● Freiberg テスト

側臥位で股関節を屈曲，内旋すると疼痛が誘発される．

● FAIR 肢位

患者に疼痛側を上にした側臥位をとらせ，股関節に屈曲（flexion），内転（adduction），内旋（internal rotation）の肢位をとらせると痛みが誘発される手技のことである（図 8）．

F．詐病を見分ける検査

1．Hoover テスト

詐病やその他の心因性要因による自覚的下肢痛や坐骨神経痛のために，下肢伸展挙上ができない場合に用いる．仰臥位で下肢伸展挙上を指示する際に，検者の手掌を患者の踵に当てておく．本気で下肢伸展挙上を行う場合は，非挙上側の検者の手掌に踵を押し下げようとする力を感じるが，詐病で挙げていない場合は，押し下げる力を感じない．

2．Flip 徴候

詐病で SLR テスト陽性を装う場合に用いる．患者を診察台の端に座らせ，股関節，膝関節 90° 屈曲位から，検者が下腿を持ち上げ膝関節を伸展するか，患者に膝関節を伸展させる．これは SLR テストと同義であるので本当に下肢放散痛を感じる患者は，この手技でも腰痛，殿部痛，下肢放散痛が誘発され，膝を伸展できず，無理に下腿を持ち上げると上体が後方に倒れるか，これを防ごうとして手を後ろに着く．SLR テストは陽性であっても，この手技で容易に膝を伸展できる場合は詐病や非器質的腰痛が疑われる（図 9）．

（永田見生）

文献

1. Newton DRL. Discussion on the clinical radiological aspects of sacroiliac disease. Proc Roy Soc Med 1957 ; 50 : 850–3.
2. 菊地臣一．腰痛．東京：医学書院；2003. p.144-5, p.158–70.
3. 池田亀夫ほか監修．腰椎・仙椎．図説臨床整形外科講座．東京：メジカルビュー社；1982.
4. 柳　務．森　健躬ほか編．脊椎・脊髄疾患　診断と治療．東京：医歯薬出版；1982. p.21.
5. 岩谷　力．鳥巣岳彦ほか編．標準整形外科．第 9 版．東京：医学書院；2005. p.771–3.

頚椎後縦靱帯骨化症 ossification of the posterior longitudinal ligament in cervical spine

■どんな疾患か

1) 概念と病態

- 脊椎椎体の後面を連結する後縦靱帯の骨化によって，脊髄または神経根の圧迫障害をきたす疾患である．
- 1960年に月本が，本症の剖検例を報告して以来，脊髄症状を惹起する疾患として注目され，1975年から厚生労働省特定疾患研究の対象となっている．
- 成因は不明である．
- 欧米に比べ日本での頻度は高く，日本における一般住民を対象にしたOPLLの疫学調査では30歳以上の一般住民での頻度は1.9～4.3%である．
- 中高年に発症し，頚椎部では約2倍男性に多い．
- 骨化型はその広がりによって，連続型，分節型，混合型，その他型に分類される．

2) 臨床症状と問診のコツ

- 多くの症例では誘因なく発症するが，転倒や頚部外傷などで急性に発症し重篤な脊髄麻痺に陥ることもある．
- 初発症状は頚部痛，上肢のしびれ感，痛みが多い．進行すると下肢のしびれ感，痛み，知覚鈍麻，上下肢の腱反射異常，病的反射が出現し痙性麻痺を呈する．麻痺が高度になれば全横断脊髄麻痺となり膀胱直腸障害も出現する．

図1 頚椎後縦靱帯骨化症の頚椎単純X線側面写真
第2頚椎から第6頚椎にかけて混合型の靱帯骨化（矢印）を認める．

- 脊髄症状は，筆者らの症例では約40%にみられ，骨化靱帯による脊柱管狭窄率が60%を超える症例ではほとんどの症例に脊髄症状がみられている．
- 初診時脊髄症状がない症例では将来脊髄症状が新たに出現する頻度は約20%である．

アドバイス 発症誘因として外傷が関与していないかを聞くことは患者の予後に関係するので重要である．
本症は遺伝的背景が関与しており，患者兄弟の約30%に後縦靱帯骨化が認められるので家族歴も問診で詳しく聞く．

3) 必要な検査と所見

- 単純X線像および断層撮影：多くの場合は，脊椎側面単純写真（図1）によって骨化の存在は確認できるが，靱帯骨化の有無の判定が困難な場合は，頚椎側面断層写真が有用である．
- CT：脊柱管水平断層面における骨化の広がりを確認できる（図2）．最近では三次元CTによる立体的な骨化の広がりも把握できる．
- MR：骨化と脊髄との関係がよく観察でき，骨化による脊髄の圧迫の程度を知るのに有用

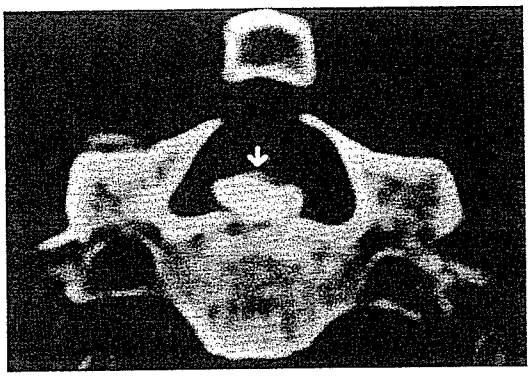

図2　頚椎後縦靱帯骨化症のCT
椎体後面から脊柱管内に突出した後縦靱帯骨化（矢印）を認める．

である．

4）診断のポイント

◎画像による骨化の証明と臨床症状によってなされる．骨化が軽微な場合は無症状のこともあるので，骨化の程度と神経所見の有無の因果関係を慎重にとらえて診断する必要がある．

5）鑑別診断のポイント

◎本症では，頚部や背部の痛み，上下肢のしびれ，痛み，痙性麻痺などがみられるため，頚椎症や脊髄腫瘍，肩関節炎，上肢の絞扼性神経炎などの有痛性疾患や脊髄変性疾患などとの鑑別が必要である．HTLV-1 associated myelopathy（HAM）との鑑別にはHTLV-1感染の有無をチェックする．

■どんな治療をするか

1）治療方針

◎本症は必ずしもすべての症例が脊髄症状を呈するわけではなく，多くの症例では頚部痛や手指のしびれ感のみである．このような症例については保存的治療が第一選択である．

◎神経根症状については，保存的治療での改善が期待できる．

◎大きな靱帯骨化があるにもかかわらず，脊髄症状のみられない症例に対して，外傷を起因として重篤な脊髄麻痺が出現する場合もあり予防的手術を推薦する意見もあるが一般的ではない．

◎すでに脊髄症状を発症した症例については保存的治療に固執すると症状の増悪がみられる場合があるので手術的治療を考慮すべきである．

2）治療法

保存療法

◎本症においては脊髄症状が外傷を契機として出現する場合もあるので，日常生活における頚部の外傷や不良姿勢の防止には留意する必要がある．頚部の等尺性筋力訓練は毎日励行するよう指導する．症状が肩凝りや軽度のしびれのみの場合は特に通院治療は行わず，定期的検診のみを行う．

