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Original Article

Significant relationship between local angle at fused segments and C2-7 angle: Average duration of longer than 20 years after anterior cervical discectomy and fusion

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Abstract

Background: The authors have focused their attention to the radiological durability of cervical sagittal alignment after anterior cervical discectomy and fusion (ACDF) using autologous bone grafting. **Materials and Methods**: Among the patients who underwent ACDF with trans-unco-discal (TUD) approach between 1976 and 1997, 22 patients (16 males and 6 females) made return visits for a clinical evaluation. Patients with trauma or previously treated by anterior cervical fusion or by posterior decompression were excluded from the present study. Clinical evaluation included adjacent segment degeneration (ASD), osseous fusion, local angle at the fused segments and C2-7 angle of cervical spine. **Results**: The duration after ACDF ranged from 13 to 34 years with an average of 21.3 ± 7.0 years. A single level fusion was done on 8 patients, 2 levels on 11 patients, 3 levels on 2 patients, and 4 levels on 1 patient. Imaging studies indicated that 12 of the 22 patients (54.5%) were graded as having symptomatic ASD. Osseous bony fusion at ACDF was recognized in all cases. None of the patients demonstrated kyphotic malalignment of the cervical spine. Average degrees of local angle at the fused segments and the C2-7 angle were 7.06 and 17.6, respectively. Statistical analysis indicated a significant relationship between the local at the fused segments and C2-7 angles. **Conclusions**: Sagittal alignment of the cervical spine was durable long after ACDF when the local angle at the fused segments was well stabilized.

Key words: Anterior cervical, cervical alignment, interbody fusion, local angle, trans-unco-discal approach

INTRODUCTION

Anterior cervical discectomy and fusion (ACDF) has been the standard procedure to treat cervical disorders of myelopathy or radiculopathy caused by cervical spondylosis, disc herniation or ossification of the posterior longitudinal ligament.[1-5] Although technical advancement in ACDF has been made, there is currently no consensus on the optimal technique. The surgical essence in ACDF is to achieve the neural decompression and to provide a solid osseous fusion. In the present study, authors have focused their attention to the radiographic durability of cervical sagittal alignment long after ACDF with trans-unco-discal (TUD) approach[6] using autologous bone grafting with an average duration of longer than 20 years.

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MATERIALS AND METHODS

A clinical investigation was established in patients who underwent ACDF using autologous iliac bone grafting between

1976 and 1997 in Osaka City University Hospital and affiliated hospitals. A combined anterior and lateral approach to cervical discs, what we call TUD approach,[6] was applied by a single surgeon. All patients presented with radiculopathy and/or myelopathy due to disc herniation, osteophyte formation or ossification of the posterior longitudinal ligament (OPLL), and underwent ACDF. Patients with trauma or previously treated by anterior cervical fusion or by posterior decompression were excluded from the present study. Among the patients identified in our neurosurgical registry, 22 patients (16 males and 6 females) made return visits for a clinical evaluation.

TUD approach

Technical detail of the TUD approach was published in 1976. The key concept of the TUD approach is a combined anterior and lateral approach to cervical discs with uncectomy on the approach side. Osteophyte, OPLL and disc material can be removed safely with special attention to avoid the injury of vertebral artery. Extensive removal of posterior and lateral osteophyte verified the sufficient decompression of spinal cord and both nerve roots. After the intervertebral decompression, autologous bone grafting of iliac bone was accomplished for interbody fusion, followed by external rigid fixation. External rigid fixation was applied for 1 to 3 months after surgery to assure the appropriate spinal curvature of cervical spine.

