—Review—

Cervical Anterior Fusion with the Williams-Isu Method: Clinical Review

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Abstract

Anterior decompression and fusion of the cervical spine is a widely accepted treatment for cervical canal disease. The Williams-Isu method involves cervical anterior fusion with autologous bone grafts from cervical vertebral bodies. Its advantages are a wide operative field, excellent graft fusion, the absence of problems related to the iliac donor site, and direct visualization of the nerve root. For detailed decompression of the cervical root, an ultrasonic bone curette (SONOPET, Stryker Japan K.K., Tokyo) may be useful. To prevent graft extrusion, bioabsorbable screws featuring a head are placed in 4 corners of the bone graft and are fixed with a tap on a part of the graft. The screws are visualized on postoperative X-ray, computed tomography, and magnetic resonance imaging studies. In 69 patients reported elsewhere there were no complications attributable to screw insertion, screw or graft extrusion, or surgery-related infections. When adequate bone cannot be harvested, a piece of ceramic hydroxyapatite is placed between the bone grafts. This sandwich method reinforces the graft, and radiological evidence suggests that it yields better results with respect to the angle and height of the fused segment. For the surgical treatment of cervical ossification of the posterior longitudinal ligament, a large vertebral bone window and a large bone graft are needed; this may result in postoperative radiological worsening. Radiological studies have shown that cervical ossification of the posterior longitudinal ligament can, as can cervical spondylosis, be addressed with the Williams-Isu method. Detailed radiological studies in patients treated with the Williams-Isu method have demonstrated that the range of motion and the disc height of the fused segment must be considered to prevent worsening in that segment after anterior fusion. The Williams-Isu method cannot completely correct cervical alignment, and great caution must be exercised in patients with preoperative malalignment. To reduce the levels to be fused in patients with multilevel lesions due to cervical disease, the Williams-Isu method can be combined with the transvertebral approach. The transvertebral approach facilitated by the wide Williams-Isu window allows the root bifurcation area to be confirmed during the early stage of surgery and possible decompression along the root. Radiological examination has shown that the combination of the Williams-Isu method and transvertebral approach does not affect the fusion level compared with the Williams-Isu method alone and produces better results than does the transvertebral approach alone.
(J Nippon Med Sch 2012; 79: 37–45)

Key words: cervical anterior fusion, Williams-Isu method, sandwich method, cervical disease

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Introduction

Anterior decompression and fusion of the cervical spine is an accepted treatment for patients with cervical canal disease resulting in nerve root or cord compression. Williams[1] and Isu et al.[2,3] developed cervical anterior fusion with autologous bone grafts from cervical vertebral bodies; this is known as the Williams-Isu method (**Fig. 1**). Its advantages are a wide operative field, excellent graft fusion, the absence of problems related to the iliac donor site, and clear visualization of the nerve root[2,3]. We review the surgical procedures and clinical and radiological results of the Williams-Isu method.

History of the Williams-Isu Method

Williams[1] first reported anterior fusion with autologous bone grafts in 1992. Subsequently, Isu et al.[2] described 90 patients who underwent anterior cervical fusion using autologous bone grafts obtained from cervical vertebral bodies. In all 90 patients 1- to 3-level fusion was confirmed, although anterior angulation was detected in 4 patients (4.4%). Isu et al. also used the Williams-Isu method to treat 40 patients with cervical ossification of the posterior longitudinal ligament (OPLL)[3] and obtained good results at 3 years' follow-up, although anterior angulation was present in 1 of 8 patients (12.5%) who underwent 3-level fusion. Kim et al.[4,5] have documented that surgical results are preserved over the middle to long term, and the Williams-Isu method is now an accepted technique for anterior cervical fusion[6–8].