◎神経根症状に対しては頚椎牽引や温熱療法を薬物治療との併用で実施しているが，頑固なものについては持続的頚部硬膜外注入を行う．

手術療法

◎外科的治療は脊髄麻痺が進行し，痙性歩行や手指の巧緻運動障害の著しいもの，疼痛の激しくみられるもの，脊髄麻痺が進行するものなどに適応される．

◎手術の目的は脊髄の骨化による圧迫をとる除圧手術が行われる．

◎手術方法は前方経路による前方除圧固定術と後方からの椎弓切除術，椎弓形成術の二つに大別される．最近では椎弓形成術が主流である．

3）合併症と予後

◎頚椎後縦靱帯骨化症患者の約60％に胸椎および腰椎の黄色靱帯骨化症を合併するとされており，本症患者の術前には後縦靱帯骨化あるいは黄色靱帯骨化の合併の有無を調べておくことが重要である．

◎後方手術の術後に残存した靱帯骨化が増大することがあるので長期的な経過観察も必要である．

◎脊髄症状に対して手術を行った患者の予後はおおむね良好であり，多くが完全自立した生

活を送っているが，脊髄症状が出現しても手術的治療を施行しなかった患者の予後は不良であり，大部分が病院あるいは介護施設での生活を余儀なくされている．

4) コ・メディカルへ伝えるべきこと

・本症においては，脊髄症状が外傷を契機として出現する場合もあるので，日常生活における頚部の外傷や不良姿勢の防止には留意する必要がある．

・安易に整骨院などで頚椎牽引やマッサージなどを本症の病態を理解せず行うと，脊髄症状を惹起する場合があるので医師の指示下に行うよう指示する．

（松永俊二）

頚椎黄色靱帯石灰化症 calcification of ligamentum flavum in cervical spine

■どんな疾患か

1) 概念と病態

・胸椎や腰椎の黄色靱帯の肥厚や骨化は，よく知られているが頚椎では黄色靱帯の骨化はまれであり，黄色靱帯の石灰化による神経根や脊髄の圧迫によって症状が出現する．

・本症の成因は加齢による靱帯の退行変性，動的ストレス，偽痛風との関連性，内分泌異常などがあげられているが不明である．

・本症は1976年に南光によって最初に報告され，本邦ではすでに多くの報告がなされている．しかし，外国での報告はきわめて少ない．

・黄色靱帯は肥厚しており，石灰化部は腫瘤状あるいは結節状になって脊柱管内に膨隆している．

・石灰化巣の内容は，骨砂様の物質で細顆粒状の結晶が靱帯線維間に沈着している．黄色靱帯も弾力線維数は，減少し断裂などの変性所見が著しい．

・石灰化物質は，hydroxyapatite，calcium pyrophosphate，リン酸カルシウムなどが報告されている．

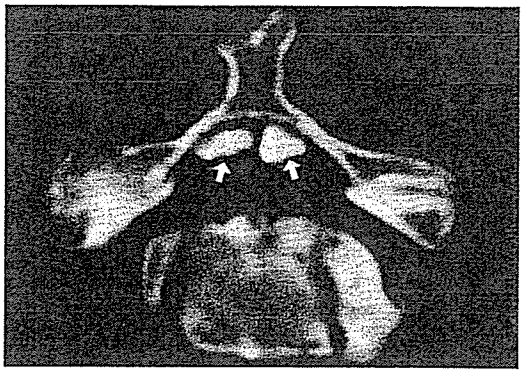

図1 頚椎黄色靱帯石灰化症のCT
椎弓内面から脊柱管内へ膨隆する黄色靱帯の石灰化（矢印）を認める．

・石灰化発生高位は中下位頚椎が多く，第5-6頚椎，第4-5頚椎，第6-7頚椎の順に多い．

・大部分は60歳以上の高齢者にみられ，男女比は1：5と圧倒的に女性に多い．

2) 臨床症状・問診のコツ

・初発症状は，上肢のしびれ感などの知覚異常が多い．

・臨床症状は頚部痛，上肢の知覚異常，痙性麻痺など頚椎症性脊髄症と似ている．

・成因との関係で，偽痛風や内分泌異常との関係が示唆されているので，その点を十分問診する．

3) 必要な検査

・単純X線像および断層撮影：脊椎側面単純写真で，椎弓後方あるいは椎弓間部に小豆大あるいは大豆大の石灰化陰影が確認できるが，疑わしい場合は頚椎断層写真が有用である．

・CT：椎弓腹側から円形あるいは楕円形の脊柱管内に突出する石灰化巣が確認できる（図1）．

・MR：石灰化による脊髄の圧迫の程度を知るのに有用である．

4) 診断のポイント

・臨床症状のみでは特徴的なものがなく，頚椎

症性脊髄症との鑑別は困難である．
- 確定診断にはX線所見が必要である．

5）鑑別診断
- 頸部や背部の痛み，上下肢のしびれ，痛み，痙性麻痺などをきたす，頸椎症や脊髄腫瘍，肩関節炎，上肢の絞扼性神経炎などの有痛性疾患や脊髄変性疾患などとの鑑別が必要である．

■どんな治療をするか

1）治療方針
- X線上石灰化がみられても，脊髄症状や神経根症状のみられない場合は保存的治療を行う．
- 脊髄症状や神経根症状のみられるものは椎弓切除術によって石灰化巣を摘出し除圧を行う．

保存療法
- 日常生活における頸部の外傷や不良姿勢の防止に留意し，頸部痛などの局所症状については，頸部の等尺性筋力訓練を指導し温熱療法や消炎鎮痛剤を併用する．ビスホスフォネート投与によって石灰化が縮小したとする報告もある．

手術療法
- 椎弓切除による石灰化巣の摘出が行われてきたが，最近では，椎弓を温存し石灰化した黄色靱帯の摘出のみを行う椎弓形成術も報告されている．手術成績は概して良好である．

2）合併症と予後
- 合併症と予後頸椎以外にの部位での石灰化がしばしばみられる．特に膝関節半月板に多く，股関節，恥骨結合，肩関節，肘関節にもみられる．後縦靱帯骨化症や黄色靱帯骨化症との合併も少数ではあるが報告されている．手術成績は良好であり予後は良好であるが，腱反射の亢進は術後も残存する傾向がある．

3）コ・メディカルへ伝えるべきこと
- 本症においては脊髄症状が外傷を契機として出現する場合もあるので，日常生活における頸部の外傷や不良姿勢の防止には留意する必要がある．
- 安易に整骨院などで頸椎牽引やマッサージなどを本症の病態を理解せず行うと，脊髄症状を惹起する場合があるので医師の指示下に行うよう指示する．

（松永俊二）

頸椎分離すべり症 cervical spondylolysis with spondylolisthesis

■どんな疾患か

1）概念と病態
- まれな疾患であり，頸椎の後方要素の形成異常に伴い椎体が前方にすべる．頸椎分離症は腰椎でみられる pars interarticularis に相当する上下椎間関節の間の articular “pillar” の欠損として定義されている．
- 発生部位は，これまでの報告では第6頸椎に多い．
- 性差としては男性に多い．
- この先天性の異常と外傷性頸椎すべりや骨折と区別することは重要である．

2）臨床症状・問診のコツ
- 無症状のこともあるが，頸部痛や後頭部痛で発見される場合が多い．肩の痛みや上肢の知覚障害を呈することもある．まれではあるが，脊髄症状を呈したとの報告もある．

