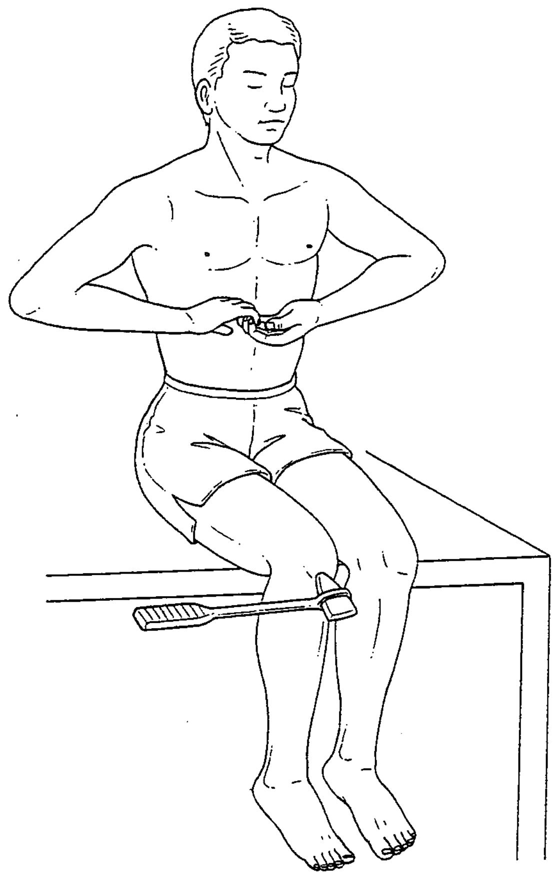
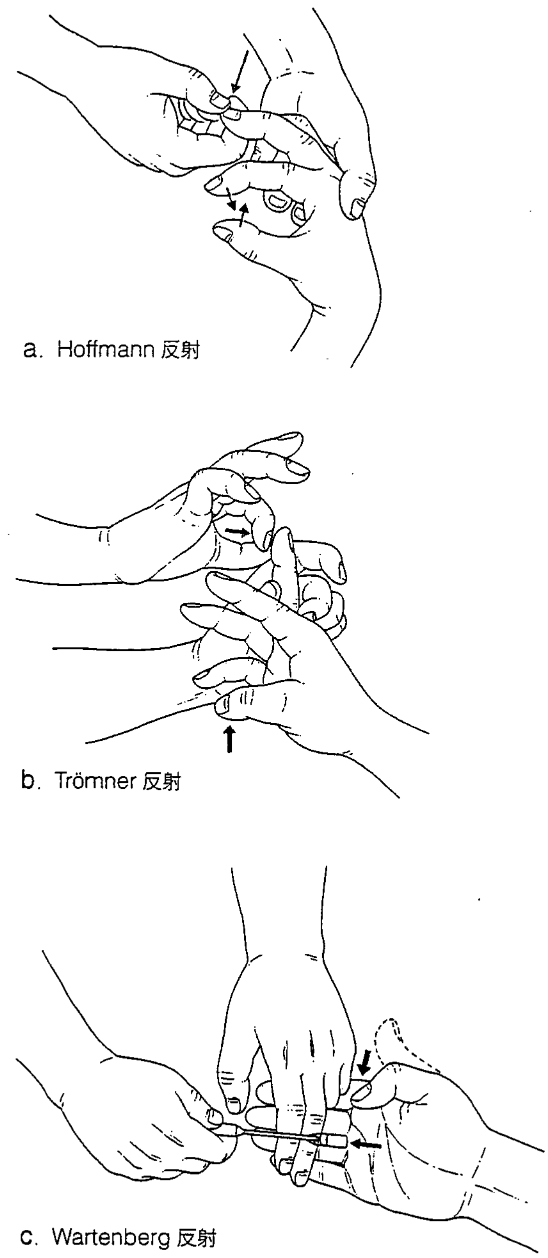


図 6 Jendrassik 法による膝蓋腱反射増強



a. Hoffmann 反射

b. Trömner 反射

c. Wartenberg 反射

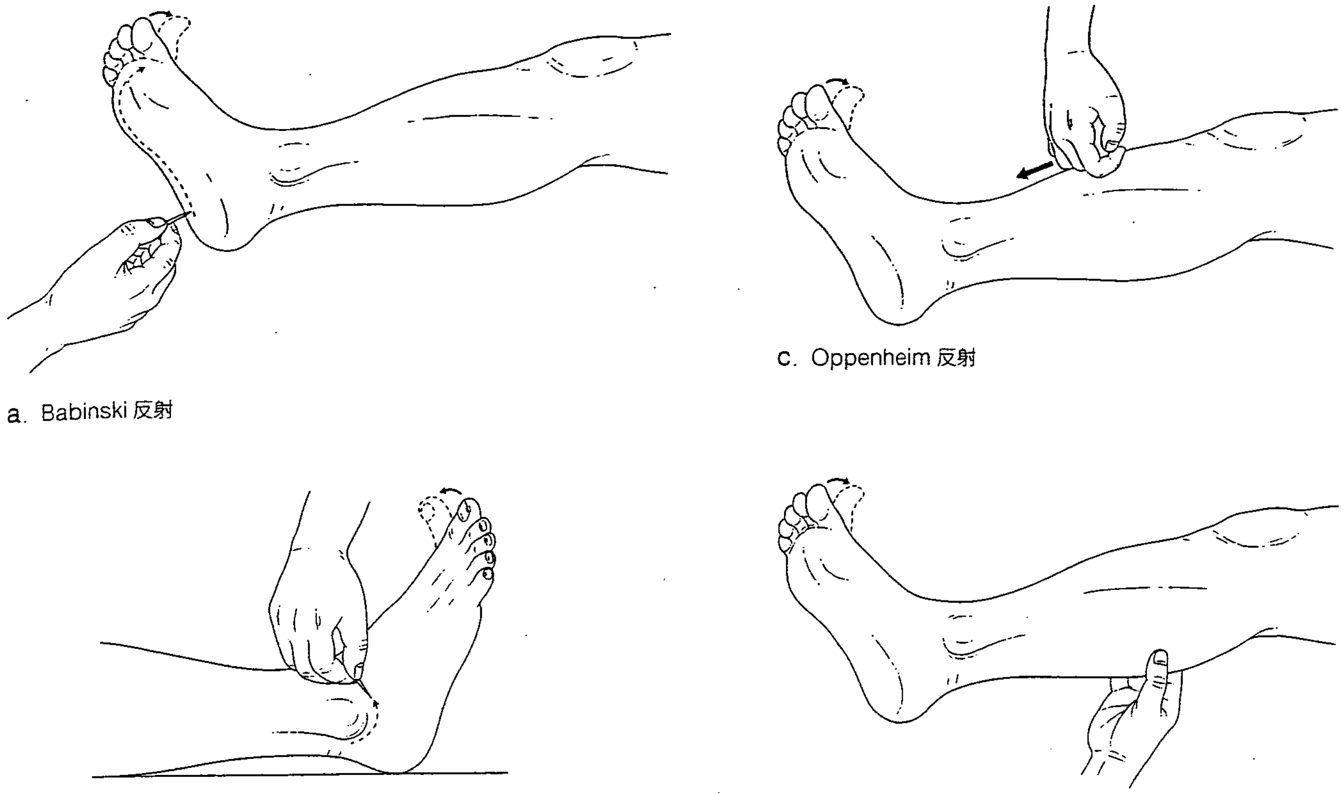
図 7 病的手指屈筋反射

の障害を考える.

下顎反射は脳幹を反射中枢とする. C1-4 髄節の情報を与える筋伸張反射として清水ら[3]は独自に肩甲上腕反射（scapulohumeral reflex〈Shimizu〉）を提唱している. 被検者を座位で両上肢を下垂させるか肘関節を 90° 屈曲位にして肩甲棘中央部と肩峰の 2 か所を打腱器で叩き, 肩甲骨の挙上または肩関節の外側の動きのみられた場合に反射亢進として判定する検査である. これは C1-4 髄節の上位運動ニューロンの障害を反映した反射である.

病的反射には Hoffmann 反射, Trömner 反射, Wartenberg 反射などの手指屈筋反射（図 7）と, Babinski 反射とその変法である Chaddock 反射, Oppenheim 反射, Gordon 反射（図 8）などがある. Babinski 反射の注意点として, 小児では 2 歳ごろまで通常陽性である. また, 錐体路障害があっても必ず陽性に出るとは限らないし, 錐体路障害の程度と反射の陽性度も比例しない. 足の屈筋のみが麻痺した場合には錐体路障害がなくても Babinski 反射が陽性になる. 腱反射の亢進や病的反射, クローヌス（間代痙攣）の出現は錐体路の障害を意味している. クローヌスは反射の亢進と同じ意義があり, 膝クローヌスと足クローヌスがある. 前述した筋力検査, 知覚検査とこの反射の検査を組み合わせれば障害レベルの高位診断に役立つ（表 3）.

胸椎病変では下肢は脊髄障害により痙性を示すが, 腰髄レベルでも病変があると下肢腱反射は低下するため胸椎病変がマスクされることがある. また下位胸椎の脊髄円錐上部の障害は多彩であり, 痙性麻痺とは限らず弛緩性麻痺のこともある. 症状は下肢症状が主体であり, 両側性に出ることが多い. 脊髄円錐部障害では下肢症状はほとんどなく, 鞍状の知覚障害（saddle anesthesia〈サドル型感覚消失〉）や膀胱直腸障害が多くみられる. 胸髄レベルの病変の神経学的高位診断は, 特徴的な反射がなく知覚検査に頼るところが多い. しかし, Beevor 徴候[4]は有用な検査であるので行う必要がある. これは患者を



a. Babinski 反射

b. Chaddock 反射

c. Oppenheim 反射

d. Gordon 反射

図 8 Babinski 反射とその変法

表 3 頚椎神経根障害レベルと所見

障害神経根	筋力低下	知覚障害*	反射異常
C1, C2	頚部屈曲・伸展	頭頂部, 後頭部	なし
C3	頚部側屈	頚部	なし
C4	肩挙上	肩部, 鎖骨上前胸部	なし
C5	肩外転	上腕外側	上腕二頭筋反射消失（低下）
C6	肘屈曲, 手関節伸展	前腕橈側～手橈側部	上腕二頭筋反射低下 腕橈骨筋反射低下
C7	肘伸展, 手関節屈曲, 手指伸展	手掌中央部	上腕三頭筋反射低下
C8	手指屈曲, 母指伸展	手尺側部	なし
T1	手指開閉	前腕尺側部	なし

＊知覚障害は図 5 参照.