Our Surgical Procedures (Fig. 1)

After the anterior surface of the vertebral body is approached, microscopic discectomy is performed. With a spinal saw (Williams microsurgical saw; R.C.W. Spine Co., Inc. San Luis Obispo, CA, USA), 2 blocks of bone tissue are removed from the cervical vertebral bodies above and below the intervertebral space. First, we usually remove bone tissue (15 mm wide, 5 mm thick) located at a depth of 15 mm from the upper vertebral body, and then we harvest tissue (15 mm wide) at a depth of 15 mm from the lower vertebral body. The thickness of bone tissue obtained from the lower vertebral body depends on the length of tissue removed from the upper vertebral body because its length represents the width of the length in the bone window. The posterior parts of the vertebral bodies are then removed, and the spinal cord and roots are decompressed by removing posterior osteophytes, herniated discs, or the posterior longitudinal ligament with an air drill and an ultrasonic bone curette (SONOPET, Stryker Japan K.K., Tokyo)[9,10]. At decompression, we make banks the depth of the thickness of the graft on the upper and lower vertebral body to protect the spinal canal. The 2 bone tissue blocks are fused by placing the cancellous and cortical parts of the bone top to bottom and suturing them with 3 interrupted 3-0 Dexon sutures to form a single graft. The bone grafts are then turned vertically 90° and inserted into the space; they are held firmly in place by the cancellous bone of the adjacent vertebra. All patients were treated under cranial traction; none underwent fixation by plate.

Devices Used

1. Bioabsorptive Screws

A complication of cervical anterior fusion is graft extrusion, which results in a high rate of reoperation. The placement of a cervical anterior titanium plate may prevent this complication but is not risk-free. The use of bioabsorbable screws has helped prevent graft extrusion in patients treated with the Williams-Isu method (**Fig. 2**)[11,12]. Because they contain hydroxyapatite particles (30% by weight), the strength of screws (Super FIXSORB 30, Takiron Co., Ltd., Osaka) of unsintered hydroxyapatite (uHA) and poly-L-lactic acid (PLLA) is greater than that of PLLA screws or cortical bone[13]. The uHA-PLLA screws are completely absorbed by resolution into water and carbon dioxide upon in vivo hydrolysis, are osteoconductive, and retain 85% of their strength in postoperative week 12, 75% in week 24, and 50% in week 50[13]. This

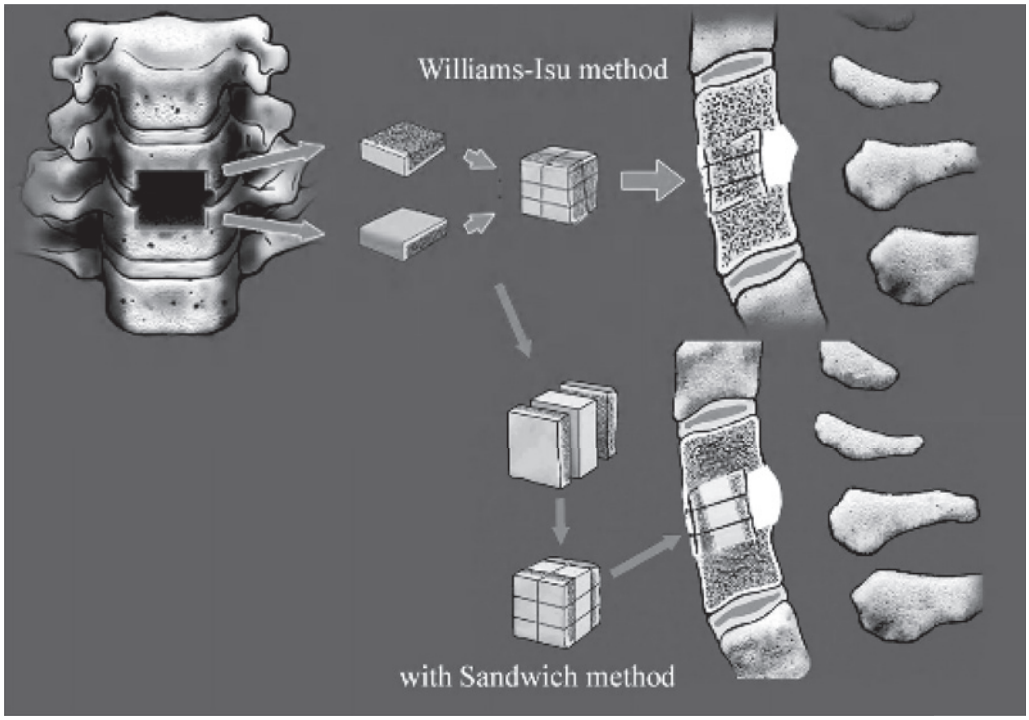

Fig. 1 Schematic diagram of the Williams-Isu method with and without the sandwich method.

