Original Article
Anatomy-related risk factors for the subsidence of titanium mesh cage in cervical reconstruction after one-level corpectomy

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Abstract: To clarify anatomy-related risk factors in the cervical spine with subsidence of titanium mesh cage (TMC) after one-level cervical corpectomy and fusion, we have assessed the radiological examinations and clinical outcomes for 236 patients. All the patients were underwent one-level corpectomy and TMC fusion between August 2003 and March 2006. The effects of the cervical posture, segmental curvature and endplate gradient on the postoperative phenomenon for these patients were evaluated. Our results suggested that in the patients who were followed up for 12 months, TMC subsidence occurred in 54 (28.6%) cases. C6 corpectomy had a significant higher risk (26/60, 43.3%) for TMC subsidence, which was correlated with the variation of the gradient of the vertebral endplates against cervical levels. Although the clinical outcome was comparable with those in the literature, the patients may have subsidence-related problems such as neck-shoulder pain, neurological deterioration and instrumental failure. In conclusion, to reduce the incidence of subsidence, TMC design should be optimized to be in line with anatomic characteristics of the cervical spine.

Keywords: Cervical spine, corpectomy, titanium mesh cage, subsidence

Introduction

Many papers have reported that anterior cervical corpectomy and fusion with titanium mesh cage (TMC) has been a safe and effective surgical treatment for cervical diseases [1-4]. TMC fusion facilitates the grafting of autogenously local bone and obviates complications of harvesting bone block. However, it requires a longer period to achieve a solid fusion than conventional auto-graft, and subsidence is frequently observed in the early postoperative period. Many factors, such as age, sex, fusion level, endplate preparation and bone mineral density, have already been known to be potential risk factors, but the anatomic factors of the cervical spine have not been emphasized [5-12].

Since the first description of cervical anterior corpectomy with fusion, many papers reported that it was an established treatment for cervical diseases with clinically satisfactory outcomes. However, the choice of materials for reconstruction after cervical corpectomy is still controversial. The traditional autologous bone graft has been demonstrated to yield a high fusion rate, but donor site complications were reported in approximately 15%, including subcutaneous hematoma, wound infection, and chronic wound pain. Allografts such as cow bone or hydroxyapatite graft were also used, but are questioned because of graft collapse and nonunion [13, 14]. As a solution to these problems, titanium mesh cage (TMC) has been developed and used, and the relevant investigations have proved advantages of a comparable fusion rate and non-existence of donor complications. However, postoperative subsidence was reported to be prevalent, which caused doubts about its value in cervical restoration. The purpose of this study was to elucidate the effect of the cer-
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**Materials and methods**

**Patient population**

Between August 2003 and March 2006, a total of 412 patients with cervical diseases underwent anterior cervical corpectomy and fusion with TMC. Anterior cervical plates were also employed to stabilize the affected segments. Among them, 236 cases of one-level corpectomy were investigated, and the remaining cases of two- or three-level procedures were not included in the study, because multilevel fusion with TMC, to our minds, significantly increased postoperative subsidence. This series included 128 men and 108 women and their mean age at operation was 51.3±6.4 years (ranging from 37 to 78 years). Preoperatively, the patients complained of neck pain, irradiating pain in arm and gait disturbance. At physical examination, they were found with sensory disturbance, motor problems and myelopathy signs. The diagnosis indicated cervical spondylitis myelopathy, cervical disc herniation and ossification of posterior longitudinal ligament. The level of corpectomy and fusion was performed due to spinal compression found in preoperative MR images: C3 vertebra in 12 cases, C4 in 68 cases, C5 in 79 cases, and C6 in 73 cases and C7 in 14 cases.

**Surgical technique**

All the operations were performed by the same senior spine surgeon. Under general anesthesia, the patients were placed in the supine position with neck slightly extended. After necessary discectomies, the vertebral bodies were partially removed by an appropriate reamer until the posterior longitudinal ligament was fully exposed, which was excised when hypertrophied, ossified or when disc materials intruded posteriorly to the ligament. All cartilaginous endplates were removed down to the level of bleeding sub-chondral bone with curettes. TMC (Mesh, Depuy, U.S.A.) were then filled with autologous bone fragments from the excised vertebra, with end caps employed to increase contact areas in most cases. TMC were then inserted into the intervertebral space under distraction, which was between 2-3 mm for one-level corpectomy. The TMC was located at the anterior-middle column of the vertebrae, usually 2-3mm below the vertebral anterior border. Finally, anterior cervical plate fixation (Slimloc, Depuy, U.S.A.) was performed across the segments to be fused. Postoperatively, all patients were required to wear a Philadelphia hard cervical collar for 2 months.