3）必要な検査
- 単純X線像および断層撮影：片側あるいは両側の “pillar” 部での分離（図1），二分脊椎（図2），椎間関節の異常な傾斜，上下関節突起の低形成，分離部の反対側の椎弓根の低形成などの所見がみられる．分離部は骨折に比べて辺縁が丸みがあり皮質化している．
- CT：分離の診断に有用である．
- MR：分離すべり症ですべりに伴う脊柱管の狭窄状態を確認する場合には必要である．

4) 診断のポイント

- 臨床症状のみでは，特徴的なものがなく確定診断にはCTが有用である．

5) 鑑別診断

- 外傷性の骨折やすべり，あるいは椎弓根の欠損などの先天性奇形との鑑別が重要である．

どんな治療をするか

1) 治療方針

- 基本的には，保存治療を行い不安定性や頑固な痛みがある場合に例外的に手術的治療を行う．

保存療法

- 頚椎の回旋動作にて症状が増悪する場合があるので，日常生活における頚部の外傷や不良姿勢の防止に留意する．
- 頚部痛などの局所症状については頚椎装具を使用して局所の安静を保ち，温熱療法や消炎鎮痛剤を併用する．

手術療法

- 分離部の固定をしたという報告があるが一般的には手術は行われない．

2) 合併症と予後

- 保存的治療で局所症状は改善し，予後は良好である．

3) コ・メディカルへ伝えるべきこと

- まれな疾患ではあるが，頚部痛などの原因にこのような疾患があることを認識することが重要であり，安易に整体治療などを行わないよう指導する必要がある．

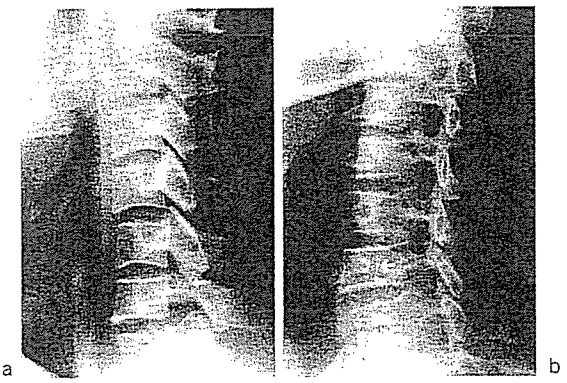

図1　第6頚椎の分離（矢印）を認める（44歳，男性）．
a　側面像，b　斜位像

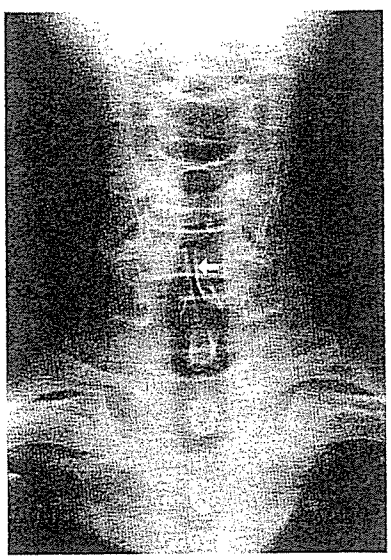

図2　二分脊椎の合併（44歳，男性）

（松永俊二）

Mod Rheumatol (2006) 16:30–35
DOI 10.1007/s10165-005-0453-3

ORIGINAL ARTICLE

Masao Yukioka · Yoshio Komatsubara
Kazuhiko Yukioka · Tomoko Toyosaki-Maeda
Kazuo Yonenobu · Takahiro Ochi

Adrenocorticotropic hormone and dehydroepiandrosterone sulfate levels of rheumatoid arthritis patients treated with glucocorticoids

Received: August 31, 2005 / Accepted: December 21, 2005

Abstract To assess adrenal function with respect to the presence or absence of steroid therapy, we investigated differences in the blood levels of adrenocorticotropic hormone (ACTH) and dehydroepiandrosterone sulfate (DHEAS) in relation to steroid (prednisolone) administration in 123 patients with rheumatoid arthritis (RA). Levels of ACTH and DHEAS were significantly lower in the steroid-treated group than in the non-treated group (ACTH: 11.79 pg/ml vs 27.92 pg/ml) (DHEAS: 418.12 ng/ml vs 883.91 ng/ml) ($P < 0.0001$). We observed no steroid dose-related differences in ACTH levels. However, DHEAS levels showed a slight decrease at a prednisolone dose of 2.5 mg/day, with a significant decrease being observed at a dose of 5 mg/day when statistical adjustments were made for age and sex ($P < 0.0001$). At doses of 7.5 mg/day or greater, DHEAS levels were significantly lower than those for 5 mg/day ($P < 0.0006$). These results suggest that low-dose prednisolone reduces adrenal function in patients with RA. We recommend that doses of prednisolone should be limited to 5 mg/day or less in consideration of adrenal function when treating RA patients. The measurement of ACTH and DHEAS may be useful for evaluating adrenal function in patients with RA.

M. Yukioka (✉) · Y. Komatsubara
Department of Orthopaedic Surgery, Yukioka Hospital, 2-2-3 Ukita, Kita-ku, Osaka 530-0021, Japan
Tel. +81-6-6371-9921; Fax +81-6-6371-4199
e-mail: jimu@yukioka.or.jp

K. Yukioka
Department of Internal Medicine, Yukioka Hospital, Osaka, Japan

K. Yonenobu
Osaka Minami Medical Center, Osaka, Japan

T. Toyosaki-Maeda
Frontier Drug Discovery, Discovery Research Laboratories, Shionogi and Co. Ltd., Osaka, Japan

T. Ochi
Department of Rheumatology National Hospital Organization, Sagamihara National Hospital, Sagamihara, Japan

Key words Adrenocorticotropic hormone (ACTH) · Dehydroepiandrosterone sulfate (DHEAS) · Rheumatoid arthritis (RA) · Steroid administration · Stress

Introduction

Dehydroepiandrosterone (DHEA) and dehydroepiandrosterone sulfate (DHEAS) are secreted by the adrenal cortex and are classified as sex hormones.[1] Dehydroepiandrosterone sulfate levels markedly increase during adolescence, and reach a peak at about 20 years of age, after which they decrease with age. As such, DHEAS may be used as a parameter of aging.[2,3] Previous studies have suggested that DHEAS prevents osteoporosis, cardiovascular disease and arteriosclerosis, and it is becoming increasingly recognized that DHEAS is important for maintaining a healthy state.[4,5] In patients with rheumatoid arthritis (RA), there have been reports of normal, increased, and decreased DHEAS values.[6–9] However, steroids are often administered to these patients, and may decrease the levels of adrenocorticotropic hormone (ACTH) and DHEAS via negative feedback mechanisms.[1] Furthermore, a previous study has reported that blood levels of DHEAS are constant for a long period,[8] but that mental or physical stress and inflammatory responses may influence DHEAS levels via ACTH.[1,10] In this study, we investigated differences in the blood levels of ACTH and DHEAS in subjects on and off of various doses of steroids. In addition, we examined changes in ACTH and DHEAS levels in 14 patients for whom these parameters were measured twice.