Fig. 2 After the graft is inserted in the Williams-Isu method, bioabsorbable screws with heads are placed in the 4 corners of the bone graft to prevent graft extrusion.

type of screw is 12 mm long and 2.7 mm in diameter, and its head is 5 mm in diameter. After application of the Williams-Isu method, these bioabsorbable screws are inserted into the 4 corners of the bone graft[11,12], the screw heads prevent graft extrusion **(Fig. 2)**. These uHA-PLLA screws were used in 69 patients, and no complications were encountered that could be attributed to screw insertion, screw or graft extrusion, or surgery-related infections **(Fig. 3)**[12]. The uHA-PLLA screws are visualized on postoperative X-ray, computed tomography (CT), and magnetic resonance imaging (MRI) studies. This safe and easy method shortens the hospital stay and reduces the risk of graft extrusion and of complications associated with the use of nonabsorbable devices.

2. Sandwich Method

Suzuki et al.[14] and Takayasu et al.[15] have described the sandwich method, an augmentation of the Williams-Isu method, for treating patients with cervical disease. In the sandwich method, the ceramic hydroxyapatite is inserted between the bone grafts when the amount of harvested bone is inadequate **(Fig. 1 and 3)**. Kim et al.[16] have performed a radiological study to examine the efficacy of the sandwich method by comparing the alignment of the whole spine and the fused segment in patients who had received a sandwich graft and in a control group. Although they found no difference between the groups with respect to the

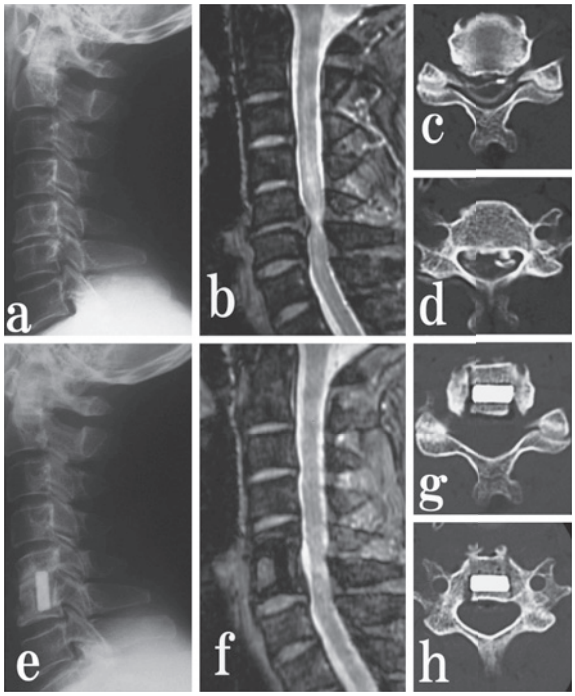

Fig. 3 Preoperative (upper panel) and postoperative (lower panel) radiographs of the cervical spine in a patient who underwent C5–C6 anterior fusion using the Williams-Isu-sandwich method augmented with absorbable screws.
a: Radiograph, lateral view; preoperative
b: Sagittal T2-weighted MRI, preoperative
c, d: CT myelograph, axial view, preoperative
e: Radiograph, lateral view; postoperative
f: Sagittal R2-weighted MRI, postoperative
g, h: CT, axial view, postoperative

alignment of the whole spine, the alignment and height of the fused segment were significantly better in the sandwich graft group. The fused segment angle in the sandwich graft group versus the control group was 3.9° ± 3.3° to 0.1° ± 3.5° versus 2.4° ± 4.0° to −3.5° ± 3.1° ($p<0.05$), and the fused segment height was 94.0% ± 3.8% versus 90.9% ± 3.3% ($p<0.05$). These results indicate that the sandwich method reinforces the graft and yields better results with respect to the angle and height of the fused segment.

In patients undergoing surgery to treat cervical OPLL, the large vertebral bone window should be removed, and a large bone graft may result in radiological worsening postoperatively. Kim et al.[17] have studied patients with cervical OPLL who have undergone anterior fusion with the Williams-Isu method. The clinical results were satisfactory, and the posttreatment change in whole cervical alignment was almost the same as in patients treated for cervical spondylosis. The alignment of the fused segment changed from 3.6° ± 3.3° to −0.5° ± 4.8°, and the height of the fused segment decreased to 94.5% ± 4.4%. There was no statistically significant difference in treatment outcomes between patients with OPLL and patients with cervical spondylosis, indicating that both conditions can be treated with the Williams-Isu method.