**Figure 1.** To describe the posture of the cervical spine, a line is drawn between the posterior inferior border of C2 and the posterior superior border of C7. If the posterior walls of the vertebral bodies of C3 to C6 are located anteriorly to this line, it is called lordotic (A), if it is at this line, straight (B), and if it is posterior to this line, kyphotic (C).
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Radiological examination

Lateral view of the cervical spine with the patient in a standing position was taken preoperatively and 1 day postoperatively, and at regular intervals thereafter until fusion was achieved. The lateral plain radiographs of the cervical spine were evaluated. The posture of the cervical spine in the neutral position was described as lordotic, straight, or kyphotic (Figure 1). Furthermore, the gradient of the vertebral endplates adjacent to the fusion segments, segmental curvature (the angle of the endplates), and the height of the fusion segments (the height of the anterior border, the mid-portion, and posterior border at the lateral radiograph) were measured (Figure 2). Subsidence was defined as loss of more than 3 mm in any of the three measured heights when TMC had clearly penetrated the vertebral endplates.

Graded outcome

In the study of graded clinical outcome, a modified Odom's scheme was used. Excellent was defined as complete relief of symptoms; good as intermittent discomfort, but there was no interference with daily activities; fair as subjective improvement, but there was impaired physical activity; poor as no improvement at all; and worse as actual worsening of the symptoms.

Statistical analysis

Statistical analysis was performed by Mann-Whitney U test, Fisher's exact test and Student's t-test for multiple comparisons by Statistic Analysis System (SAS statistic software, Statistic Institute of Second Military Medical University). Results are expressed as the groups mean ± SD. The p value (two-tailed) of less than 0.05 was considered statistically significant.

Results

Radiological findings

In this study, 47 patients were lost at the last follow-up of the 12 months, and all the radiographs of the remaining 189 patients were independently evaluated by two surgeons and one radiologist. When there was difference in views between the two surgeons, the opinion of the radiologist was decisive. At the last follow-up, we concluded that subsidence of TMC occurred in 54 (28.6%) cases, which was tabulated against the fused level. Subsidence occurred in 2 out of 11 cases at C3, 11 of 56 cases at C4, 14 of 52 cases at C5, 26 of 60 cases at C6, and 1 of 10 cases at C7. The results showed the TMC implanted for C6 corpectomy had a statistically significant higher risk of subsidence as compared with the other levels (P<0.0001).

There was no significant difference in the cervical posture between subsidence and no subsidence before operation, after operation and at the final follow-up (Table 1). In most patients, the cervical posture improved postoperatively and remained the status till the last follow-up.
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In most subsided instances, the cages had sunken into the posterior part of the superior endplate of the lower vertebral body, and only 7 cages had penetrated the inferior endplate of the upper vertebral body. The height of fusion segments decreased more at the posterior border of the vertebral body, and less at the anterior border (4.1±0.5 mm vs. 2.6±0.6 mm, P<0.001) (Table 2). The gradient of both upper and lower endplates increased against the level of the vertebrae, and reached the maximum at C6 level, then decreasing at C7. However, the segmental curvature of different levels was comparatively stable against the cervical level (Figure 3).

**Outcome and complications**

The clinical outcome was comparable with those in the previous reports. Ninety-seven (51.3%) patients had an excellent outcome, 47 (24.9%), a good outcome, 28 (14.8%) fair, 14 (7.4%) poor, and 3 (1.6%), a worse outcome. The outcome was not related to the occurrence of subsidence (P=0.466). But neck-shoulder pain was more frequently observed in the patients of subsidence group (38/54 vs. 29/135, P<0.001). Another subsidence-related problem was neurological deterioration. In four patients, neurological deterioration was definitely correlated with TMC subsidence because they occurred at a matched time, and one patient underwent posterior revision surgery (Figure 4). In the other two patients, screw breakage occurred with obvious subsidence of TMC, though bony fusion had already been achieved. Anterior revision surgery was performed to replace the broken screws.

**Discussion**

In the process of anterior cervical corpectomy and fusion, restoration of the intervertebral space and enlargement of the neural foramen has been thought to be the key point for satisfactory clinical outcome. Although the clinical relevance of subsidence is still controversial, the acquired advantages may be diminished and devalued by subsidence. Nakase reported kyphotic deformity; instrument failure and neurological deterioration might develop following subsidence, and possibly need revision surgery. Das and Kanayama also dealt with these complications with TMC subsidence in their reports.

In this group, however, subsidence did not produce significant clinical effects and severe cervical kyphosis. The reason might be that only the patients with one-level corpectomy were studied. However, axial pain was more frequently observed in the patients with postoperative subsidence. Bucking of the ligamentum flavum and stenosis of the neural foramen following subsidence were possibly responsible for this postoperative pain. When they resulted in recompression of the spinal cord and the nerve roots, neurological deterioration might develop.