Patients and methods

Of 130 RA patients meeting the criteria established by the American College of Rheumatology,[11] for whom levels of ACTH and DHEAS were measured between February 2002 and September 2002, there were 123 patients (137

samples) for whom confirmation of the undertaking and dosages or non-undertaking of prednisolone therapy could be made (patients treated with betamethasone were excluded). In the 14 patients for whom these parameters were measured twice, the values at the second measurement were also evaluated. Subjects were 123 patients (26 males, 97 females) consisting of 19 inpatients and 104 outpatients, with a mean age of 57.24 years (±12.58) at the time of examination. Steroids had been administered to 78 of these patients, the daily prednisolone doses were 2.5 mg in 16 patients, 5 mg in 47 patients, 7.5 mg in 9 patients, and 10 mg in 6 patients (Table 1).

Adrenocorticotropic hormone levels were determined by a one-step IRMA (immunoradiometric assay) method using biotinylated antibodies, and, for B/F (bound/free) isolation, avidin-bound beads were used (Allegro HS-ACTH IRMA kit: Nichols Diagnostics, San Juan Capistrano, CA, USA). Serum DHEAS was determined after serum was allowed to react competitively with I-labeled DHEAS in a DHEAS antibody coated tube (DHEA-S kit: Coat-A Count DHEA-SO_4, Mitsubishi Kagaku Iatron, Tokyo, Japan). In addition, we investigated the correlations of ACTH and DHEAS values with age, erythrocyte sedimentation rate (ESR), matrix metalloproteinase (MMP_3), red blood cell count (RBC), and rheumatoid factor (RF). Blood samples were measured between 08:30 and 11:00 h. Before the measurement of these values, informed consent was obtained from all patients.

Reproducibility of ACTH and DHEAS measurements

Using 3 samples of ACTH with different concentrations, Intra-day ACTH concentrations were evaluated 10 times on 1 day. The coefficients of variation (CV) were 3.8%, 2.4%, and 2.2%. Inter-day ACTH concentrations were evaluated daily over a period of 5 days. The CV were 1.3%, 5.1%, and 3.6%. Using 3 samples of DHEAS with different concentrations, intra-day DHEAS concentrations were evaluated 20 times on 1 day. The CV were 7.2%, 4.7%, and 3.4%. Inter-day DHEAS concentrations were evaluated daily over a period of 10 days. The CV were 10.6%, 4.9%, and 4.2%. These values confirmed the reproducibility of ACTH and DHEAS measurements.

Table 1. Characteristics of 123 rheumatoid arthritis (RA) patients treated with various doses of prednisolone

Steroid dose (mg)	No. of cases	Sex		Age (years)[a]
		Male	Female	
0	45	6	39	54.76 ± 12.37
2.5	26	1	15	61.13 ± 7.91
5	47	11	36	56.45 ± 14.65
7.5	9	5	4	60.33 ± 8.02
10	6	3	3	67.00 ± 3.03
Total	123	26	97	57.24 ± 12.58

[a] Mean ± SD

Statistical analysis

Differences between the ACTH and DHEAS levels of steroid-treated and non-treated RA patients were compared using a Wilcoxon rank sum test. In addition, the effects of steroids on ACTH and DHEAS levels were evaluated by analysis of variance with steroid dosage as a factor, and by analysis of covariance with steroid dosage as a factor and with age and sex as covariates. Prior to the comparison, it was confirmed that there were no correlations between ACTH or DHEAS levels and age, CRP, ESR, MMP_3, RBC, or RF through simple correlation coefficients and partial correlation coefficients. P values of less than 0.05 were considered to be significant.

Results

Differences in ACTH and DHEAS levels related to the steroid administration and dosage

In the steroid-treated group, ACTH and DHEAS levels were lower (Wilcoxon's test, $P < 0.0001$) (Table 2) than the non-treated group. There were no dose-related differences in ACTH levels (Table 3). However, DHEAS levels in the steroid-treated group were lower than in the non-treated group at a prednisolone dose of 2.5 mg/day (Table 4), and significant decreases in DHEAS levels were observed at doses of 5 mg/day ($P < 0.0002$) or greater after adjustments were made for age and sex (Table 4). In addition, at doses of 7.5 mg/day or higher, DHEAS levels were significantly lower than at doses of 5 mg/day ($P < 0.0006$).

Table 2. Adrenocorticotropic hormone (ACTH) and dehydroepiandrosterone sulfate (DHEAS) levels in RA patients on and off steroid treatments

Steroid administration	No. of cases	ACTH (pg/ml)	DHEAS (ng/ml)
No	45	27.92 ± 19.74	883.91 ± 655.23
Yes	78	11.79 ± 10.13	418.12 ± 442.83

Values are mean ± SD
$P < 0.0001$

Table 3. ACTH levels in RA patients according to prednisolone dose

Dose (mg)	No. of cases	Mean (pg/ml) ± SD	P[a]
0	45	27.92 ± 19.74	
2.5	16	13.31 ± 8.50	0.0004*
5	47	11.51 ± 8.47	<0.0001*
7.5	9	7.67 ± 4.56	0.0003*
10	6	16.17 ± 24.70	0.0514

[a] Adjusted for age and sex
* Significant difference compared with 0 mg dose

Table 4. DHEAS levels in RA patients according to prednisolone dose

Dose (mg)	No. of cases	Mean (ng/ml) ± SD	P^a
0	45	883.91 ± 655.23	
2.5	16	443.94 ± 369.54	0.1648
5	47	482.43 ± 503.51	0.0002*
7.5	9	196.11 ± 173.38	0.0002*
10	6	178.50 ± 176.39	0.0271*

[a] Adjusted for age and sex
* Significant difference compared with 0 mg dose

Changes in ACTH and DHEAS levels in 14 patients for whom these parameters were measured twice

In one of the 14 patients, a steroid-free treatment approach was switched to prednisolone therapy at a dose of 5 mg/day. In another patient, the daily steroid dose was increased from 5 to 7.5 mg. In both of these patients, DHEAS levels decreased (Fig. 1). Some of the remaining 12 patients showed changes in ACTH and DHEAS levels, despite the constant steroid dosage (Fig. 2).

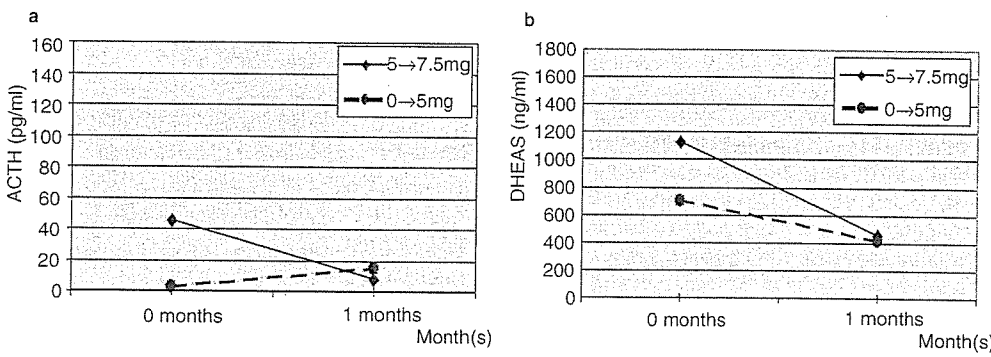

Fig. 1. Changes in adrenocorticotropic hormone (*ACTH*) and dehydroepiandrosterone sulfate (*DHEAS*) levels after increased doses of prednisolone in two patients