3. Radiological Study of the Williams-Isu Method

According to Russegger et al.[18], the Williams-Isu method is an elegant means of obtaining autologous bone from the cervical segment for fusion. However, they expressed reservations about the use of spondylotic vertebral bone as a graft in patients undergoing cervical anterior fusion with a titanium plate and cage, because the Williams-Isu method risks postoperative kyphosis and worsening of cervical spine alignment. In fact, Isu et al.[2,3] have reported anterior angulation in some patients treated with the Williams-Isu method but provided no radiographic details.

Kim et al.[4] addressed this issue in their study of 59 patients; they provided detailed radiographic results at mid-term follow-up (average, 58 months). They reported no problems with graft intensity, although the angle of the fused segment changed from 3.6° to −3.2°. Alignment of the whole spine changed from 13.7° to 11.1°, and postoperative alignment was not worse than the preoperative flexion posture. Of the 59 patients, 3 showed kyphotic alignment after surgery. In 2 of these patients, preoperative alignment had been straight; postoperatively there was a marked loss in the angle of the fused segment that affected flexion mobility of the fused segment. In the other patient, alignment was kyphotic both before and after surgery. Application of the Williams-Isu method does not correct whole cervical alignment, and caution must be exercised in patients with malalignment. The postoperative angle of the

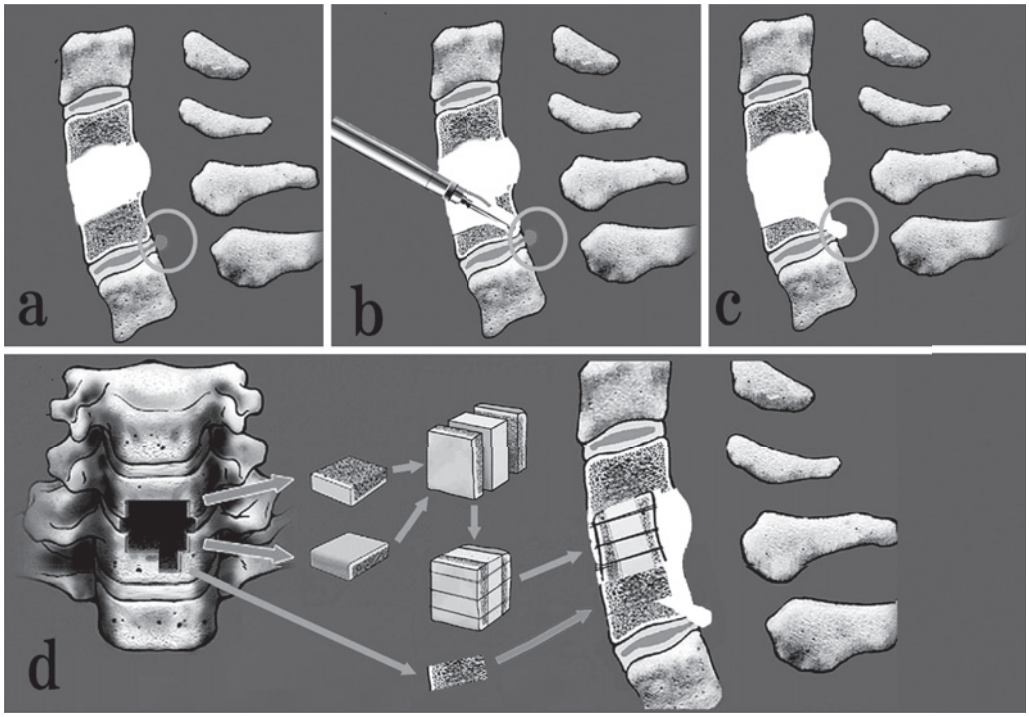

Fig. 4 Schematic diagrams of the combined approach using the Williams-Isu method and the transvertebral approach.
a: The posterior part of the vertebral bodies and osteophytes or the OPLL or both are removed, and the spinal cord and roots are decompressed from the wide window prepared with the Williams-Isu method.
b, c: From this window, instrumentation-aided decompression of the cervical cord or nerve root or both are possible.
d: Two blocks of bone tissue are removed with a spinal saw from the cervical vertebral bodies above and below the intervertebral space. For anterior fusion, a bone graft made from the 2 bone tissue blocks and a ceramic insert is introduced into the space.

fused segment affects its range of motion for flexion, and kyphosis can develop in patients with preoperative straight alignment if the flexion mobility of the fused segment is great. This information is useful for developing a strategy for anterior cervical fusion and for the predicting the risk of postoperative kyphosis.