Clinical evaluation

Clinical evaluation included a neurological as well as radiological examination. The neurological condition was estimated using the Neurosurgical Cervical Spine Scale (NCSS) [Table 1].[7] NCSS before surgery was estimated based on the hospital medical chart, and NCSS at a follow-up visit was scored by patient himself or herself. Adjacent segment degeneration (ASD) at the fused segments was evaluated based on neurological symptoms and MRI T2-weighted sagittal images and classified into 4 grades as shown in Table 2. Grade 0 or 1 ASD was recognized as asymptomatic ASD, and Grade 2 or 3 as symptomatic ASD. Osseous bony fusion was evaluated using plain lateral radiography of the cervical spine. Solid osseous fusion was defined as a clear osseous bridge at the intervertebral space. The local angle of the fused segments was determined as the angle made by the 2 lines parallel to the superior wall of the upper fused vertebral body and the inferior wall of the lower fused vertebral body [Figure 1]. The total alignment of the cervical spine was evaluated with the C2-7 angle of spinal curvature [Figure 1]. A line is extended from the posterior inferior corner of the C2 vertebral body down to the posterior inferior corner of the C7 vertebral body. Lordosis is considered present if all intervening vertebral bodies are anterior to this line. If at least 1 vertebral body is traversed by the line, cervical alignment is judged to be straight. If the intervening vertebral bodies are posterior to the line, kyphosis is present.

Statistical analysis

All data was expressed as the mean ± standard deviation. Statistical analysis was conducted using the paired t-test, the unpaired t-test and the Spearman rank correlation coefficient. The level of significance was a probability value of less than 0.05.

Table 1: Summary of the neurosurgical cervical spine scale

Lower extremity motor function	
1	Total disability: chair-bound or bedridden
2	Severe disability: needs support in walking on flat surfaces, and unable to ascend or descend stairways
3	Moderate disability: difficulty in walking on flat surfaces, and needs support in ascending or descending stairways
4	Mild disability: no difficulty in walking on flat surfaces, but mild difficulty in ascending or descending stairways
5	Normal: normal walking, with or without abnormal reflexes
Upper extremity motor function	
1	Total disability: unable to perform daily activities
2	Severe disability: severe difficulty in daily activities with motor weakness
3	Moderate disability: moderate difficulty in daily activities with hand and/or finger clumsiness
4	Mild disability: no difficulty in daily activities, but mild hand and/or finger clumsiness
5	Normal: normal daily activities, with or without abnormal reflexes
Sensory function and/or pain	
1	Severe disturbance: severe difficulty in daily activities with incapacitating sensory disturbance and/or pain
2	Moderate disturbance: moderate difficulty in daily activities with sensory disturbance and/or pain
3	Mild disturbance: normal daily activities, but mild sensory disturbance and/or pain
4	Normal: neither sensory disturbance nor pain

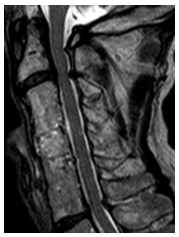
RESULTS

A total of 22 of these patients made return visits for a clinical evaluation. There were 16 males and 6 females. The age of patients at surgery ranged from 39 to 65 years with an average of 48.7 ± 6.94 years of age. The duration after ACDF ranged from 13 to 34 years with an average of 21.3 ± 7.0 years. A single level fusion was done on 8 patients, 2 levels on 11 patients, 3 levels on 2 patients, and 4 levels on 1 patient. Radiological summary of 22 patients is shown in Table 3.

Retrospective scoring of NCSS at the surgery indicated an average score of 3.73 ± 0.18 in lower extremity motor function, 3.59 ± 0.19 in upper extremity motor function, 2.73 ± 0.10 in sensory function and/or pain and 10.05 ± 0.37 in total. A self-check scoring of NCSS at a follow-up visit demonstrated an average score of 3.72 ± 0.18 in lower extremity motor function, 3.91 ± 0.22 in upper extremity motor function, 2.73 ± 0.10 in sensory function and/or pain and 10.36 ± 0.58 in total. Statistical analysis of NCSS indicated significant recovery of upper extremity motor function and no significant deterioration of lower extremity motor and sensory function and/or pain.