仰臥位にして頭部を挙上させたときの臍の偏位をみる検査であり，腹筋の麻痺や筋力の左右差を判定する．臍が上方に移動すれば第 10 胸髄髄節より尾側，臍が下方に移動すれば第 10 胸髄髄節より頭側の障害が存在することが疑われる．

1．錐体路障害にみられるその他の反射

● Marie-Foix 反射

足指を握って強く足底に屈曲させると下肢全体の屈曲が起こり，足は背屈する反射である．

● Mayer 徴候

正常では中指，環指，小指を中手–基節関節で屈曲させると母指が内転するが，この反射が欠如することを Mayer 徴候とよぶ．一側のみにこの Mayer 徴候が出現すると錐体路障害として信頼できる．

● Rossolimo 反射

足底筋反射の一種で足底や足趾の付け根を打腱器で上方へ向けて叩き，足趾の足底への屈曲をみる反

射であり，通常出現しないが錐体路障害があると陽性になる．

● Mendel-Bechterew 反射

足背の中央部外側を打腱器で叩き足趾の足底への屈曲をみる反射であり，足底筋反射の一種である．

2. 錐体交叉部の病変による交叉性麻痺

後頭頚椎移行部には錐体交叉が存在しており，この部位では上肢と下肢への上位運動ニューロン線維が独特な走行（図 9）をするため錐体交叉部近傍の病変では特徴的な交叉性麻痺を呈する．脳幹部の錐体交叉部で上肢への線維が交叉する部分のみが障害されると上肢のみ対麻痺が生じ，下肢は麻痺のない交叉性麻痺（Bell 麻痺）[5] が出現する．脳幹部の錐体交叉部ですでに交叉した上肢への線維と，まだ交叉していない下肢への線維が一側性に障害されると，一側上肢と反対側下肢の交叉性片麻痺（Wallenberg 麻痺）[6,7] が出現する．また錐体交叉部の上下肢への線維が交叉する前で髄外から徐々に圧迫されると，同側上肢→同側下肢→反対側下肢→反対側上肢の順に麻痺が進行する．

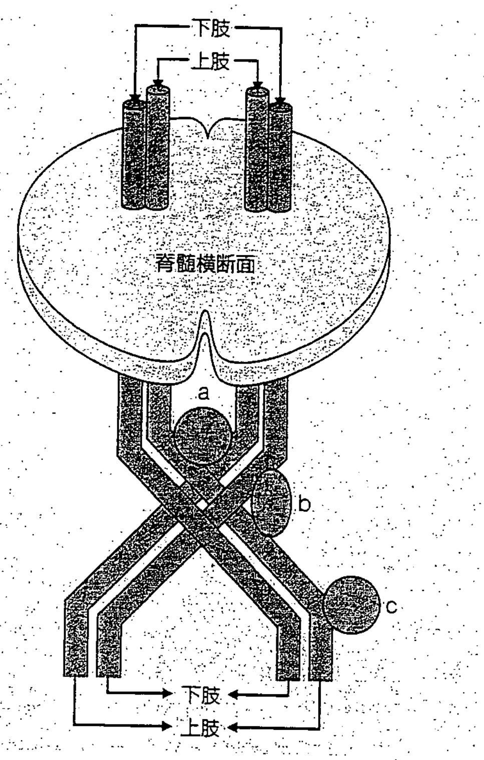


図 9 錐体交叉部における交叉性麻痺の病態
a の部分の病変：上肢のみの麻痺（Bell 麻痺），b の部分の病変：一側上肢と反対側下肢の麻痺（Wallenberg 麻痺），c の部分の病変：同側上肢→同側下肢→反対側下肢→反対側上肢の麻痺へと進行していく．

脳神経検査

脳神経の検査は頚椎・胸椎疾患の鑑別診断として必要であり，とくに上位頚椎病変では下位脳神経症状を呈する場合があるので脳神経の検査も忘れず行う．副神経が障害されると，胸鎖乳突筋や僧帽筋の筋力低下や筋萎縮が生じる．舌咽神経や迷走神経の障害では，構音障害や嚥下障害が生じる．構音障害や嚥下障害はまれにくちばし状の頚椎前縦靱帯骨化（図 10）により食道や反回神経が圧迫されて，嚥下障害や嗄声が出現する場合もある．舌下神経の障害では，舌筋の萎縮や舌の偏位を認める．三叉神経障害では顔面の知覚障害が出現する．延髄部空洞症や脊髄癆などで三叉神経脊髄路核が障害されると，温痛覚の脱失が顔面の周辺から鼻・上唇へ向かって進行する有名な onion-peel 型の知覚障害がみられる．顔面神経の麻痺は眼瞼下垂などで診断されるが，眼輪筋や口輪筋の筋力の検査も行う．眉間反射は眉間を打腱器で叩いて両側の眼輪筋の収縮をみるもので，末梢性顔面神経麻痺では患側の反射が低下し，中枢性顔面神経麻痺では反射が亢進する．また Parkinson 病の人ではこの反射が亢進しており Myerson 徴候とよぶ．

歩行状態の検査

歩行状態の観察も頚椎・胸椎疾患の診察では重要であり，種々の異常歩行とその原因疾患を知る必要がある．頚椎・胸椎疾患の診察をする場合に注意すべき異常歩行には以下のものがある．

a. 痙性歩行

下肢に痙性がある場合にみられる異常歩行であり，膝を伸展してあまり床から足を上げず狭い歩幅で歩行する．

b. はさみ脚歩行

脳性麻痺の患者でよくみられる異常歩行であり，両脚をはさみのように交叉して歩く．

c. 失調性歩行

脊髄後索性障害による脊髄性失調歩行と小脳障害による小脳性失調歩行がある．両足を広げた不安定な歩行であり，体幹も不規則に動揺する．脊髄障害では，開眼時には異常がなくても閉眼するとすぐに体幹が動揺する Romberg 徴候[8] がみられる．また

図 10　頚椎側面 X 線像
くちばし状の頚椎前縦靱帯骨化（➡）により嚥下困難と嗄声を生じた．

小脳性失調歩行の場合は指鼻テストや膝踵テストなどの平衡感覚のテストの異常もみられる．

d．鶏歩行

下垂足がある際にみられる異常歩行であり，つま先が床に引っかからないように膝を高く持ち上げ，膝を下ろすときはつま先から投げ出して足底全体を接地する．

e．麻痺性歩行

弛緩性麻痺でみられる異常歩行であり，重力に対して骨盤の保持や膝の伸展ができないため肩を揺らして歩行する．中殿筋の麻痺がないか調べるため Trendelenburg 徴候の有無を観察する．

f．小刻み歩行

Parkinson 病の患者にみられる特徴的異常歩行であり，膝を曲げ前かがみの姿勢で小刻みで歩行し，足はあまり床から上げず手の振りも少ない．歩き始めの第 1 歩が出にくいすくみ足や，急に止まることが困難な前方突進歩行を呈する．

g．片麻痺歩行

片麻痺患者でみられる異常歩行であり，外側に患脚を円を描くように振り出して歩行するいわゆる分回し歩行を呈する．

運動失調の検査

小脳性の運動失調の検査も頚椎および胸椎の診察を行う場合忘れず行う．小脳性運動失調は測定障害，共同運動不能，変換運動障害，振戦，時間測定異常などがあるが，簡便な検査法として以下の検査がある．

a．鼻指鼻テスト

被検者の片手の示指を本人の鼻先に当てさせ肘を伸ばすと届くくらいの距離に固定した検者の示指の先を触れるように指示して，この動作を交互に行わせるテストである．1 回ごとに検者は示指の位置を変えるようにする．小脳性運動失調がある場合は企図振戦が出現したり，著しく動作が緩慢になる．

b．指鼻テスト

被検者に片手の示指で自分の鼻先ともう片方の手の示指の指先のあいだを交互に触らせるテストであり，小脳性運動失調があると企図振戦が出現したり，また閉眼でこのテストを行うと異常が顕著に出現する．

c．踵膝テスト

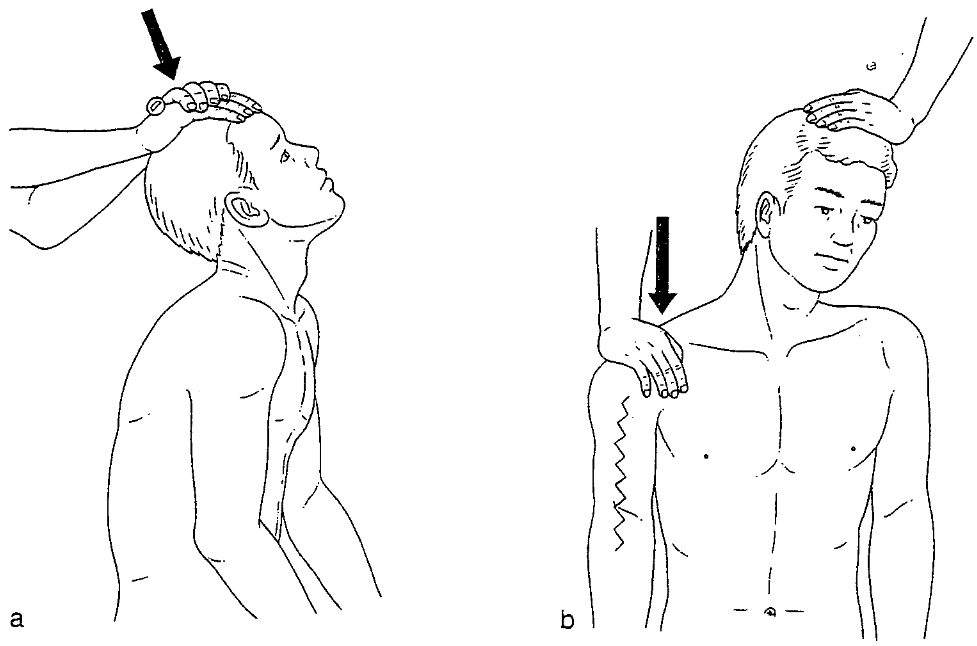
下肢で行う小脳性運動失調の有無をみる検査であり，仰臥位で一側の踵を対側の膝につけ元に戻す運動を繰り返して行わせる．閉眼でも同じ動作をさせる．

特殊な検査・徴候

以下に述べる検査や徴候はいずれも被検者に対して検者が被動的な外力を加えることにより疼痛出現や脈の消失などの症状を誘発させる検査である．臨床的には確かに有用な検査であるが被検者にとっては不快な検査であることを常に留意して検査する必要がある．

a．Lhermitte 徴候[9]

被検者を仰臥位にして頚を被動的に前屈させた際



a b

図11 Jacksonテスト
a：頭部圧迫テスト．頸椎を過伸展させる．頭頂部から体軸方向に圧迫を加え，肩甲帯や上肢への放散痛の出現をみる．
b：肩押し下げテスト．頸を一側に側屈させる．反対側の肩を下方に圧迫．肩や上腕への疼痛の出現をみる．

に電撃様の疼痛が背部から四肢へ放散する徴候であり，多発性硬化症などの脊髄の脱髄疾患にみられるが髄膜炎，脊髄腫瘍などでもみられる．

b．Kernig徴候[10)]