After application of the Williams-Isu method, the angle of the fused segment may exhibit some worsening; however, this worsening can be ameliorated by combining the Williams-Isu method with the sandwich method. To elucidate this phenomenon, Kim et al.[19] followed up 30 patients who had undergone treatment with the combined Williams-Isu-sandwich method. They found that the fused segment angle worsened by 3.3° ± 3.7° on average. After fusion, all patients experienced graft subsidence that was primarily inferior and posterior. To further clarify this issue Kim et al. divided the 30 patients into those who did not manifest worsening of the segmental angle (group I, n=20, 0.9° ± 0.9°) and those who did (group II, n=10, 8.0° ± 2.2°). Preoperatively, the range of motion at the fused segment was 4.3° ± 3.7° in group I and 11.2° ± 5.7° in group II ($p<0.05$), and the disc height of the fused segment was 4.2 ± 1.0 mm in group I and 5.0 ± 1.8 mm in group II ($p<0.05$). Postoperatively, the fused segment angle gradually worsened in both groups. In group I, it was almost stable after 14 days, whereas in group II it worsened after 1 month and was stable after 3 months **(Fig. 4)**. These results indicate that the preoperative range of motion and the disc height of the fused segment must be considered to prevent worsening in that segment after anterior fusion. Such detailed information is useful for the selection and postoperative monitoring

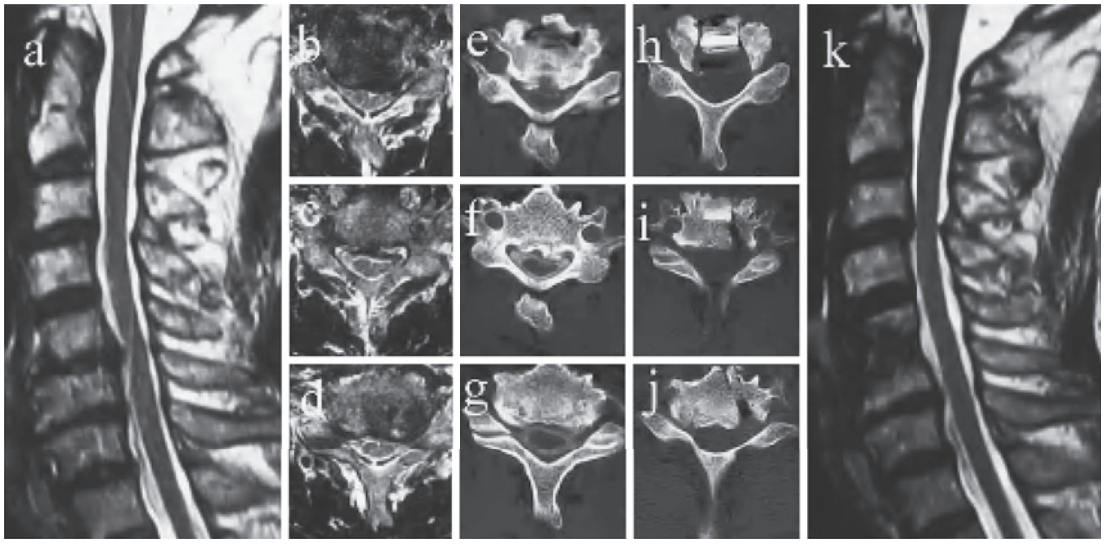

Fig. 5 Preoperative and postoperative radiographs of the cervical spine of a patient who underwent surgery with the combined approach, i.e., C5–C6 anterior fusion and the C6–C7 transvertebral approach.
a: T2-weighted MRI scan, sagittal view, preoperative.
b–d: T2-weighted MRI scan, axial view, C5–C6 to C6–C7 level, preoperative.
e–g: CT myelograph, axial view, C5–C6 to C6–C7 level, preoperative
h–j: CT scan, axial view, C5–C6 to C6–C7 level, postoperative.
k: T2-weighted MRI scan, sagittal view, postoperative.

of patients eligible for treatment with the Williams-Isu method.