Assessment of ASD indicated that 4 patients were graded into Grade 0, 6 patients into Grade 1, 7 patients into Grade 2 and 5 patients into Grade 3. The average grade was 1.6. A total of 12 of the 22 patients (54.5%) were graded as having symptomatic ASD. Osseous bony fusion at ACDF was recognized in all cases [Figure 2]. The local angle at the fused segments ranged from -6.56 to 22.9 degrees with an average of 7.06 degrees. The C2-7 angle of spinal total alignment ranged from 0 to 55.8 degrees with an average of 17.6 degrees. None of the patients demonstrated kyphotic alignment of the cervical spine. Statistical analysis indicated that there was a significant relationship between the local angle at the fused segments and the C2-7 angle ($\gamma = 0.58$, $P = 0.0068$) [Figure 3]. There was no significant relationship between occurrence of symptomatic ASD of Grade 2 or 3 and spinal sagittal alignment of the local angle at the fused segments or C2-7 angle. There was no significant difference regarding the local angle at the fused segments, C2-7 angle or the number of spinal fusion levels between the asymptomatic ASD and symptomatic ASD.

Table 2. Four grades of adjacent segment degeneration at the fused segments

Grade	Definition	Representative image
0	No neurological deterioration No cord compression	
1	No neurological deterioration Mild cord compression No signal change on T2WI	
2	Mild neurological deterioration Mild cord compression Faint signal change on T2WI	
3	Severe neurological deterioration Severe cord compression Clear signal change on T2WI	

DISCUSSION

In the present study, the authors have focused their attention to the radiological durability of cervical sagittal alignment after

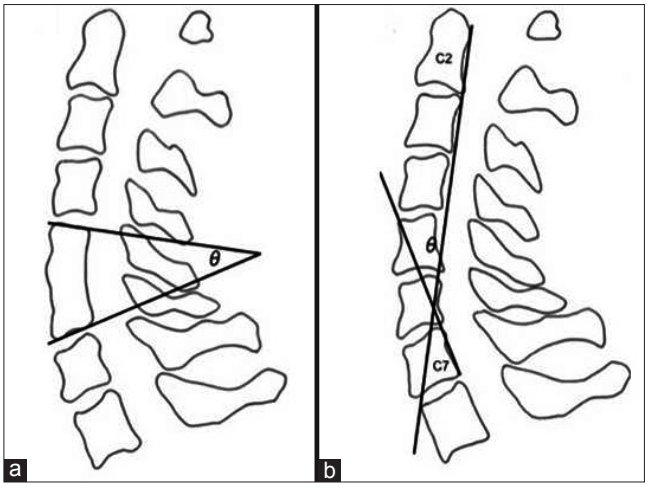


Figure 1: The measurement method of the local angle of the fused segments (a) and the C2-7 angle of spinal curvature (b)

Figure 2: Representative cases of 1-level fusion (26 years after ACDF) (a), 2-level fusion (32 years after ACDF) (b), 3-level fusion (22 years after ACDF) (c) and 4-level fusion (34 years after ACDF) (d)

Table 3. Radiological summary of 22 patients

Case No.	Disease	Age	Sex	Postop. years	Number of fusion	Osseous fusion	Kyphosis	ASD
1	CS	40	M	34	4	+	-	1
2	CS	41	M	31	2	+	-	3
3	OPLL	48	M	32	2	+	-	2
4	OPLL	40	M	30	1	+	-	2
5	CS	52	F	25	1	+	-	3
6	OPLL	55	F	24	2	+	-	3
7	CS	49	M	26	2	+	-	2
8	CS	39	F	26	1	+	-	2
9	CS	51	F	26	1	+	-	2
10	CS	47	F	23	2	+	-	3
11	CS	50	F	22	2	+	-	1
12	CS	51	M	22	1	+	-	2
13	CS	51	M	22	3	+	-	3
14	OPLL	42	M	17	3	+	-	0
15	OPLL	54	M	14	2	+	-	0
16	OPLL	60	M	14	1	+	-	0
17	OPLL	46	M	13	1	+	-	2
18	CS	65	M	14	1	+	-	1
19	OPLL	42	M	13	2	+	-	1
20	OPLL	44	M	14	2	+	-	1
21	OPLL	58	M	13	2	+	-	1
22	OPLL	46	M	14	2	+	-	0

CS: Cervical spondylosis with osteophyte or disc disease

ACDF with TUD approach using autologous bone grafting. The shortcoming of the present study is the uneven results obtained by return visits, because the patients with poorer outcome or deterioration might be more inclined to make return visits. The points of the present study are as follows: 1) the long-term radiological outcome after ACDF of TUD approach with an average duration of longer than 20 years were demonstrated; 2) None of the patients demonstrated the kyphotic malalignment of cervical spine and pseudoarthrosis at the final follow-up visit, although ASD has been observed in 12 of 22 patients (54.5%); 3) the lordotic angle at the fused segments resulted in a significant correlation with the C2-7 angle of cervical alignment.