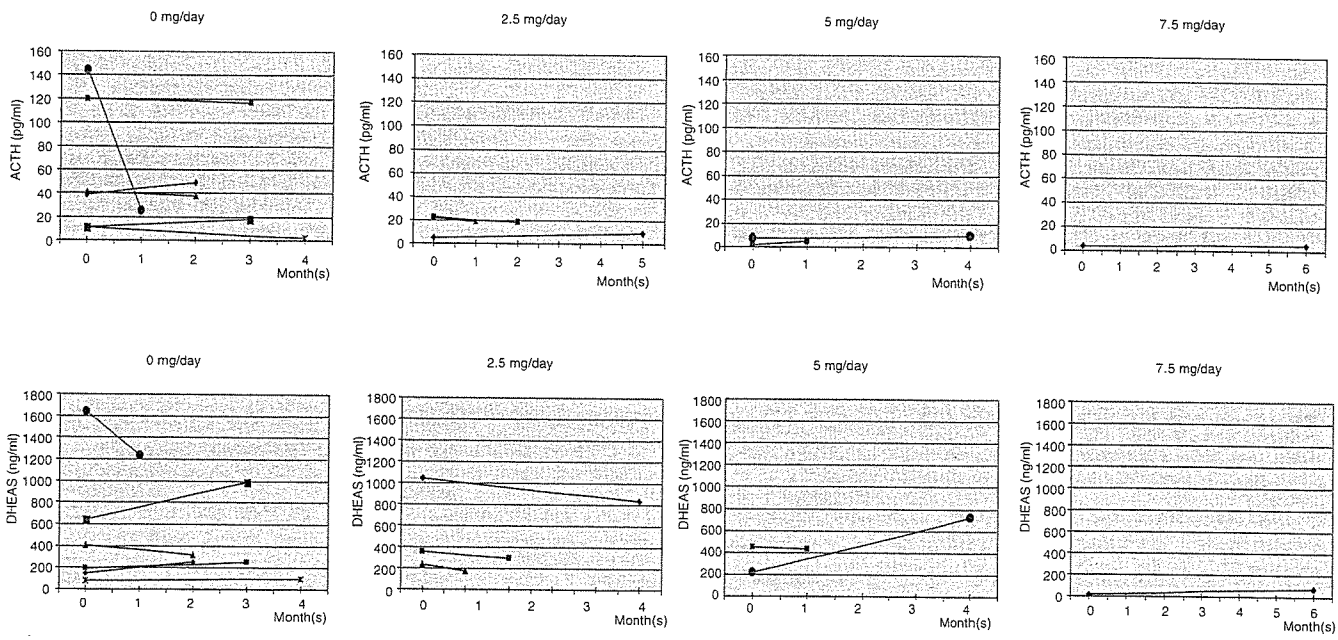

Fig. 2. Changes in adrenocorticotropic hormone (*ACTH*) and dehydroepiandrosterone sulfate (*DHEAS*) levels in patients on fixed doses of steroids

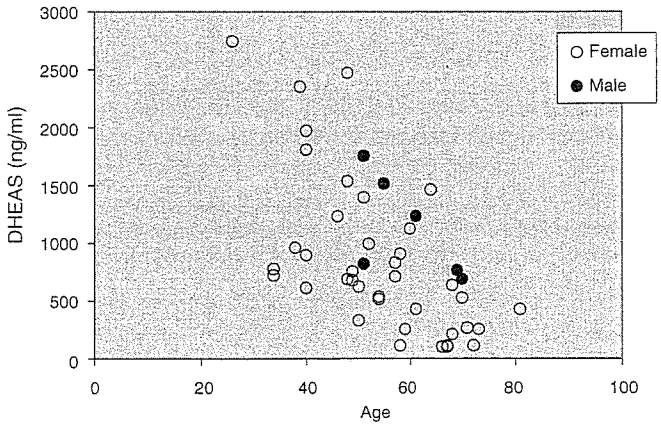

Fig. 3. Dehydroepiandrosterone sulfate (*DHEAS*) levels in rheumatoid arthritis patients without steroid treatment

Correlations of ACTH and DHEAS with age, ESR, CRP, MMP_3, and RBC values

We observed a correlation between ACTH and DHEAS (r = 0.37125). Dehydroepiandrosterone sulfate was negatively correlated with age (r = –0.43464). In addition, CRP values were correlated with ESR (r = 0.50421), RF (r = 0.46516), and MMP_3 (r = 0.39224) (r > 0.3000 or more was extracted).

Discussion

Dehydroepiandrosterone sulfate levels decrease with age,[2,3] and a high blood DHEAS level is related to a long life span.[12] It is also thought that DHEAS may exhibit anti-aging actions. In our patients, DHEAS was negatively correlated with age, supporting that supposition. Furthermore, cortisol and DHEAS are secreted by the adrenal cortex as a result of stimuli from ACTH secreted by the pituitary gland.[1] However, cortisol has a negative feedback mechanism, and blood levels of cortisol show a marked circadian variation.[1,13] In addition, steroids are administered to a high percentage of patients with RA. In comparison to cortisol, DHEAS does not have any negative feedback mechanism, and there may be less marked circadian variations,[1] meaning that the measurement of ACTH and DHEAS levels may be more useful for evaluating adrenal function.

Studies have reported that the blood levels of DHEAS in patients with RA are lower,[6–8] or similar[9] to those of normal controls; however, in the Hall et al.[7] study involving a large number of samples, it was reported that blood levels of DHEAS are lower in patients with RA, and that these levels are further reduced in patients receiving steroids or in those with a history of steroid use. We found that the levels of DHEAS and ACTH were decreased in the group receiving steroid therapy. There were no steroid dose-related differences in ACTH levels. However, DHEAS levels were reduced at a prednisolone dose of 2.5 mg/day, with levels significantly lower at a dose of 5 mg/day, and with further decreases at doses of 7.5 mg/day or higher. We consider a negative feedback mechanism to be involved in steroid therapy-related decreases in the levels of DHEAS and ACTH. While we observed significant differences in levels of DHEAS, there were no significant differences in ACTH levels related to steroid dose, possibly because there was circadian variation in ACTH[1] and because samples were not collected at a specific time point (samples were collected between 08:30 and 11:00 h). Another study has reported that steroid therapy reduces the responsiveness of ACTH to hypoglycemic stress stimuli, although the function of ACTH is maintained.[14] Many of our subjects visited our hospital as outpatients from distant areas by train or bus, which may have influenced ACTH levels as a result of physical activity.[15] In addition, mental stress and increases in interleukin-6 and tumor necrosis factor-α may influence the ACTH level.[1,10] These factors may have contributed to no steroid dose related differences being noted in the ACTH levels, which differed from our results for DHEAS levels.