Combining the Transvertebral Approach with the Williams-Isu Method

The transvertebral approach is useful for decompression in patients with cervical radiculopathy; because the intervertebral disk is preserved, mobility is retained[20]. However, the narrowness of the operative field may result in insufficient decompression and necessitate the use of sophisticated techniques. In addition, the transvertebral approach is restricted to patients with cervical disk hernia, mild cervical spondylosis, and segmental OPLL[20]. On the other hand, the Williams-Isu method provides a wide operative field and allows decompression to be performed safely and steadily.

Patients with cervical spondylosis or OPLL may present with lesions on multiple levels. Compared with single-level fusion, multilevel fusion accelerates degenerative changes at the adjacent level[21], and the more levels that are subjected to fusion, the greater is the incidence of operative complications[22,23]. Kim et al.[24] have reported that the combination of the Williams-Isu method and the transvertebral approach reduced the fusion level and yielded satisfactory clinical results (**Fig. 5 and 6**). The transvertebral approach from the wide Williams-Isu window facilitates confirmation of the root bifurcation area during the early stage of surgery and decompression along the root. After fusion-level decompression, the transvertebral approach is applied. By means of a surgical saw, a 4 × 4 mm bone graft is removed at a depth of 15 mm from the decompression site of the approached vertebral bone. Through this window the cervical spinal cord and nerve root are decompressed with an air drill and an ultrasonic bone curette[9,10]. To retain disk function, the intervertebral disk is cut only at the posterior part of the annulus fibrosus. For anterior fusion, a graft prepared with the sandwich method[14–16] is inserted. A harvested bone block is placed in the area of deletion created for the transvertebral approach. To prevent graft extrusion and increase the strength of fixation, bioabsorptive screws are inserted into the 4 corners of the bone

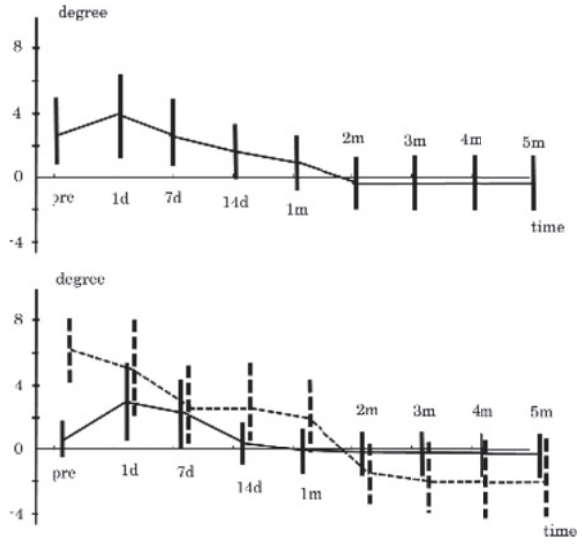

Fig. 6 Serial changes in the fused segment angle over time.
(upper) The fused segment angle gradually worsened postoperatively; it was almost stable after 2 months.
(lower) In group I, fused segment angle worsening occurred within 1 month; however, fused segment angle became almost stable after 14 days (line). In group II, it also worsened after 2 months but was stable after 3 months (dotted line).

graft[12]. In 20 patients who had undergone surgery, the fused segment angle changed from 4.3° ± 3.9° to 1.1° ± 4.2°, and the height of the fused segment decreased to 94.4% ± 3.7%. These results are similar to those obtained in patients with cervical spondylosis or cervical OPLL who underwent single-level fusion with the Williams-Isu method alone[16,17]. However, the combination of the Williams-Isu method and the transvertebral approach raises concerns regarding the angle and height of the fused segment, because the lower vertebral body of the fused segment, i.e., the vertebral body involved in the transvertebral approach, may collapse. In all 20 patients mobility of the operated transvertebral approach level was retained; the range of motion changed from 6.6° ± 3.9° to 7.5° ± 4.7°, and the height of the disk space narrowed by 4.8% ± 2.5% after the operation. On the other hand, in patients treated with the transvertebral approach alone, the range of motion of the operated segment changed from 8.1° ± 5.7° to 6.1° ± 3.1°, and the height of the disk space narrowed by 8.3% ± 6.0% after the operation[20]. The difference between the patient groups was significant ($p<0.05$). These results indicate that the combination of the transvertebral approach and the Williams-Isu method has a similar effect on the fusion level as does the Williams-Isu method alone and has an effect on the transvertebral approach level that is superior to that of the transvertebral approach alone.