被検者を仰臥位にして片側の股関節を屈曲して下腿を持ち上げるようにすると膝関節が屈曲し伸展できない徴候であり，髄膜刺激による膝屈筋の攣縮によって出現する．

c．Brudzinski徴候[11)]

Kernig徴候と同じく髄膜刺激症状であり，被検者を仰臥位にして頸を被動的に前屈させると股関節と膝関節が自動的に屈曲し疼痛を惹起する徴候である．

d．Jackson頭部圧迫および肩押し下げテスト[12)]

頸椎を過伸展させ頭頂部から体軸方向に圧迫を加え肩甲帯や上肢への放散痛の出現をみる頭部圧迫テスト（図11a）と，頸を一側に側屈させ反対側の肩を下方に圧迫し肩や上腕への疼痛が誘発されるのをみる肩押し下げテスト（図11b）はいずれも頸部神経根障害による根性疼痛の誘発テストである．

e．Eatonテスト[13)]（図12）

被検者を座らせて検者の片手で頸椎を側屈させ，他方の手で患側の上肢を後下方に牽引し上肢の疼痛やしびれ感が誘発されるかをみるテストで，頸部神経根症の診断に役立つ．

f．Spurlingテスト[14)]（図13）

neck compression testともよび，患者を座らせて頸椎を患側へ側屈させ，やや後屈位で頭頂部に両手で下方向の圧迫を加え上肢への疼痛が誘発されるかをみる検査で，一種の椎間孔圧迫テストである．頸部神経根症の診断に役立つが，検査により症状が増悪することがあるので注意して検査する必要がある．

g．Adsonテスト[15)]（図14）

患者の橈骨動脈を触れ深呼吸をしながら患側に頸を伸展および回旋させ，脈拍の変化を検査する．脈拍の消失は胸郭出口における鎖骨下動脈と神経束の圧迫を示唆し胸郭出口症候群の診断に用いられる．

h．Wrightテスト[16)]（図15）

過外転テストともよぶ．患者を座位にして両肩を90°外転させ，橈骨動脈の脈拍の変化と症状の誘発や増悪を調べる．陽性は肋鎖間隙での神経・血管の圧迫が疑われる．胸郭出口症候群の診断に用いられる．

i．Edenテスト[17)]（図16）

患者を座位にして，胸を張り肩を後下方に引っ

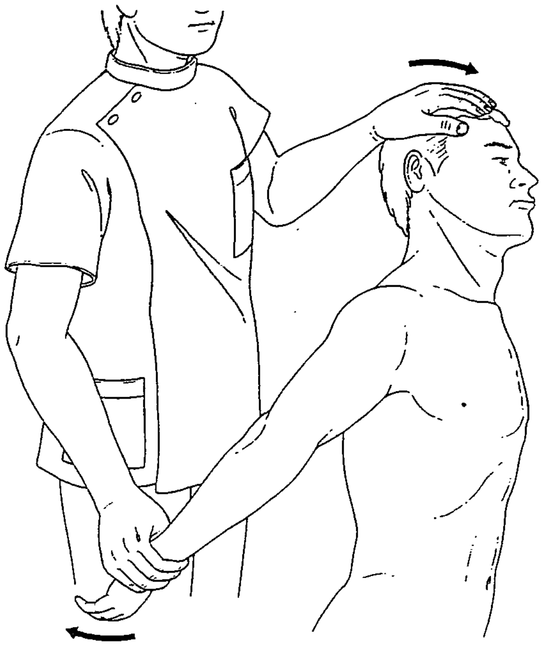


図 12　Eaton テスト
患者は座位とし，検者の片手で頚椎を側屈する．他方の手で患側の上肢を後下方に牽引．上肢の疼痛やしびれ感が出現するかみる．

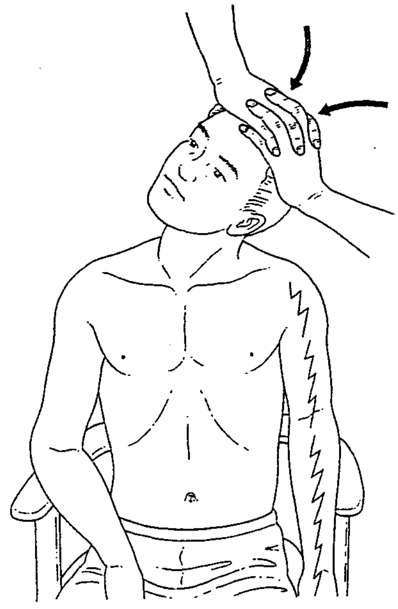


図 13　Spurling テスト
患者は座位とし，頚椎を患側へ側屈させ，やや後屈位で頭頂部に両手で下方への圧迫を加え，上肢への疼痛が出現するかみる．

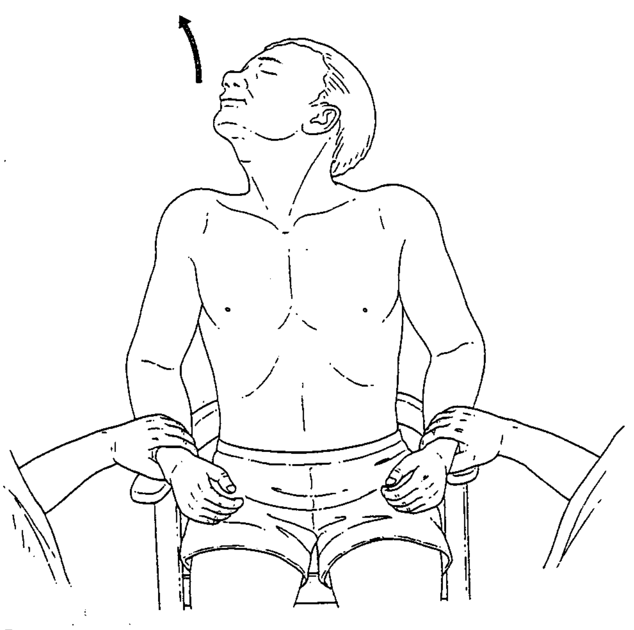


図 14　Adson テスト
患者の橈骨動脈を触れ，患者に深呼吸しながら患側に頚を伸展および回旋させ，脈拍の変化を検査する．

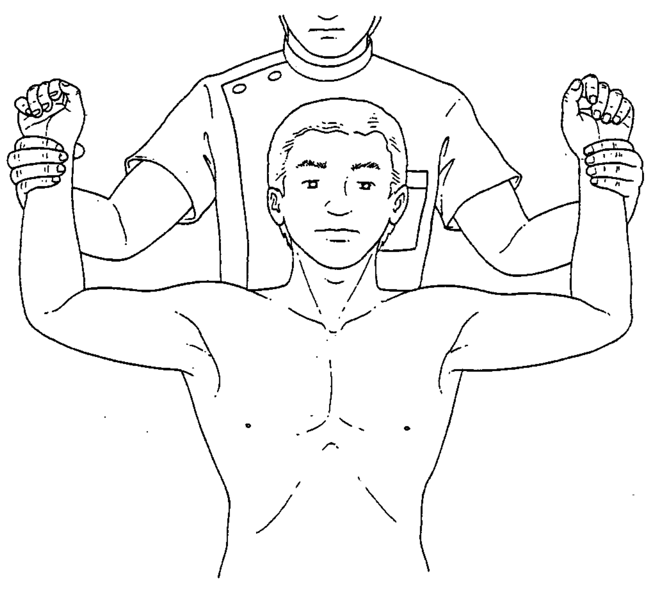


図 15　Wright テスト
患者は座位とし，両肩を 90° 外転させる．橈骨動脈の脈拍の変化と症状の誘発や増悪を検査する．

張った姿勢で橈骨動脈の脈拍の変化と症状の誘発や増悪を調べる．陽性は肋鎖間隙での神経・血管の圧迫が疑われる．胸郭出口症候群の診断に用いられる．

j. Morley テスト[18)]（図 17）

鎖骨上窩で前・中斜角筋のあいだを圧迫し，圧痛や放散痛の有無を調べる．圧迫により局所の圧痛や放散痛を認めた場合は胸郭出口症候群，とくに斜角筋部での圧迫を疑う．

k. Roos の 3 分間テスト[19)]（図 18）

患者を座位で両肩を 90° 外転させ，肘を 90° 屈曲させた肢位で両側の手指を 3 分間開閉させ続けさせる検査．上肢に疲労感や疼痛，しびれなどが誘発されたり，3 分間の継続ができない場合を陽性と