A previous study has reported that blood DHEAS levels are constant during clinical courses.[8] However, in our study, some of our patients showed changes in ACTH and DHEAS levels, although the steroid dosage was not changed. This may be related to physical or mental stressors, including increased RA activity.[10,16–19] Concerning the relationship between stress and hormones, Nishikaze and colleagues hypothesized that urinary 17-hydroxycorticosteroid (17OHCS mg/g Cr.) and 17-ketosteroid sulfates (17KS-S mg/g Cr.), respectively, reflect the level of stress and recovery ability, and reported that the level of stress and the ability to cope with stress can be assessed by measuring these two urinary hormones.[20–22] Briefly, 17OHCS levels increase in the alarm reaction and resistance phases of Syle's general adaptation syndrome.[23] In the exhaustion phase, the 17OHCS and 17KS-S levels decrease. In the recovery phase, the 17KS-S level increases. We previously reported that the level of stress could be evaluated by measuring urinary levels of 17OHCS and 17KS-S in patients with RA.[24] Urinary 17OHCS is a metabolite of blood cortisol, and 17KS-S is a metabolite of blood DHEA(S).[20] In the presence of ACTH stimulation, cortisol is secreted by the adrenal cortex. We consider that the level of stress in patients with RA and their recovery ability can be evaluated by measuring ACTH and DHEAS levels, and urinary levels of 17OHCS and 17KS-S. Based on Syle's general adaptation syndrome, it is considered that the levels of ACTH and cortisol may increase in the alarm reaction and resistance phases. However, we speculate that when ACTH stimulation shifts to cortisol in these phases, there may be no change or a reduction in DHEAS levels.[9,25] In the exhaustion phase, the adrenal gland function appears to become inhibited, with cortisol and DHEA levels decreasing despite an increase in ACTH levels. In addition, when functional disorders of the hypothalamic-pituitary-adrenocortical (HPA) system occur, the levels of ACTH and DHEAS decrease.[26] Increases in ACTH and decreases in DHEAS were observed in cases of adrenal hypofunction.[1] In this study, as was reported by Hall et al.,[19] DHEAS was not

correlated with ESR or CRP. However, some studies have found correlations between DHEAS and these parameters.[27,28] We speculate that DHEAS levels are increased in patients with marked inflammatory responses, involving ESR and CRP, in the resistance phase described by Syle.[9,10] Thus, the measurement of ACTH and DHEAS may be useful for evaluating HPA system function and stress.

An association between blood levels of DHEAS and osteoporosis has also been suggested,[4,29,30] and it has been suggested that DHEA intake helps prevent osteoporosis.[31–33] On the other hand, it has been reported that prednisolone at doses of more than 5 mg/day may increase the risk of osteoporosis.[34,35] This was supported by the results of our study. In short, DHEAS levels in patients receiving prednisolone at 7.5 mg/day or higher are lower than in those who receive 5 mg/day, thus increasing the risk of osteoporosis.[36] We therefore consider DHEAS may be a possible blood marker of osteoporosis in patients with RA. Dehydroepiandrosterone sulfate levels in the 45 patients not on steroid therapy are presented in Fig. 3. There was a marked variation in DHEAS levels. In patients with decreases in DHEAS, adrenal function may have been reduced. In this group with decreases in the DHEAS levels, adrenal hypofunction may have been associated with the various factors described above. Prior to steroid therapy, adrenal function in patients with RA should be evaluated by measuring blood levels of ACTH and DHEAS.

Acknowledgments Parts of this research were subsidized with a grant from the Japanese Ministry of Health, Labor, and Welfare, and were previously presented at the 2004 ACR annual scientific meeting.[37] We deeply appreciate the support of the Japanese Ministry of Health, Labor, and Welfare.

References

1. Stewart PM. The adrenal cortex: Williams textbook of endocrinology. 10th ed. Philadelphia: Saunders; 2003. p. 491–551.
2. Mobbs CV, Hof PR. Dehydroepiandrosterone and aging. In: Mobbs CV, Hof PR, editors. Functional endocrinology of aging (interdisciplinary topics in gerontology, 29). Basel: Karger; 1998. p. 217–27.
3. Haden ST, Glowacki J, Hurwitz S, Rosen C, LeBoff MS. Effects of age on serum dehydroepiandrosterone sulfate, IGF-I, and IL-6 levels in women. Calcif Tissue Int 2000;66:414–8.
4. Cormier C, Souberbielle JC, Kahan A. DHEA in bone and joint diseases. Joint Bone Spine 2001;68:588–94.
5. Kawano H, Yasue H, Kitagawa A, Hirai N, Yoshida T, Soejima H, et al. Dehydroepiandrosterone Supplementation improves endothelial function and insulin sensitivity in men. J Clin Endocrinol Metab 2003;88(7):3190–5.
6. Deighton CM, Watson MJ, Walker DJ. Sex hormones in postmenopausal HLA-identical rheumatoid arthritis discordant sibling pairs. J Rheumatol 1992;19:1663–7.
7. Hall GM, Perry LA, Spector TD. Depressed levels of dehydroepiandrosterone sulphate in postmenopausal women with rheumatoid arthritis but no relation with axial bone density. Ann Rheum Dis 1993;52:211–4.
8. Kogure T, Fujinaga H, Niizawa A, Shimada Y, Itoh T, Terasawa K. Serum DHEAS level dose not correlate with disease activity in postmenopausal patients with rheumatoid arthritis. Clin Rheumatol 1998;10:245–52.
9. Kanik KS, Chrousos GP, Schumacher HR, Crane ML, Yarboro CH, Wilder RL. Adrenocorticotropin, glucocorticoid, and androgen secretion in patients with new onset synovitis/rheumatoid arthritis: relations with indices of inflammation. J Clin Endocrinol Metab 2000;85:1461–6.
10. Sternberg EM, Chrousos GP, Wilder RL, Gold PW. The stress response and the regulation of inflammatory disease. Ann Intern Med 1992;117:854–66.
11. Arnett FC, Edworthy SM, Bloch DA, McShane DJ, Fries JF, Cooper NS, et al. The American Rheumatism Association 1987 revised criteria for the classification of rheumatoid arthritis. Arthritis Rheum 1988;31:315–24.
12. Lane MA, Ingram DK, Ball SS, Roth GS. Dehydroepiandrosterone sulfate: a biomarker of primate aging slowed by calorie restriction. J Clin Endrocrinol Metab 1997;82:2093–6.
13. Neeck G, Federlin K, Graef V, Rusch D, Schmidt KL. Adrenal secretion of cortisol in patients with rheumatoid arthritis. J. Rheumatol 1990;17:24–9.
14. Kuroki Y, Takabayashi C, Nishiyama K, Shimada T, Shiozawa S, Chihara K, et al. Adrenocorticotropic hormone response to hypoglycemic stress was preserved by a single bedtime 3-mg dose of prednisolone in patients with rheumatoid arthritis. Mod Rheumatol 2004;14:291–5.
15. Soya H. Stress response to exercise and its hypothalamic regulation: possible role of arginine-vasopressin. In: Nose H, Gisolfi CV, Imaizumi K, editors. Exercise, nutrition and environmental stress, Traverse City: Cooper Publishing; 2001. p. 21–37.
16. Wilder RL, Sternberg EM. Neuroendocrine hormonal factors in rheumatoid arthritis and related conditions. Curr Opin Rheumatol 1990;2:436–40.
17. Bateman A, Singh A, Kral T, Solomon S. The immune-hypothalamic-pituitary-adrenal axis. Endocrine Rev 1989;10:92–112.
18. Busbridge NJ, Grossman AB. Stress and the single cytokine: interleukin modulation of the pituitary-adrenal axis. Mol Cell Endocrinol 1991;82:C209–14.
19. Hall J, Morand EF, Medbak S, Zaman M, Perry L, Goulding NJ, et al. Abnormal hypothalamic-pituitary-adrenal axis function in rheumatoid arthritis. Arthritis Rheum 1994;37:1132–7.
20. Nishikaze O, Furuya E. Stress and anticortisols_17-ketosteroid sulfate conjugate as a biomarker in tissue repair and recovery. J UOEH 1998;20(4):273–95.
21. Nishikaza O, Furuya E, Murakami K. Distortion of adaptation (wear and tear and repair and recovery)-17-KS-sulfates and illness susceptibility in humans. Health Tactics 21st Cent 1994;223–7.
22. Nishikaza O, Furuya E, Maezawa M. Distortion of adaptation (wear and tear and repair and recovery)-17-KS-sulfates and psychosocial stress in humans. Health Tactics 21st Cent 1994;335–40.
23. Selye H. History of the stress concept. In: Goldberger L, Breznitz S, editors. Handbook of stress. 2nd ed. New York: Free Press; 1993. p. 7–17.
24. Yukioka M, Komatsubara Y, Shichikawa K, Maeda A, Yukioka K, Furumitsu Y. Measurement of stress levels in RA patients using urinary steroid hormones. Clin Rheumatol 2004;16:301–7.
25. Parker L, Eugene J, Farber D, Lifrak E, Lai M, Juler G. Dissociation of adrenal androgen and cortisol levels in acute stress. Horm Metab Res 1985;17:209–12.
26. Omura M, Nishikawa T, Iizuka T, Kino T, Yoshida A, Saito H, et al. Studies on serum levels of androstenedione, dehydroepiandrosterone and dehydroepiandrosterone sulfate in ageing and in patients with adrenocortical disease. Clin Biochem 1992;645–7.
27. Feher KG, Feher T, Meretey K. Interrelationship between the immunological and steroid hormone parameters in rheumatoid Arthritis. Exp Clin Endocrinol 1986;87:38–42.
28. Mirone L, Altomonte L, D'agostino P, Zoli A, Barini A, Magaro M. A study of serum androgen and cortisol levels in female patients with rheumatoid arthritis. Correlation with disease activity. Clin Rheumatol 1996;15:15–9.
29. Sambrook PN, Eisman JA, Champion GD, Pocock NA. Sex hormone status and osteoporosis in postmenopausal women with rheumatoid arthritis. Arthritis Rheum 1988;31:973–8.
30. Greendale GA, Edelstein S, Barrett-Connor E. Endogenous sex steroids and bone mineral density in older women and men: the Rancho Bernardo study. J Bone Miner Res 1997;12:1833–43.