Problems with the Williams-Isu Method

Although the Williams-Isu method requires special instrumentation and techniques to remove the vertebral bone graft, it is not difficult to perform[2,14,15]. It does not permit alignment correction, and preoperative alignment affects postoperative alignment[4]. Rajshekhar et al.[25] have also reported that preoperative alignment affects postoperative alignment and that kyphotic changes are rare in patients with preoperative lordosis. In the series of Rajshekhar et al., postoperative kyphosis was present in 16% of patients whose spine had been straight preoperatively and 75% of those whose spine had been kyphotic before surgery. Consequently, in patients with preoperative malalignment, methods other than the Williams-Isu method should be considered for cervical anterior fusion.

Worsening of the fused segment angle is a common problem in cervical anterior fusion. In patients treated with the Williams-Isu method the fused segment angle worsened to some degree. Similar observations have been made in patients treated with cervical anterior fusion by means of the Smith-Robinson method[26], the Cloword method[27], corpectomy with an iliac bone graft[25], and placement of a titanium cage[28]. According to Vavruch et al.[29] maintaining the fused segment angle without instrumentation is difficult. Proposed risk factors for subsidence of the fused segment include smoking; the treatment of lower level discs; multilevel fusion; malalignment, such as kyphosis, or a straight spine; and hypermobility at the operated disc level; however, no statistically significant risk factors have been identified[30]. The combination of the Williams-Isu

method and sandwich method can better avoid fused-segment subsidence than can the Williams-Isu method alone[16], and the careful selection of eligible patients by excluding those with preoperative hypermobility of the fused segment may improve the results of treatment[19].

Use of Ultrasonic Bone Curette at Spinal Surgery

Ultrasonic surgical aspirators, used in many neurosurgical procedures, can contribute to good treatment outcomes. The combined use of a high-speed drill and an ultrasonic surgical aspiration/irrigation system (SONOPET, Stryker Japan K.K.) has been reported for spinal surgery[9,10,31]. Its light weight and compact design allow the operator to use only one hand when manipulating an ultrasonic bone curette. In addition, an ultrasonic bone curette is useful for performing intricate procedures in a narrow operative field because its design prevents the inserted cotton from rolling and because it features both aspiration and irrigation attachments. In spinal surgery involving the removal of structures near vital structures, such as the dura mater, the insertion of cotton provides adequate protection. In keyhole surgery, use of a tapered ultrasonic bone curette allows direct visual access to the field for removal of bone and for aspiration and facilitates expansion of the foramen intervertebrale and the opening of the lateral recess. Kim et al.[9] have documented their experience with a ultrasonic bone curette in 546 spinal surgeries and addressed possible complications and how to avoid them. They encountered operative complications attributable to the use of an ultrasonic bone curette in 6 of their 546 patients (1.1%); there were 5 cases of dural puncture and 1 case of suspected spinal cord injury. All dural punctures occurred in cases in which the edge of the bone harboring the dura mater had been removed with an ultrasonic bone curette. The tip of the instrument applied suction to the dura mater, resulting in a puncture that required repair; the epidural venous plexus was damaged in some patients. To prevent dural tears and venous plexus injury, Kim et al. have recommended that cotton be placed between the ultrasonic bone curette and important structures. One patient with OPLL and a severely compressed spinal cord sustained iatrogenic spinal cord damage due to an ultrasonic bone curette; vibrations from the instrument had been transmitted directly to the spinal cord. To avoid spinal cord injury, we suggest that the ultrasonic bone curette be inserted horizontal to the dura mater to prevent the direct transmission of vibrations from the instrument to the spinal cord.

Conclusions

The Williams-Isu method is a useful technique for cervical anterior fusion. Use of absorbable screws to fix the graft shortens the hospital stay and reduces the risk of graft extrusion and complications associated with the use of nonabsorbable devices. The sandwich method reinforces the graft and yields better results with respect to the angle and height of the fused segment. The wide operative field provided by the Williams-Isu method is an advantage when the procedure is combined with the transvertebral approach, and this technique is less invasive in patients with multilevel cervical disease.

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(Received, September 29, 2011)
(Accepted, November 9, 2011)