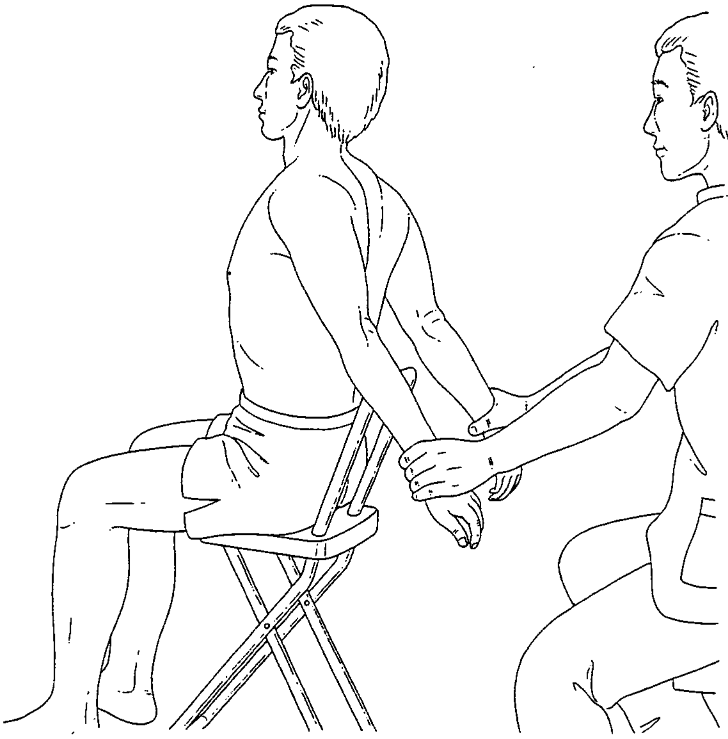


図 16　Eden テスト
患者は座位とし，胸を張り肩を後下方へ引っ張った姿勢で，橈骨動脈の脈拍の変化と症状の誘発や増悪を調べる．

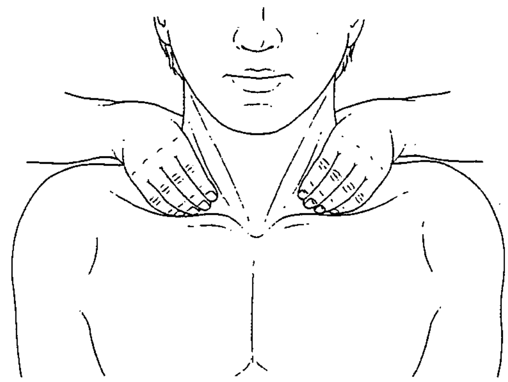


図 17　Morley テスト
圧痛や放散痛の有無を検査する．

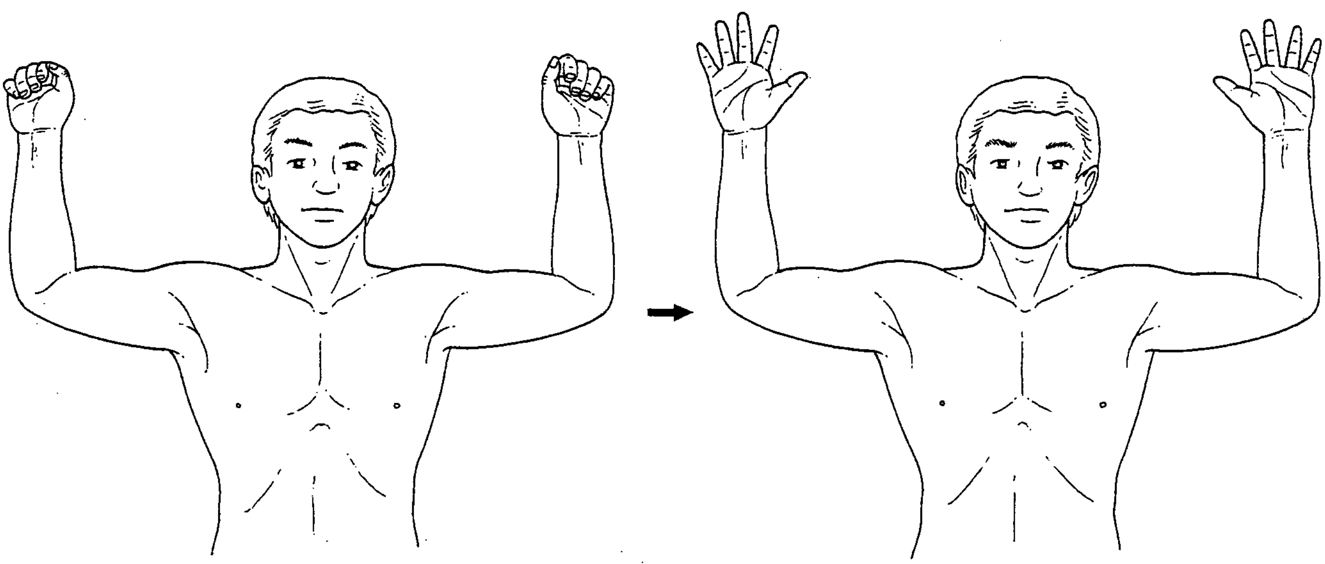


図 18　Roos の 3 分間テスト
患者は座位とし，両肩を 90° 外転，肘を 90° 屈曲させた肢位で，両側の手指を 3 分間開閉させ続ける．上肢に疲労感，疼痛，しびれが出現するか検査する．3 分間継続できない場合は陽性．

判定し，胸郭出口症候群，とくに肋鎖間隙での圧迫を疑う．

頚椎・胸椎疾患の診察では神経学的診察が中心となるが，頭蓋内病変，筋疾患，糖尿病などの代謝性疾患などでも鑑別を要する症状を呈する場合があるので局所のみの診察にとどまらず患者を全身的にとらえて診察する習慣を身につけなくてはならない．当然のことであるが，視診や問診，触診の手順を省略してはならない．また頚椎疾患では，交通事故によるむち打ち損傷などの場合に保険などの問題も関係してくるので，患者の訴える症状と他覚所見の適合性をみながら診察する必要がある．

（松永俊二）

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ORIGINAL ARTICLE

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Bone resorption of the facet joint in rheumatoid arthritis as a predictor of lower cervical myelopathy

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Abstract The purpose of the present study was to identify the risk factors to predict instability of the subaxial cervical spine and cervical myelopathy based on plain radiographs. The study was performed on 99 patients with mutilating rheumatoid arthritis (RA). From plain lateral radiographs of the cervical spine over time, rheumatoid cervical spine lesions were investigated and evaluation was made on the possibility to develop cervical myelopathy. The incidence of subaxial cervical spine lesions in the patients with mutilating RA was as high as 98%. In particular, resorption of the superior facet suggests high risk to develop cervical myelopathy. The presence of spinous process erosion is also likely to reveal such a possibility. There was no statistically significant difference in the anteroposterior diameter of cervical spinal canal between the cases with cervical myelopathy and those without it. Resorption of the superior facet is the most important factor for the development of cervical myelopathy. In the cases with rheumatoid cervical spine lesions, it is necessary to take special notice of the superior facet.

Key words Cervical myelopathy · Facet joint · Mutilating rheumatoid arthritis (RA)· Subaxial subluxation (SAS)

Introduction

In patients with rheumatoid arthritis (RA), cervical spine lesions are most frequently seen not only in the atlantoaxial joint but also in the subaxial cervical spine. With the progression of subaxial cervical spine lesions, there is a high possibility of developing cervical myelopathy due to instability of the cervical spine or to soft tissues such as rheumatoid granulation. Also, there are cases where the whole cervical spine turns to a state of fusion and stability, thereby not developing cervical myelopathy. Thus, it is difficult to predict the development of cervical myelopathy based on subaxial cervical spine lesions. In this respect, the purpose of the present study is to focus attention on those cases of mutilating RA with a high risk of developing cervical myelopathy, and to identify the risk factors in order to predict instability of the subaxial cervical spine and signs of cervical myelopathy, based on plain radiographs which can be assessed in ordinary outpatient clinics.

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Patients and methods

The study was performed on 99 patients with mutilating rheumatoid arthritis (RA) (5 male and 94 female patients) who did not have cervical myelopathy at the first visit to our hospital. For 19 patients who had been operated on the cervical spine, the study was performed on the conditions before the time of operation. The mean age of the patients at the time of study was 64.5 years old (range: 48–83 years). The average duration of RA was 17.4 years (range: 2.0–33.7 years) at the first visit and 26.4 years (range: 6.3–51.8 years) at the time of study. The average duration of radiographic follow-up was 9.0 years (range: 2.0–22.5 years). According to the classification of Steinbrocker, all cases were in Stage III or IV. There were 23 cases in Class 2, 56 cases in Class 3, and 20 cases in Class 4. According to the definition of Murasawa et al.,[1] mutilating RA was defined as the case where radiographic bone resorption of Larsen grade 5 was found in more than three finger or toe joints and more than two major joints.

Plain lateral radiographs of the cervical spine were taken in full flexion and full extension at a 1-year interval. Patients were asked to flex and extend their necks until discomfort or stiffness inhibited further movement. The radiographs were read by two of the authors without knowledge of the

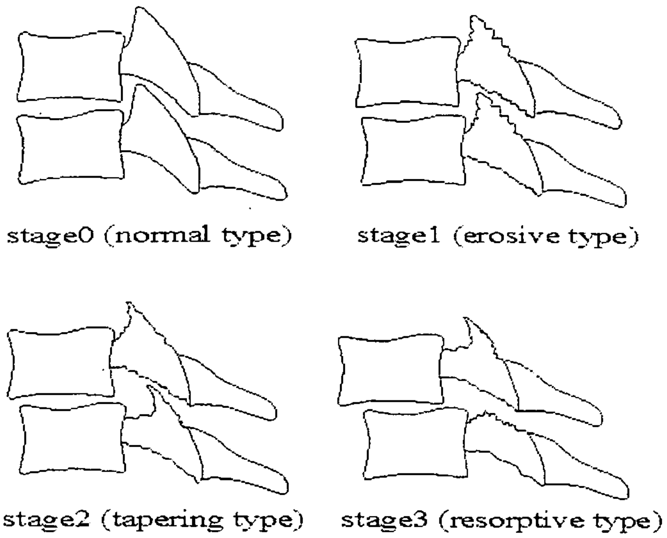


Fig. 1. Classification of the facet joint

Table 1. Incidence of subaxial cervical spine lesions classified by items

	n (%)
Facet joint erosion	96 (97)
Narrow disc space	89 (90)
Endplate erosion	87 (88)
SAS	70 (71)
Spinous process erosion	69 (70)
Immobility of cervical spine	31 (31)

SAS, subaxial subluxation

Table 2. Relationship between plain radiographic findings of subaxial cervical spine lesions and cervical myelopathy

	P value
Classified facet joint erosion	<0.001
Narrow disc space	NS
Endplate erosion	NS
SAS	NS
Spinous process erosion	<0.05
Immobility of cervical spine	NS

NS, not statistically significant

clinical or serological data. The radiological criteria used in this study were subaxial subluxation (SAS) with 2mm or more anteroposterior slip from the line drawn on the lower posterior vertebral margin, facet joint erosion, endplate erosion, spinous process erosion, narrow disc space without osteophytosis, and immobility of the cervical spine associated with spontaneous vertebral fusion or facet fusion, and these were considered as rheumatoid subaxial cervical spine lesions previously reported by Sharp et al.[2] and other researchers. We classified rheumatoid lesions of the facet joint into four stages according to the extent of erosion and its resultant shape. In stage 0 (normal type), the facet joint has a normal shape without noticeable erosion. In stage 1 (erosive type), the facet joint has a slight or medium macroscopic erosive change. In stage 2 (tapering type), the facet joint has a severe destructive change as the superior facet looks like a tapering pencil. At stage 3 (resorptive type), there is severe involvement of the facet joint. Its normal superior facet has disappeared and the inclination angle of the facet joint (the angle made by the line drawn along the joint surface of the inferior joint process and the line drawn on the posterior vertebral margin in the lateral view) has increased (Fig. 1). Also, the degree of SAS and the space available for the spinal cord (SAC) on the narrowest level in full flexion or extension were measured. The anteroposterior diameter of the cervical spinal canal was directly measured from the cranioanterior edge of C5 lamina to the posterior margin of C5 vertebral body. It was confirmed whether the patients had used steroids. Cervical myelopathy was determined through a careful neurological examination. However, on these patients this was always difficult. Thus, we evaluated it by mainly checking hyperreflexia, dysesthesia, sensory deficits, and activities of daily living. Ranawat's classification[3] was used for the evaluation of cervical myelopathy, and the level of responsibility for cervical myelopathy was determined according to neurological and radiographic (including magnetic resonance imaging) findings. For statistical analysis, the χ^2 test, Kruskal–Wallis test, and Mann–Whitney *U*-test were performed using JMP 5.1. (SAS Institute, Cary, NC, USA).