The local loss of cervical angle or kyphotic malalignment of the cervical spine is thought to contribute to progression of degenerative changes in adjacent segments long after ACDF.[8,9] ACDF may accelerate the degeneration of the adjacent segment on top of that caused by physiologic aging. Mechanisms by which kyphotic malalignment contributes to the accelerated degenerative process may involve both a change of dynamic kinematics of the cervical spine and increased biomechanical stress on the anterior vertebral elements in adjacent intervertebral segments.[10,11]

In a historical view, ACDF has been combined with autologous bone grafting to provide long-term stability of osseous fusion. Success rates of ACDF in cases of cervical spondylosis have ranged from 81% to 97%,[4,12-14] with graft dislodgement occurring at a rate of 2.1% to 4.6%, kyphosis at a rate of 3% to 10% and pseudoarthrosis at a rate of 1% to 3%.[13,15] In

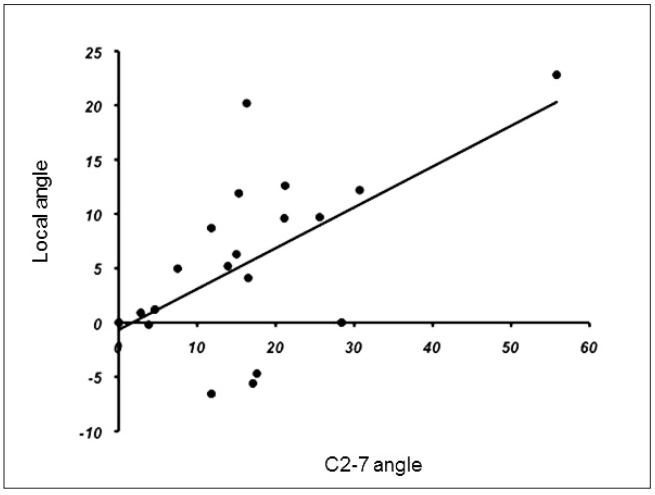


Figure 3: Statistical analysis indicating a significant relationship between the local angle at the fused segments and the C2-7 angle (γ = 0.58, P = 0.0068)

multiple-level fusions, pseudoarthrosis can occur at a rate as high as 33%.[16] These rates of fusion failure, graft dislodgement and postoperative cervical deformity have stimulated the development of fixation devices such as anterior plating or intervertebral cage to optimize the stabilization of the cervical spine. Although there have been several technical advancements in ACDF, there is currently no consensus on the optimal technique. A stand-alone interbody fusion cage has been proven to be safe and effective and is now a standard option for ACDF.[14,15,17-27] Our recent analysis suggested that the clinical outcome

with a stand-alone interbody fusion cage has been encouraging in one-level and two-level fusion procedure.[28] Cervical disc replacement by a stand-alone cage can restore physiologic disc height, provide immediate load bearing support of the cervical spine and may promote osseous fusion. Despite the advantages of a stand-alone cage, it may carry the risk of cage subsidence that may lead to kyphotic malalignment of the cervical spine long after ACDF. Mechanical support of the graft material at the anterior vertical line may be crucial to induce osseous fusion with a satisfactory angle of cervical alignment long after ACDF. Proper restoration of cervical alignment through a careful surgical technique and decompression of the neural structures cannot be overemphasized. Although a variety of internal fixation instrumentation such as cage, plate or screw can be available in the current circumstances, the basic and essential concept of ACDF appears to be unvarying in nature. Authors concluded that sagittal alignment of the cervical spine was durable long after ACDF when the local angle at the fused segments was well stabilized.

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