In terms of biomechanics, TMC subsidence may also damage the inherent stability of fixed segments and increased stress load on the

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**Table 1.** Relation between the presence of subsidence and the posture of the cervical spine

<table>
<thead>
<tr>
<th>Posture (n)</th>
<th>Before operation</th>
<th>After operation</th>
<th>Last follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>No subsidence</td>
<td>Lordotic</td>
<td>67</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>Straight</td>
<td>41</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Kyphotic</td>
<td>27</td>
<td>6</td>
</tr>
<tr>
<td>Subsidence</td>
<td>Lordotic</td>
<td>26</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Straight</td>
<td>17</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Kyphotic</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>P value</td>
<td>0.43</td>
<td>0.37</td>
<td>0.32</td>
</tr>
</tbody>
</table>

**Table 2.** Relation between the different heights of the fusion segments before and immediately after operation, and at last follow-up

<table>
<thead>
<tr>
<th>Height (mm)</th>
<th>Before operation</th>
<th>After operation</th>
<th>Last follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>No subsidence</td>
<td>A</td>
<td>21.3±0.8</td>
<td>23.9±0.9</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>22.8±1.0</td>
<td>25.4±0.9</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>20.7±0.7</td>
<td>23.1±0.8</td>
</tr>
<tr>
<td>Subsidence</td>
<td>A</td>
<td>20.5±1.0</td>
<td>23.4±1.0</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>21.8±0.9</td>
<td>25.1±0.8</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>20.1±0.8</td>
<td>23.3±0.9</td>
</tr>
</tbody>
</table>

* is the height of the anterior border, B is the height of the midportion, and C is the height of the posterior border of the fusion segments. In the patients with TMC subsidence, the loss of height of the posterior border is significant more than that of the anterior border (4.1±0.5 mm vs. 2.6±0.6 mm, P<0.001).
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Figure 3. Degrees of the endplate gradient and the segmental curvature at different fusion levels. The gradient of both upper and lower endplates increased against the level of the vertebrae, and reached the maximum at C6 level, then decreasing at C7. The segmental curvature of different levels was comparatively stable against the cervical level.

screw-plate structure. Daubs et al. reported seven patients had catastrophic failure of fixation with TMC subsidence and distal plate extrusion. In this study, screw breakage occurred in two cases of obvious subsidence, though bone fusion was definitely achieved. And still there was need for revision surgery.

Risk factors for TMC subsidence had been discussed a lot in the literature. Age and sex were often suspected to predict subsidence. Older women, especially, were thought to have a higher chance because of osteoporosis. Wrong surgical technique was also held responsible for TMC subsidence. Over-distraction, rigorous cleaning and damaging of the endplates and rigid implantation should be avoided. Despite careful attention to surgical details, we still had a high incidence of subsidence. In this study, we noticed the C6 corpectomy was most susceptible to subsidence, which was similar to the results that the interbody cages (Syncage-c and carbon fiber cages) implanted at C6 level had the highest chance to subsidence. The difference was that interbody cages tended to subside at the anterior border of the superior endplate, while TMC tended at the posterior border of the inferior endplate [15, 16]. The reason for this was not clear. The preliminary data from this study suggested that the orientation of endplates was possibly responsible for this tendency. We noticed that the incidence of TMC subsidence at different levels was correlated with the gradient of adjacent endplates, which was at the highest point when C6 vertebra was excised.

The currently used TMC design is a cancellous hollow cage, with a large bony contact area to promote fusion between the vertebral bodies. Before bony fusion, however, the contact surface of TMC with endplates was very limited, and high stress shielding facilitates subsidence [17]. The gradient of the endplates made the contact area too small and increased the load on the endplate excessively, especially at the posterior border of the lower endplate. Another factor was the size of TMC, especially its width. TMC should rest on the epiphyseal ring to have sufficient support. The third problem with TMC was that it was to be clipped before its application. If manual clipping was not suitable and sharp fingerprints penetrated into the vertebral endplates, subsidence was likely.

Some improvements had been made in the use of TMC. The incidence of subsidence was first expected to be decreased with the use of end caps, which was designed to increase contact surface, but the results might be disappointing. In our opinion, TMC should be designed to be more in line with the anatomical characteristics of the cervical spine, especially the endplates: 1) Changes should be made for both upper and lower butt ends of TMC. Fornix shape is more
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Figure 4. A and B. Radiograph demonstrating the subsidence into C7 of TMC after 3 months, and the patient complained of neurological deterioration.

consistent with adjacent lower endplates and oblique shape for upper endplates; 2) To enlarge the contact surface of TMC and get more support from the epiphyseal ring, a wider cage should be developed; 3) A set of TMC with different heights for one or two-level corpectomy is needed and incorrect manual clipping for TMC must be avoided during the operation. The butt ends of TMC should be more consecutive and smooth.

In conclusion, a high incidence of subsidence has been found in the use of TMC for cervical corpectomy. Although several factors were responsible for this problem, mismatch between TMC ends and adjacent endplates was evident. We hold that efforts should be made to optimize TMC design before its application. And then more satisfactory clinical outcome could be achieved.

Disclosure of conflict of interest

None.

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