Results

At the initial point of this study, 85% of these 99 patients already had rheumatoid subaxial cervical spine lesions on plain lateral radiographs. At the time of study, the incidence of rheumatoid subaxial cervical spine lesions was 98%. The incidence of facet joint erosion was 97%. When classified by items, the stages of the facet joint were classified into: stage 0 (normal type) 3%, stage 1 (erosive type) 71%, stage 2 (tapering type) 15%, and stage 3 (resorptive type) 11%. Each stage reflected increasing involvement and rheumatoid destruction of the facet joint. Narrow disc space without osteophytosis was found in 90% of the cases, endplate erosion in 88%, SAS in 71%, spinous process erosion in 70%, and immobility of the cervical spine associated with spontaneous vertebral fusion or facet fusion in 31% of the cases (Table 1). Subaxial cervical spine lesions were found at high frequency in C5 and C6. Eighty-seven cases had used steroids. The cases of cervical myelopathy of II or more in Ranawat's classification were seen in 29 of 99 cases. The level of responsibility for cervical myelopathy was seen at the atlantoaxial joint in eight cases, and the subaxial cervical spine in 21 cases. In plain radiographic findings of the subaxial cervical spine, a statistically significant difference from cervical myelopathy was found in SAC, classified facet joint erosion, and spinous process erosion. No significant difference was noted in SAS, endplate erosion, immobility of the cervical spine, and narrow disc space without osteophytosis (Table 2). Also, no significant association was found between the use of steroids and subaxial cervical

Table 3. Stage of the facet joint and cervical myelopathy

	Ranawat I	Ranawat II	Ranawat IIIA	Ranawat IIIB
Normal type, *n*	2	1	0	0
Erosive type, *n*	59	2	9	0
Tapering type, *n*	7	0	5	3
Resorptive type, *n*	2	3	2	4

n, number of patients

Table 4. Spinous process erosion and cervical myelopathy

	Ranawat I	Ranawat II	Ranawat IIIA	Ranawat IIIB
Yes, *n*	42	5	15	7
No, *n*	28	1	1	0

n, number of patients

myelopathy. Among the cases with facet joint erosion, cervical myelopathy was detected in 11 of 70 cases in stage 1 (erosive type), 8 of 15 cases in stage 2 (tapering type), and 9 of 11 cases in stage 3 (resorptive type). Resorptive image of the superior facet suggests a particularly high risk of developing cervical myelopathy ($P < 0.001$) (Table 3). In the cases with spinous process erosion, cervical myelopathy was found in 27 of 69 patients, and this suggested a high possibility of developing cervical myelopathy if spinous process erosion was present ($P < 0.05$) (Table 4). Subaxial subluxation became more severe as the stage of the facet joint moved from stage 0 (normal type) to stage 1 (erosive type), stage 2 (tapering type), and stage 3 (resorptive type). It was 0.5 mm on average in stage 0, 1.5 mm in stage 1, 3.3 mm in stage 2, and 7 mm in stage 3 ($P < 0.001$). Subaxial subluxation became more severe when spinous process erosion was present. It was 3.1 mm on average in the patients with spinous process erosion ($P < 0.001$) (Fig. 2). In SAC, a statistically significant difference was found depending on whether or not cervical myelopathy was present ($P < 0.0001$). Space available for the spinal cord was 11.5 ± 2.1 mm on average in the cases with cervical myelopathy and 14.2 ± 1.8 mm on the cases without cervical myelopathy (Fig. 3). On the other hand, no significant difference was noted in the anteroposterior diameter of the cervical spinal canal depending on whether or not cervical myelopathy was present (Fig. 4). However, in the patients with mutilating RA who developed cervical myelopathy, cervical myelopathy occurred even when SAS was mild if the anteroposterior diameter of cervical spinal canal was narrow (Fig. 5).

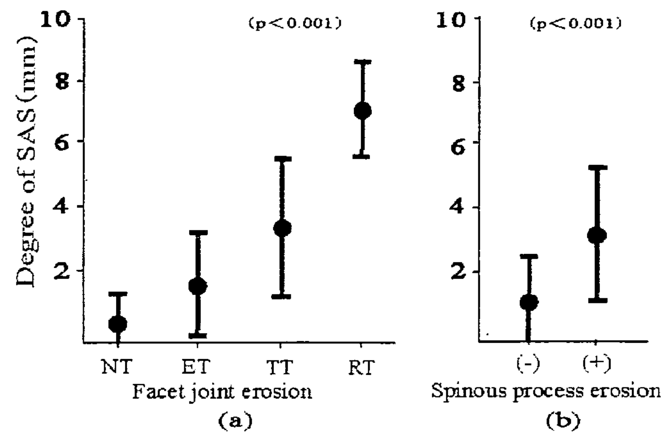


Fig. 2a,b. Plain radiographic findings and the degree of subaxial subluxation (*SAS*). **a** SAS becomes more severe as the stage of the facet joint is turned to normal type (*NT*), erosive type (*ET*), tapering type (*TT*), and resorptive type (*RT*). **b** SAS becomes more severe when spinous process erosion is present

Case reports

Case 1 (Fig. 6)

Vertebral fusion was found on C5–C6. Erosive change of the facet joint and mild SAS were seen at C4/5. Eight years later, vertebral fusion was found on C3–C4, and SAS advance was noted at C4/5. However, the facet joint of C4/5 maintained its shape and merely showed erosive change. SAS at C4/5 advanced, but remained as mild subluxation.

Case 2 (Fig. 7)

Tapering change of the facet joint and moderate SAS were found at C5/6. Nine years later, tapering change advanced, but remained as tapering type and no progress was seen in SAS.

Case 3 (Fig. 8)

Tapering change was found in the facet joint and SAS was mild at C5/6. Three years later, the superior facet disappeared and the inclination angle of the facet joint increased. Severe SAS was seen and cervical myelopathy developed.

Case 4 (Fig. 9)

Resorption of the facet joint, increased inclination angle of the facet joint, and moderate SAS were seen at C6/7. Two years later, severe SAS and cervical myelopathy developed.

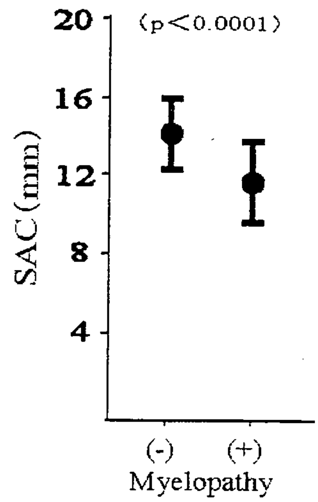


Fig. 3. Relation of cervical myelopathy and space available for the spinal cord (*SAC*). In SAC, a statistically significant difference was found depending on whether or not cervical myelopathy was present

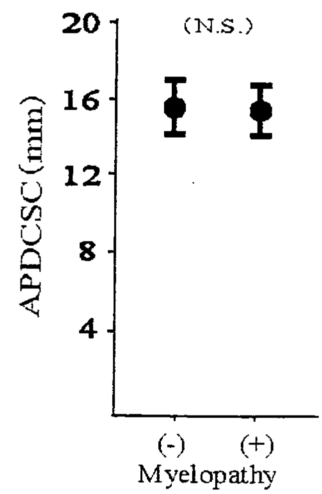


Fig. 4. Relation of cervical myelopathy and the anteroposterior diameter of cervical spinal canal (*APDCSC*). No significant difference was noted in APDCSC depending on whether or not cervical myelopathy was present

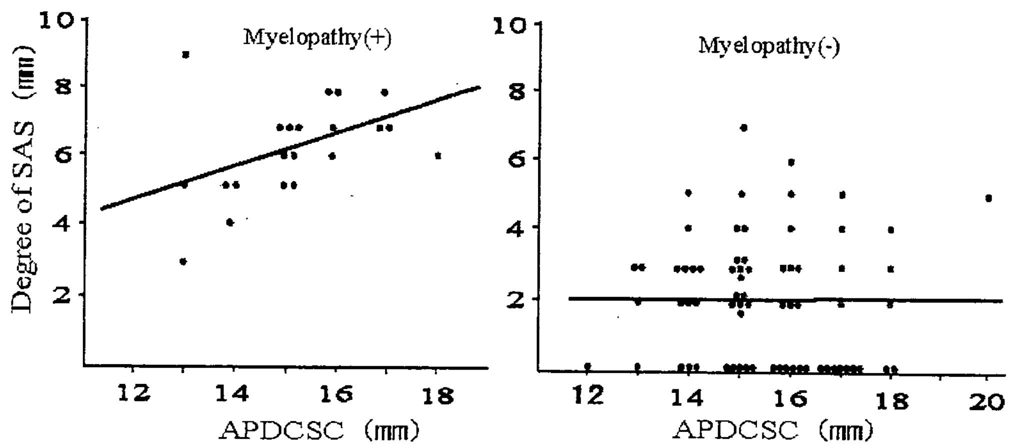
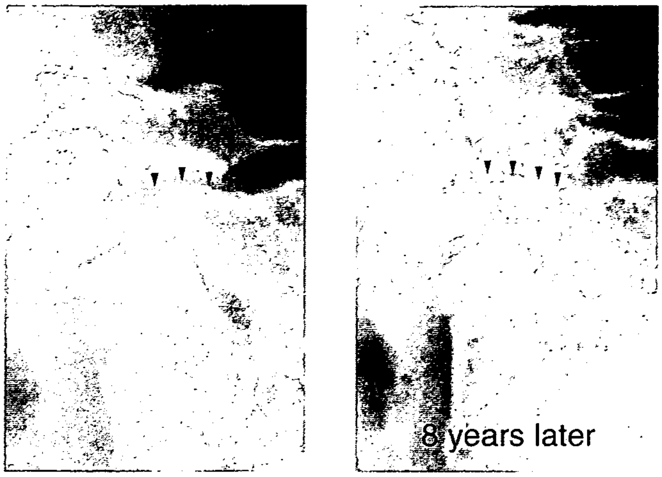


Fig. 5. In the patients with mutilating rheumatoid arthritis who develop cervical myelopathy, cervical myelopathy develops despite a mild degree of subaxial subluxation (*SAS*) if the anteroposterior diameter of cervical spinal canal (*APDCSC*) is narrow

Discussion

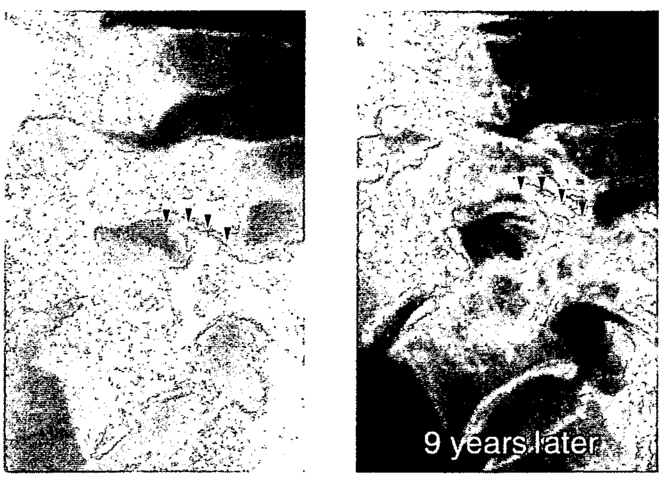
According to the report by Da Silva et al.,[4] who described the results of a retrospective study on 609 patients with RA, 242 patients had undergone the operation on joints associated with RA, and the cumulative ratio of surgical operation for 30 years was 33.7% ± 3.8%, while the cervical spine operation was found only in two cases, and the cumulative incidence was 0.4% ± 0.4%. This may mean that there was less possibility to cause clinical problems even when the cervical spine lesion was detected on plain radiographs of the patients with RA. However, patients with mutilating RA often require the cervical spine operation. Laiho et al.[5] reported that 26% of patients with arthritis mutilans hand deformity had been operated on their cervical spine. Nineteen patients (19%) in the present study had been operated on the cervical spine. If cervical myelopathy developed, the prognosis was poor. There are reports that one half of the patients died within 1 year after the diagnosis of myelopathy[6] or that, among 21 patients who did not undergo operation despite the presence of cervical myelopathy, all patients became bedridden within 3 years and died within 7 years after the diagnosis.[7] When an operation was performed to treat cervical myelopathy, activities of daily living could be maintained or improved at least for a certain period.[8] This suggests that it is important to take adequate action at an earlier stage.

