratio of 1.470. It indicated that there may exist an ascent-to-descent curve that depicted the bone graft's creeping substitution procession. During the period of 3- to 15-month postoperative, the trend of radioactive count ratio was from smaller to bigger, then to smaller, which means that radionuclide uptake was from weak to strong and then to weak correspondingly. This result is similar with the finding in monitoring bone graft survival performed in rabbits by Jian-guo et al. (2005). It was also consistent with the phenomenon that bone forms actively in the early stage and then gradually slows down to the level close to bone graft bed.

It is believed that bone graft survival is the premise and basis of acquiring bony fusion with adjacent vertebrae. Only the surviving bone can possibly obtain confirmed bony fusion. The bone graft that has not survived well in the early stage of transplantation usually presents with "cold zone" in the radionuclide image. The less concentration denotes lower radioactive count ratio in the graft than in the normal control areas. In this study, all cases were found with bone graft survival. This is similar with Matge's report that bone fusion rate is 90% 6 months postoperative, 100% one year postoperative (Matge, 2002). On one hand, it might be due to the porous structure of the cancellous bone graft which is easier to establish a good blood supply than cortical bone graft, while on the other hand, it may be due to the initial stability provided by titanium cage and anterior plate. However, that the bone graft within the cage survived did not mean that there was certainly, effective bony fusion. The three cases in this study, with radioactive count ratios 1.635, 1.527 and 1.626, respectively, higher than the normal control group value, finally proved to be non-bony fused by CT scan reconstruction. From CT scans, images defects in the bone graft could be clearly observed. The translucent zone was deemed discontinuous or composed of fibrous tissue which might be verified only by biopsy or operative exploration. Also, it has been found that the common trait among the three non-bony fusion cases had the slight bone defect in the middle of the bone graft. It was assumed that new bone formation started simultaneously from proximal and distal ends of the bone graft contacting the adjacent vertebrae. The blood supply necessary for new bone formation may also be derived from the proximal and distal vertebrae unilaterally and respectively together with the angiogenesis. The bone graft survival will not lead to the final bony fusion, however, the cases that obtained bony fusion all showed bone graft's survival. As it is well known, internal fixation is applied to acquire initial stability

and the bony fusion provides long-term stability. Bone graft's failure to survive will probably bring about the non-bony fusion and further instability of fixed segment.

Conclusion

In comparison with the CT scan reconstruction, the radionuclide bone CT scan can more directly reflect the bone graft survival status due to its accurate monitoring of bone metabolism in the titanium cage. The variety of bone graft might be earlier perceived by SPECT/CT than CT scan reconstruction relying on the observation to modality. It is a direct, sensitive and effective method to evaluate the bone graft survival status in the opaque titanium cage by radionuclide bone CT scan and it can make good predication of the bony fusion. At the same time, it also proved that the ACDF with titanium cage and plate instrumentation could acquire good and common bony fusion.

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