31. Villareal DT, Holloszy JO, Kohrt WM. Effects of DHEA replacement on bone mineral density and body composition in elderly women and men. Clin Endocrinol 2000;53:561–8.
32. Straub RH, Scholmerich J, Zietz B. Replacement therapy with DHEA plus corticosteroids in patients with chronic inflammatory diseases-substitutes of adrenal and sex hormones. Z Rheumatol 2000;59:108–18.
33. Gordon CM, Grace E, Emans SJ, Goodman E, Crawford MH, Leboff MS. Changes in bone turnover markers and menstrual function after short-term oral DHEA in young women with anorexia nervosa. J Bone Miner Res 1999;14:136–45.
34. Nawata H, Soen S, Takayanagi R, Tanaka I, Takaoka K, Fukunaga M, et al. Guideline on the management and treatment of glucocorticoid-induced osteoporosis of the Japanese Society for Bone and Mineral Research (2004). J Bone Miner Metab 2005;23: 105–9.
35. Michel BA, Bloch DA, Wolfe F., Fries JF. Fractures in rheumatoid arthritis: an evaluation of associated risk factors. J Rheumatol 1993;20:1666–9.
36. Van Staa TP, Leufkens HGM, Cooper C. The epidemiology of corticosteroid-induced osteoporosis: a meta-analysis. Osteoporos Int 2002;13:777–87.
37. Yukioka M, Komatsubara Y, Furumitsu Y, Yukioka K, Morris SJ, Ochi T. Variations in ACTH and DHEA(S) levels of RA patients after steroid administration. Arthritis Rheum 2004;50: 342.

Mod Rheumatol (2006) 16:289–293
DOI 10.1007/s10165-006-0499-x

ORIGINAL ARTICLE

Shunichi Henmi · Kazuo Yonenobu · Takashi Masatomi
Kunihiko Oda

A biomechanical study of activities of daily living using neck and upper limbs with an optical three-dimensional motion analysis system

Received: March 1, 2006 / Accepted: June 5, 2006

Abstract In activities of daily living such as eating meals, the neck and upper limbs move in coordination. However, no methods have been established to analytically and quantitatively capture motion of the neck and limbs during these activities. We used a Vicon 512 system to simultaneously measure ranges of motion (ROMs) for the cervical spine, shoulders, elbows, and forearms. Correlations between the motion analyzer and the universal goniometer were >0.76. Repeatability of measurements using this analyzer were ≤3° for all values. This system is thus highly accurate and can be useful for motion analysis of the neck and upper limbs. The sum of flexion angles for the cervical spine, shoulders and elbows were almost constant for each activity, at 261° for shampooing, 207° for washing the face, and 185° for eating a meal.

Key words Daily activity · Neck movement · Three-dimensional (3D) motion analysis · Upper limb movement · Vicon

Introduction

In activities of daily living that use the upper extremities, such as eating meals, washing the face, and shampooing, the neck and upper limbs move in coordination. Conversely, if part of this coordinated system is impaired, compensatory movement of the other components will be indispensable for accomplishing activities. However, disability of the upper limb and neck is evaluated by functional assessment, mainly by measuring range of motion (ROMs) for each joint and assessing typical activities of daily living using a questionnaire. Data obtained using these methods are therefore subjective, static and nonanalytical.

With recent rapid advances in computer technology, motion analysis using optical three-dimensional (3D) motion analyzers has become more sophisticated and has seen application in various fields including gait analysis, computer graphics, and computer game animation.[1–4] To the best of our knowledge, no previous reports have examined systems evaluating combined motion of the neck and upper limbs.[5–7] This kind of technology would seem applicable to quantitative analysis of motions of the neck and upper limbs. The purpose of the present study was thus to assess the reliability of using a motion analyzer and to analyze the neck and upper limb motion during activities of daily living in a healthy volunteer. Analysis of neck and upper limb motion during activity would help in the formation of reconstruction plans appropriate for the individual condition of patients with joint deterioration.