Regarding the risk factor to predict cervical myelopathy based on plain radiographic images, there is no satisfactory predictor other than SAC[9–11] and rapid and extensive progress of peripheral articular lesions.[12] Up to now, there have been reports describing that rheumatoid lesions in posterior regions such as the facet joint, the spinous process, etc., are closely related to anterior slip.[13–16] Based on the results of a biomechanical study, White and Panjabi[17] reported that anterior instability appears as the result of the destruction of posterior elements of the spine around the facet joint. Kuwahara et al.[18] reported that pathological findings of the cervical spine, which were most frequently found at autopsy in patients with RA, were synovitis in the facet joints, and that RA granulation was found at high



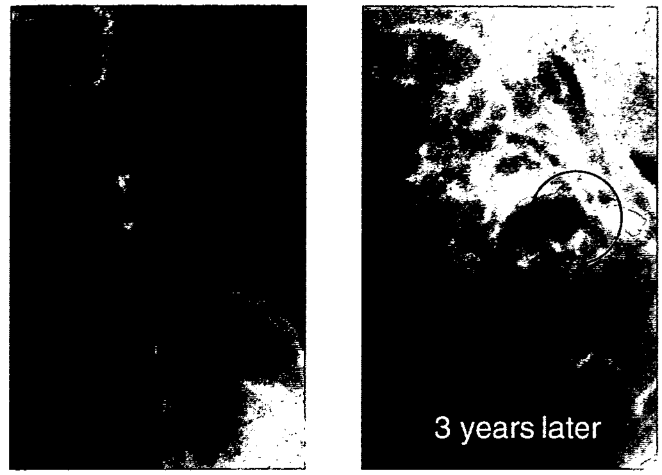
Case 1

Fig. 6. Case 1. A 63-year-old woman; duration of disease 22 years; stage 1 (erosive type) (*arrowheads*)



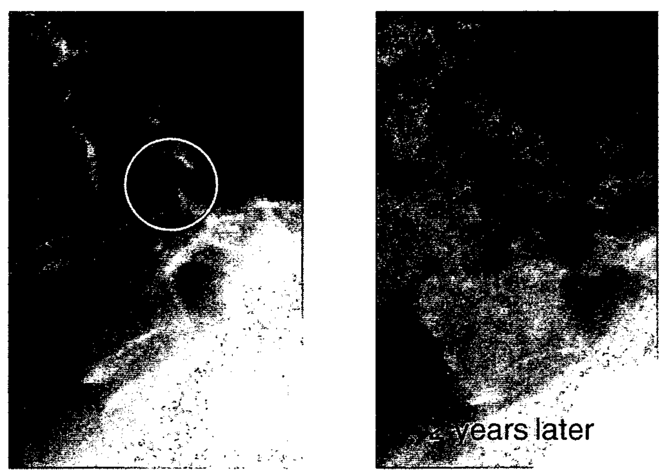
Case 2

Fig. 7. Case 2. A 63-year-old woman; duration of disease 17 years; stage 2 (tapering type) (*arrowheads*)



Case 3

Fig. 8. Case 3. A 73-year-old woman; duration of disease 15 years; stage 3 (resorptive type) (*area in circle*)



Case 4

Fig. 9. Case 4. A 50-year-old woman; duration of disease 15 years; stage 3 (resorptive type) (*area in circle*)

frequency in the facet joint or posterior elements such as bone marrow of the spinous process or the attaching region of ligaments. In the results of our present study, facet joint erosion was most frequently seen in the rheumatoid subaxial cervical spine. Therefore, we focused on the facet joint to delineate dynamic instability caused by subaxial cervical spine lesions. There is a report that anterior slip of the affected segment becomes severe when the inclination angle of the facet joint becomes greater.[13] However, this angle needs a measurement by a level because normal values are different. So we think the superior facet is a useful viewpoint to predict marked cervical instability by daily visitor medical examinations. If there is erosive change of the superior facet as seen in the upper portion of Fig. 10, mild SAS occurs but this does not become severe. If there is tapering of the superior facet as seen in the middle portion of Fig. 10, moderate SAS occurs but also does not become severe. If the superior facet is resorbed as seen in the lower portion of Fig. 10, severe SAS occurs and this is more likely to develop cervical myelopathy. In general, in cases of cervical spondylosis a narrow canal is an important factor in the development of cervical myelopathy. This has also been reported regarding RA.[10] However, in the results of the present study there was no statistically significant difference in the anteroposterior diameter of cervical spinal canal in the patients with mutilating RA, depending on whether cervical myelopathy was present. In the subaxial cervical spine of the patients with mutilating RA, a narrow canal is not an important factor in the development of cervical myelopathy. On the other hand, a narrow SAC is a risk factor connected directly with cervical myelopathy. Severe SAS that decreases SAC is closely related to resorptive change

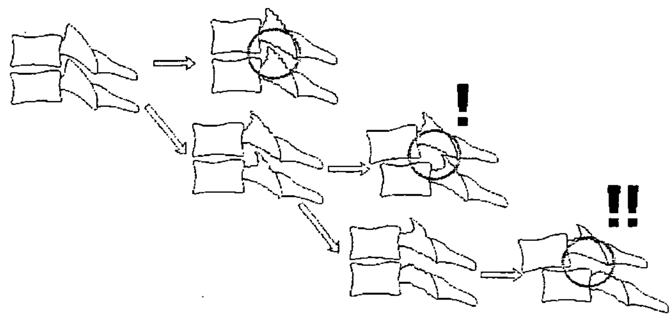


Fig. 10. Facet joint erosion and the progress of subaxial subluxation (*SAS*). As the facet joint is resorbed, anterior instability of the cervical spine increases, and cervical myelopathy develops rapidly

of the facet joint, tapering change of the facet joint, or spinous process erosion, and these may be important findings in predicting cervical myelopathy.

As causes of spinal cord compression in the subaxial cervical spine of the patients with RA, not only a bone factor associated with SAS but also rheumatoid granulation tissues or formation of constricting band on the dura mater have been reported.[19] The immunological process as well as the mechanical process due to instability may cause soft tissue proliferation and adhesion at the site of facet resorption and spinous process erosion. These are not identifiable from plain radiographs, and this suggests that magnetic resonance imaging is necessary in routine medical practice.

In summary, among rheumatoid subaxial cervical spine lesions, facet joint erosion was classified into four types depending on the morphological features of the facet joint seen on plain lateral radiographs. In patients with mutilating RA, there is a high risk for the development of cervical myelopathy if there is resorptive change and tapering change in the cervical facet joint, and it is necessary to take special note of the facet joint. Spinous process erosion is also a risk factor in the prediction of cervical myelopathy. In patients with mutilating RA, no significant difference was noted in the anteroposterior diameter of the cervical spinal canal between patients with cervical myelopathy and those without it. Resorption of the facet joint is the most important factor for the development of cervical myelopathy. In the subaxial cervical spine in those patients with mutilating RA, it is necessary to take special note of the facet joint.

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Impact of interlaminar graft materials on the fusion status in atlantoaxial transarticular screw fixation

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Object. Structural interlaminar graft materials were used for atlantoaxial transarticular screw fixation (TSF), and its impact on the fusion status was investigated.

Methods. Forty-two patients (10 men, 32 women, mean age 51 years, mean follow-up period 45 months; 30 with rheumatoid arthritis, and 12 with os odontoideum) underwent TSF and modified Brooks posterior wiring involving titanium cables. As interlaminar graft materials, autologous bone from posterior iliac crest alone was used in 20 patients (Group A), and a structural spacer (13 ceramic spacers, nine titanium mesh cages) in 22 (Group B). Lateral radiographs were evaluated to determine bone fusion, alignment of the cervical spine, and wire loosening. Solid osseous fusion was obtained in 95% of Group A and 96% of Group B patients. The mean atlantoaxial angle was 19.1 ± 9.7° and 16.7 ± 10.4° before surgery ($p = 0.45$), and 27.4± 7.8° and 22.1 ± 5.5° after surgery ($p = 0.02$) in Groups A and B, respectively. Atlantoaxial hyperlordosis (atlantoaxial angle ≥ 30°) was observed in 32% of Group A and 18% of Group B patients ($p = 0.26$). Postoperative kyphosis occurred in 40% of Group A and 23% of Group B patients ($p = 0.28$). Loosening of the cable was demonstrated in 50% of Group A and 36% of Group B patients ($p = 0.37$). In Group B patients maintenance of cervical lordosis was more likely than in those in Group A, although the differences did not reach statistical significance.

Conclusions. These results indicate that structural interlaminar spacers can maintain proper cervical alignment without a decease in the fusion rate; the authors recommend their use in conjunction with TSF.

Key Words • **interlaminar graft** • **transarticular screw fixation** • **fusion** • **atlas** • **axis**

Atlantoaxial fixation is performed for the treatment of patients with pain and/or spinal cord compression due to atlantoaxial instability caused by RA, os odontoideum, and traumatic injury. Of the many procedures for atlantoaxial fixation that have been devised, TSF, first reported by Magerl, et al.,[7] is currently the most widely conducted therapy.[3,4] In this procedure, screws are inserted into the bilateral atlantoaxial joints, and interlaminar wiring, such as that used in the Brooks method,[2] and AICG placement are conducted between the atlantoaxial laminae. According to a biomechanical study by Naderi, et al.,[9] TSF results favorably in creating stability against rotation and lateral bending, but the combined use of TSF and posterior wiring is biomechanically more robust because posterior wiring provides superior stability against flexion and extension forces than TSF alone.

One of the problems with placing AICGs between the atlantoaxial laminae is the possibility of their collapse during wire tightening when the bone graft is fragile as is often the case in patients with RA, and such collapse may reduce the stability of the joint. When the wire is overtightened, there is a risk that the atlas and axis may be fixed in a hyperextended position. In the clinical setting, cases are often encountered in which the C1–2 laminae are placed in proximity as the wire between the laminae is tightened after TSF, even if the screw is properly inserted. As Toyama, et al.,[12,13] have reported, fixation of the atlas and axis in a hyperextended position may cause postoperative kyphosis in the lower cervical spine.

Another problem with atlantoaxial fixation in procedures combining TSF and Brooks interlaminar wiring is the loosening of cables when the wiring procedure is conducted using titanium cables.[5] A loose cable bulging into the spinal canal could cause cord compression.

To resolve these aforementioned problems, we have developed a procedure involving placement of a structural spacer between the atlantoaxial laminae.[8] The present study was conducted to elucidate whether the insertion of structural grafts between the atlantoaxial laminae would create successful bone union and resolve the various problems associated with combined TSF and posterior wiring.

Abbreviations used in this paper: AAA = atlantoaxial angle; AICG = autologous iliac crest graft; AWGC = apatite–wollastonite glass ceramic; RA = rheumatoid arthritis; TSF = transarticular screw fixation.

Clinical Material and Methods

Patient Population

Forty-two patients underwent combined TSF and Brooks-method posterior interlaminar wiring. The minimum follow-up period was 2 years. There were 10 men and 32 women with a mean age of 51.3 years (range 16–71 years). The mean follow-up period was 45.1 months (range 24–96 months). The causes of atlantoaxial instability were RA in 30 patients and os odontoideum in 12 patients. The clinical symptoms were cervical pain in all patients and cervical myelopathy in 11 of the 30 patients with RA. Myelopathy was absent in all patients with os odontoideum; however, one patient had a history of temporary quadriplegia. Of the 11 patients with myelopathy, pain was characterized as Ranawat Class IIIA in four and Class II in seven.[11] The interlaminar graft material was autologous unicortical bone harvested from the posterior iliac crest in 20 patients (Group A) and a structural graft filled with cancellous bone chips harvested from the ilium in 22 patients (Group B). An AWGC block (Nippon Electric Glass Co., Shiga, Japan) was used in 13 patients until 1998 and, thereafter, a titanium mesh cage (TMC, Moss Titanium Mesh; Dupuy-Acromed, Leeds, UK) was used in nine patients. The AWGC, developed in 1982 by Kokubo, et al.,[6] is a bioactive ceramic that has a good binding capacity with bone and stronger mechanical properties than hydroxyapatite. Posterior wiring, with titanium cables, was conducted using a modified Brooks method in all the patients.

Structural Grafts

Our surgical procedures for TSF combined with posterior wiring has been described.[8] Briefly, after exposure of posterior aspects of C-1 and C-2, guide pins are inserted bilaterally through their lateral masses, as described by Magerl, et al.[7] A double titanium cable (Atlas Cable; Medtronic Sofamor Danek, Memphis, TN) is passed under the C-1 posterior arch and the C-2 lamina and cut into two pieces. A graft site for the placement of the structural graft is meticulously prepared by drilling the lower surface of the posterior C-1 arch and the upper portion of the C-2 lamina with a diamond burr. When a titanium mesh cage is used as a structural graft, an 8- to 10-mm-high cylindrical cage is gently pressed with pliers into an oval shape to fit the interlaminar space between C-1 and C-2. A small amount of cancellous bone is harvested from the posterior iliac crest via a small incision and packed into the cage. The structural graft is gently tapped between the posterior C-1 arch and the C-2 lamina, and the titanium cables are tightened bilaterally and locked temporarily with clamps (Fig. 1). Cannulated cancellous screws (3.5 mm in diameter) are inserted over the guide wires, and the titanium cables are tightened and locked permanently. Finally, cancellous bone chips are placed across the posterior atlantal arch and the axial lamina.

Postoperative Evaluations

The presence or absence of bone union, alignment of the upper and lower cervical regions, and the presence or absence of cable loosening were investigated by assessing plain lateral radiographs obtained in a neutral position.

FIG. 1. Intraoperative photograph of the interlaminar titanium spacer. The titanium mesh cage is packed with autologous cancellous bone chips and gently placed between the C-1 and C-2 laminae.

Bone union was deemed successful when osseous trabecular formation bridged the C1–2 laminae through or around the graft and no motion was observed between the atlas and the axis in flexion or extension. As for loosening of the cable, the rounding index was determined as shown in Fig. 2 *left*; when the rounding index was 0.1 or higher, cable loosening was considered to be present. The AAA and the angle between C-2 and C-7 were measured as shown in Fig. 2 *right*. When the AAA was 30° or greater, atlantoaxial hyperlordosis was considered to be present. The statistical analysis including the unpaired t-test and chi-square test was conducted using the SPSS software (SPSS Japan, Inc., Tokyo, Japan). A probability value less than 0.05 was considered significant. Values are presented as the means ± standard deviations.

Results

Solid bone union was observed in 19 (95%) of the 20 patients in Group A and 21 (96%) of the 22 patients in Group B (Table 1). The mean AAA was 19.1 ± 9.7° and 16.7 ± 10.4° before surgery ($p = 0.45$), and 27.4 ± 7.8° and 22.1 ± 5.5° after surgery ($p = 0.02$) in Groups A and B, respectively. The mean difference between the pre- and

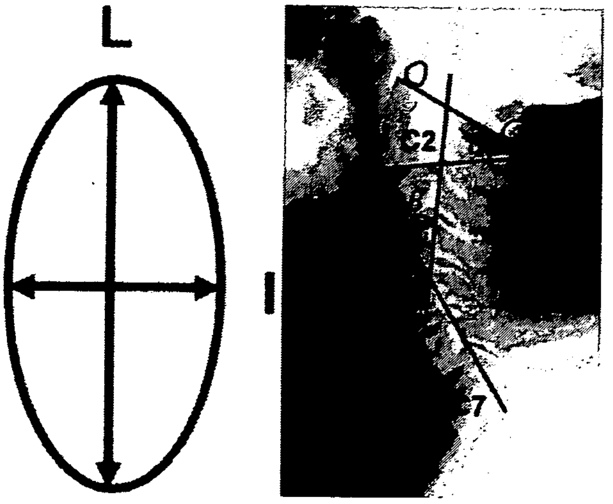

FIG. 2. Schematic diagram and radiograph demonstrating measurement techniques. *Left:* Rounding index = l/L (follow up) − l/L (immediate postoperative), where L is the longitudinal diameter of the oval formed by the titanium cable and l is the anteroposterior diameter of the oval formed by the titanium cable. When the rounding index is 0.1 or higher, cable loosening is considered to be present. Measurement of the index is made on the more loosened cable. *Right:* Representative radiograph. α = AAA, which is formed by the line tangential to the inferior aspects of the C-1 anterior and posterior arches and the line tangential to the inferior aspect of the C-2 vertebral body. β = C2–7 angle, which is formed by the lines tangential to the posterior aspect of the C-2 and C-7 vertebral bodies.

postoperative AAA was 7.5 ± 10.5° in Group A and 5.5 ± 10.4° in Group B (p = 0.55). Atlantoaxial hyperlordosis with an AAA of 30° or more was observed in seven patients (35%) in Group A and four patients (18%) in Group B (p = 0.26). The mean C2–7 angle was 18.1 ± 8.2° and 18.3 ± 10° before surgery, and 12.3 ± 11° and 17.8 ± 13.4° after surgery (p = 0.16), in Groups A and B, respectively. Postoperative kyphosis was demonstrated in eight Group A patients (40%) and five Group B patients (23%) (p = 0.28). Loosening of the cable with a rounding index of 0.1 or higher was observed postoperatively in 10 Group A patients (50%) and eight Group B patients (36%) (p = 0.37). As for structural graft materials, there was no significant difference in these investigated parameters between patients treated with AWGC and those with a titanium mesh cage.

There were no significant intra- or perioperative complications and no complications associated with the graft harvesting in either group. Dislodging of the spacer was not observed in any patients. Sinking of the spacer occurred in three patients, in all of whom there was excessive decortication of the upper portion of C-2 lamina. Neck pain improved in all patients following the surgery. Cervical myelopathy improved in all but one patient.

Discussion

In the present study, the bone union rate associated with structural interlaminar grafts for atlantoaxial fusion was comparable to that achieved using AICGs. The incidence of atlantoaxial fixation in a hyperextended position, postoperative kyphosis of the lower cervical spine, and loosening of cables tended to be lower in those in whom arthrodesis involved structural interlaminar grafts rather than AICGs, although the intergroup differences did not reach statistical significance, except for the postoperative AAA. Thus, the use of a structural interlaminar graft for atlantoaxial fixation yielded a good bone union rate and maintained proper postoperative alignment of the cervical spine, which were equivalent to results achieved using AICGs (Fig. 3). Toyama, et al.,[12,13] noted that the ideal angle for atlantoaxial fixation should be approximately 20°. Nojiri, et al.,[10] also reported that the mean AAA in healthy individuals is approximately 26.5° in men and 28.9° in women. They also reported the existence of a negative correlation between the AAA and alignment of the lower cervical spine—that is, compensatory kyphosis is likely to occur in the lower cervical spine when the postoperative AAA is large or when atlantoaxial fixation is in marked lordosis. The development of such kyphosis should be prevented in patients with RA, because it may othwise lead to the development or exacerbation of subaxial lesions of the cervical spine over the long term.

In a biomechanical study of atlantoaxial fixation, Naderi, et al.,[9] reported that posterior wiring with simulated interspinous bone graft and an oak block significantly enhanced biomechanical stability of the atlantoaxial joint against flexion and extension forces. Thus, the use of a spacer may allow for more biomechanically stable constructs. Another advantage associated with a spacer is the

TABLE 1

*Summary of fusion-related data obtained in 44 patients undergoing atlantoaxial fusion**

Group	Cases	Bone Union (%)	AAA(°)		Postop. AA Hyperlordosis (%)	C2–7 Angle (°)		Postop Kyphosis	Cable Loosening (%)
			Preop	Postop		Preop	Postop		
patient									
A	20	19 (95)	19.1 ± 9.7	27.4 ± 7.8†	7 (35)	18.1 ± 8.2	12.3 ± 11.0	8 (40)	10 (50)
B	22	21 (96)	16.7 ± 10.4	22.1 ± 5.5†	4 (18)	18.3 ± 10.0	17.8 ± 13.4	5 (23)	8 (36)
graft vehicle									
AWGC		12 (92)	19.0 ± 9.9	22.9 ± 4.3	2 (15)	15.8 ± 9.5	15.5 ± 16.1	3 (23)	5 (38)
TMC		9 (100)	13.4 ± 10.9	21.0 ± 7.1	2 (22)	22.0 ± 10.1	21.1 ± 8.0	2 (22)	3 (33)

* AA = atlantoaxial; TMC = titanium mesh cage.
† The postoperative AAA was significantly larger in Group A than in Group B (p < 0.05).

FIG. 3. Radiographs obtained in a 52-year-old woman with atlantoaxial subluxation due to RA. She underwent atlantoaxial arthrodesis involving TSF and placement of an interlaminar titanium mesh cage. *Left:* Preoperative lateral radiograph demonstrating remarkable atlantoaxial subluxation. *Center:* Lateral radiograph obtained 2 years after surgery. Solid bone union was achieved and good alignment of the upper and lower cervical spine was well maintained. *Right:* Open mouth radiograph revealing positioning of the hardware.

possibility of decreasing the incidence of complications and severity of postoperative pain associated with autologous bone grafting; the amount of autologous bone harvested can be minimized[1] and the need for bone harvesting altogether can be eliminated when allograft is available.

Potential problems with a structural graft include dislodging and sinking of the spacer. If the spacer dislodges in the spinal canal, severe neurological complications may occur; however, this was not observed in any of our patients. It is unlikely that the spacer will dislodge because the fabricated construct has excellent initial stability and eventually yields good bone union. Subsidence of the spacer often occurs in cases of interbody fusion; however, it seems uncommon in atlantoaxial fixation, unless excessive laminar decortication is conducted to accommodate the spacer, because the interlaminar space is not a load-bearing site and the lamina surfaces are composed of relatively thick cortical bones. Because the firmness of the spacer may be related to erosion of the cortical bones followed by subsidence of the spacer, surgeons should pay attention to this postoperative phenomenon.

Conclusions

Based on our findings, interlaminar structural grafts can promote an excellent bone union similar to that achieved after placement of AICGs and good maintenance of the postoperative alignment of the cervical spine. Additionally, the amount of autologous bone material harvested can be minimized. Accordingly, interlaminar structural graft–augmented fusion is recommended as a procedure in posterior atlantoaxial fixation.

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Psychologic Management of Brace Therapy for Patients With Idiopathic Scoliosis

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Study Design. A trial of brace therapy modified by a measured personality pattern of patients with idiopathic scoliosis was performed.

Objective. To evaluate the effectiveness of performing personality tests for patients with idiopathic scoliosis who undergo brace therapy.

Summary of Background Data. Brace therapy has often been used for the treatment of scoliosis. However, emotional distress can result from this therapy. Few attempts have been made to reduce such stress.

Methods. A test using the Maudsley Personality Inventory was performed on 145 adolescent females with idiopathic scoliosis, treated with brace therapy alone, before the start of brace therapy and 1 month after the start of brace therapy. On the basis of test results, the patients were rated as normal type and four abnormal types. Brace therapy was continued considering the personality pattern of patients. For all patients, changes in psychologic test results, compliance with braces wearing instructions, and correction of scoliosis were analyzed.

Result. Of the 134 patients rated as normal before the start of therapy, 108 patients were rated as abnormal pattern when tested 1 month after the start of therapy. After performing autogenic training for patients with E−N+ and E−N− personalities, and giving advice to school teachers to decrease the emotional stress for patients with E+N+ personality, 47 patients were finally rated as abnormal pattern. In total, 12 (8%) of the 145 patients dropped out. In dropouts, the average pretreatment deformity of 29° (range: 21°–37°) had increased to an average of 37° (range, 31°–48°).

Conclusion. Psychologic tests may be useful and provide a means of modifying brace therapy tailored to the psychologic conditions of individual patients.

Key words: Maudsley Personality Inventory, underarm brace, Milwaukee brace, psychologic influence. **Spine 2005;30:547–550**

Brace therapy has often been used for the treatment of scoliosis.[1–3] However, emotional stress may result from this therapy.[4–6] Few attempts have been made to reduce this stress. Most patients who wear braces for scoliosis are female adolescents. Brace therapy may cause patients great emotional distress.[7] This type of emotional distress seems to be very important, since it probably shapes the social interaction of the patient. Maudsley Personal Inventory (MPI) provides a means of investigating the personality and reactions of individuals exposed to extrinsic stress. This test has been used in other clinical fields and reported to be valuable.[8,9] At our facility, the MPI has been used when performing brace therapy for patients with scoliosis. The present study was undertaken to evaluate the effects of brace therapy planned on the basis of the results of this psychologic test with the goal of reducing the emotional distress of patients.

Materials and Methods

Maudsley Personality Inventory (MPI). We performed the MPI on patients at our outpatient clinic. The test consists of 80 questions and is aimed at assessing the patient's personality and emotional responses to extrinsic stress. An introversion/extroversion score (E score) and neuroticism score (N score) are calculated from the answers. The normal range for both E and N scores is between 19 and 29. Individuals for whom both the E and N scores are not within the normal range, can be divided into four types: E−N− type (E score < 19, N score < 19), E−N+ type (E score < 19, N score > 29), E+N− type (E score > 29, N score < 19), or E+N+ type (both E and N scores greater than 29). The E−N− type represents a passive, introverted personality with a lack of social interaction. Individuals classified in this type attempt to maintain the stability of self against stress from the external environment by becoming autistic. The E−N+ type exhibits a marked toward of neurosis, and individuals classified in this type are likely to build up tension against external stress and to foster expectation anxiety. They also tend to lack flexibility and to handle matters in certain predictable patterns. The E+N− type represents an adaptive and outgoing personality. Individuals classified in this type can tactfully overcome or handle external stress. However, their behavior is showy and usually lacks consideration for people around them so that they are likely to cause problems in social activities. The E+N+ type represents an active and outgoing personality; however, individuals classified in this type exhibit emotional instability and react violently to external stress. If anxiety over external stress cannot be resolved, they may exhibit hysteric responses. The MPI is often used to assess how subjects respond to external stress.[8,9] It allows classification of response patterns into a normal type and a few abnormal types. Additionally, changes in the response pattern of a particular subject can be evaluated by repeating this test over a period of time. The questions of this test can be understood by adolescents, and it is convenient to answer during waiting for physical examination.

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Table 1. Characteristics of Adolescent Female Patients Undergoing Brace Therapy for Idiopathic Scoliosis

	Patients Performed MPI (N = 145) (n)	Patients Not Performed MPI (N = 150) (n)
Type of brace		
Milwaukee brace	35	45
Underarm brace	110	115
Chronologic age (yr) (average)	11–16 (12.4)	10–16 (12.2)
Bone age (yr) (average)	10–14 (11.4)	10–15 (11.7)
Follow-up periods (average) (yr)	1–6 (3.6)	1–5 (3.2)

MPI = Maudsley Personality Inventory.

Study Participants. The study participants of this study were 145 adolescent females with idiopathic scoliosis who completed treatment using brace therapy alone. The type of brace used was the Milwaukee brace for 35 patients and the underarm brace for 110 patients. The survey period averaged 3 years and 10 months (range, 1–6 years). Cobb's angle at the time of first examination, before the start of brace therapy, averaged 32° (range, 26°–40°). A test using MPI was performed on all subjects before the start of brace therapy and 1 month after the start of brace therapy. On the basis of test results, the patients were rated as normal type, introverted E−N− type, highly anxious E−N+ type, passionate E+N+ type and E+N− type (a type characterized by effort to eliminate stress). Brace therapy was continued without modification for patients rated as normal type or E+N− type. For patients rated as E−N− type or E−N+ type, autogenic training was performed with videotape by psychosomatic medicine specialists, while brace therapy was continued. Autogenic training means a relaxation training and patients learn to relax by focusing on specific parts of their body and autosuggestion. For E+N+ type patients, advice was given to school teachers about the plan for brace therapy in advance, asking them to take necessary care of the patients at school during brace therapy. Emotional stress of patients should be decreased by giving correct information of brace therapy to teachers and students. Patients can continue school life without bullying under a good school environment. All patients underwent the psychologic test again 1 month later, and brace therapy was continued if they were rated as normal type or E+N− type. If they remained E+N+, E−N+, and E−N−, full-time brace therapy was switched to part-time brace therapy. Before brace therapy was started, each patient and her parents were given adequate information about significance and precautions required for therapy. For each treatment plan, the time course of psychologic test results, compliance with brace wearing instructions, correction of scoliosis, and patient satisfaction evaluated using the scale[10] prepared by the Scoliosis Research Society were analyzed. The dropout rate among these patients was compared with the rate for 150 adolescent females (Table 1) with idiopathic scoliosis who had undergone brace therapy before we began to use the MPI for treatment planning.

Statistical Analysis. Nonparametric statistical analysis was performed using the χ^2 test with appropriate degree of freedom. A probability value of less than 0.05 was considered significant. Patients' satisfaction scores were evaluated statistically by analysis of variance with pairwise comparison using Bonferroni method. The strength of association between possible factors and success of brace therapy were examined with univariate logistic regression analysis.

■ Results

Changes in MPI Test Results

In the test conducted using the MPI before the start of brace therapy, only 11 of the 145 patients were rated as abnormal (outside the normal range) (Table 2). It consists of 2 patients wearing Milwaukee brace and 9 patients wearing underarm brace. A total of 134 patients were rated as normal before the start of therapy, and character type was not significantly different between underarm brace group and Milwaukee brace group. Twenty-five patients treated with underarm brace and 1 patient treated with Milwaukee brace were rated as normal when tested 1 month after the start of therapy. The percentages rated as normal decreased significantly in both groups ($P < 0.001$). Only 1 patient treated with Milwaukee brace could preserve normal type after brace therapy. After modifying brace therapy considering personality pattern rated as abnormal (excluding those rated as the E+N− type), brace therapy was continued. As a result, patients were rated as normal type increased significantly in both groups ($P < 0.001$). A total of 47 patients were finally rated as abnormal pattern. The change from abnormal type to normal type occurred more frequently in patients with underarm brace than in patients with the Milwaukee brace.

Dropout From Brace Therapy

The percentage of dropouts from brace therapy was 0% (0of 98) for the normal type, 7% (1 of 15) for E+N− type, 29% (2 of 7) for E−N−type, 10% (1 of 10) for E−N+ type, and 53% (8 of 15) for E+N+ type (Table 3). In total, 12 (8%) of the 145 patients dropped out.

Table 2. Changes of Types in MPI Test

Character Type in MPI	Before Brace Therapy [n (%)]		1 Month After Brace Therapy [n (%)]		2 Months After Brace Therapy [n (%)]	
	UB (110)	MB (35)	UB (110)	MB (35)	UB (110)	MB (35)
Normal	101 (92)	33 (94)	25 (23)	1 (3)	83 (75)	15 (42)
E+N−	3 (3)	1 (3)	21 (19)	4 (11)	13 (12)	2 (6)
E−N−	2 (2)	0 (0)	22 (20)	9 (26)	2 (2)	5 (14)
E−N+	2 (2)	0 (0)	28 (25)	13 (37)	3 (3)	7 (20)
E+N+	2 (2)	1 (3)	14 (13)	8 (23)	9 (5)	6 (17)

MPI = Maudsley Personality Inventory; UB = underarm brace; MB = Milwaukee brace.