Material and methods

System overview

The Vicon 512 system (Vicon Peaks, CA, USA) was used as an optical 3D motion analyzer. This system was placed in the rehabilitation room of our institution. Markers comprising inflated light-reflective plastic balls (diameter, 25 mm) were attached to the skin of the subject. Marker motions were tracked and captured on charge-coupled device (CCD) cameras, and visualized on a computer display. Based on these data, each joint motion was calculated automatically on a Vicon 4.5 workstation.[8]

Individual markers were placed at 23 points as designated by the manufacturer (Fig. 1 and Table 1): head, 4

S. Henmi[1] (✉) · K. Yonenobu
Department of Orthopaedic Surgery, National Hospital Organization Osaka Minami Medical Center, Kawachinagano, Japan

T. Masatomi
Department of Orthopaedic Surgery, Osaka Kosei-Nenkin Hospital, Fukushima-ku, Osaka, Japan

K. Oda
Osaka-Isen Instructional Department, Kita-ku, Osaka, Japan

Present address:
[1]Department of Orthopaedic Surgery, Ikeda Municipal Hospital, 3-1-18 Johnan, Ikeda 563-8510, Japan
Tel. +81-72-751-2881; Fax +81-72-754-6374
e-mail: syunichi-henmi@hosp.ikeda.osaka.jp

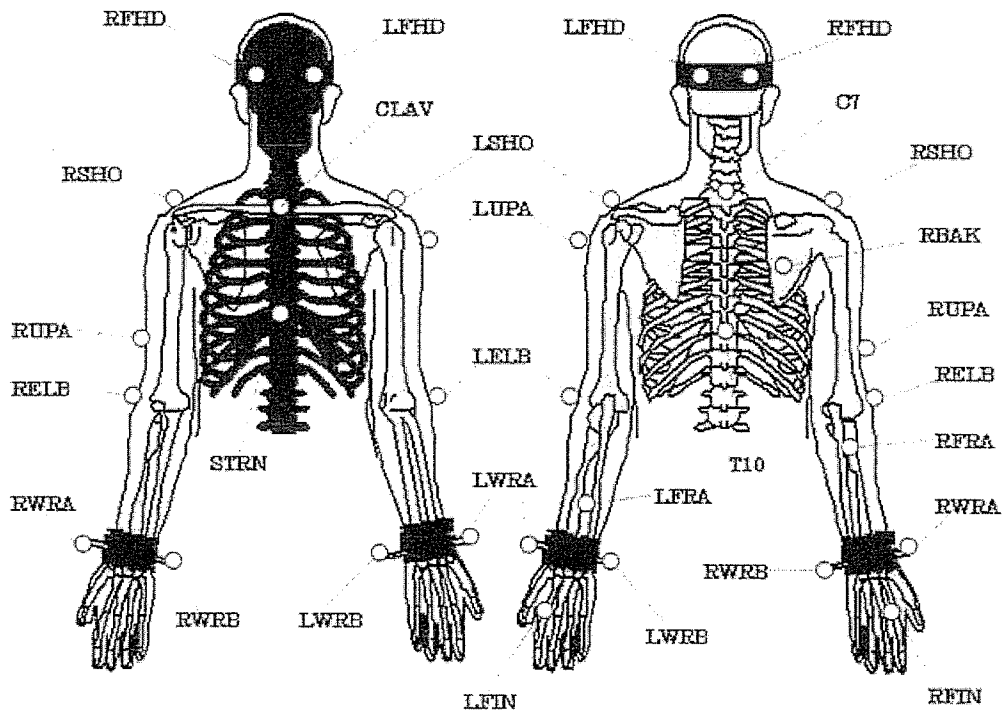

Fig. 1. Marker arrangement designated by Vicon. *Abbreviations*: see Table 1

Table 1. Marker configuration defined by Vicon

Marker name	Definition
LFHD	Left front head
RFHD	Right front head
LBHD	Left back head
RBHD	Right back head
C7	7th cervical vertebrae
T10	10th thoracic vertebrae
CLAV	Clavicle
STRN	Sternum
RBAK	Right back
LSHO	Left shoulder marker
LUPA	Left upper arm marker
LELB	Left elbow
LFRA	Left forearm marker
LWRA	Left wrist marker A
LWRB	Left wrist marker B
LFIN	Left fingers
RSHO	Right shoulder marker
RUPA	Right upper arm marker
RELB	Right elbow
RFRA	Right forearm marker
RWRA	Right wrist marker A
RWRB	Right wrist marker A
RFIN	Right fingers

markers; trunk, 5 markers; and each upper limb, 7 markers. As markers were light and did not require a power or light source such as a light-emitting diode, subjects were able to move naturally. Six CCD cameras were placed around each subject, with four cameras placed at a height of 3 m, and the remaining two cameras placed at a height of 1 m to capture the front of the thoracic region (Fig. 2). Sampling frequency of the cameras was 60 Hz.

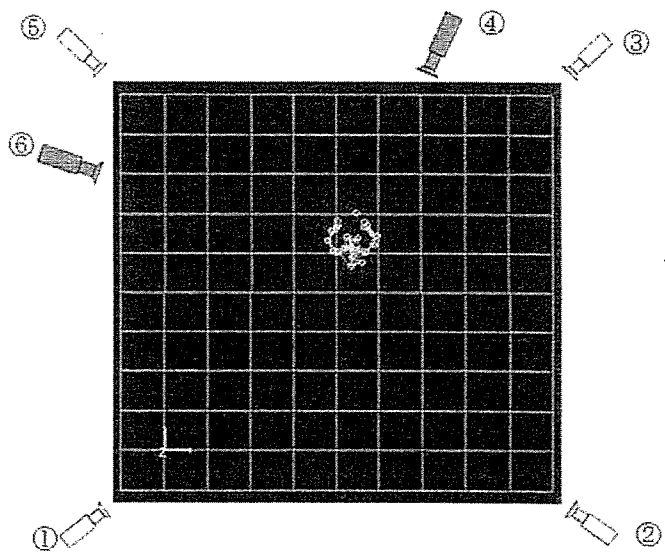

Fig. 2. Top view of set-up for this study

Evaluation of accuracy

Performance and accuracy of the Vicon 512 system has been confirmed previously.[9,10] However, in clinical trial, while moving skin markers during various motions a deterioration in the accuracy can occur. Therefore, the first part of the study assessed the accuracy of the motion analyzer on neck and upper limb motions in a clinical setting.

Subjects comprised five healthy volunteers (3 women, 2 men). Mean subject age was 23 years (range, 20–28 years). Ranges of motion examined were cervical spine flexion and

extension, shoulder flexion, elbow flexion and extension, and forearm pronation and supination. The following two examinations were performed. First, maximum ROMs were examined by comparing angles calculated using the analyzer with those measured using a conventional universal goniometer (Minato Medical Science, Osaka, Japan). In the analysis of differences between two methods the correlation coefficient was used and P values were adjusted with Pearson's correlation coefficient test. The level of significance was set at a P value of 0.05 or less. Next, the error of this system consisted of standard deviations of calculated maximum ROMs by repeating all measurements three times. Makers were reapplied between each measurement. Repeatability in measurements of ROMs were examined by comparing the error of the analyzer with those of the conventional universal goniometer.

Analysis of motions in activities of daily living

Three motions were studied using the same five volunteers participated in the evaluation of accuracy: eating a meal, washing the face, and shampooing. The motions were not actually performed, but were acted out. Points of maximum angle in cervical spine flexion, shoulder flexion, and elbow flexion were measured during these activities, and relationships between each maximum angle were then analyzed.

Results

Maximum angle of each joint measured by the motion analyzer and universal goniometer are summarized in Table 2. The correlation coefficient was >0.76 for all values (range, 0.76–0.94). Correlation between the motion analyzer and universal goniometer was very high for cervical flexion (0.90), shoulder flexion (0.94), and elbow flexion (0.91). P values with Pearson's correlation coefficient test were less than 0.05 at all angles.

Error of measurements using the analyzer was examined by looking at differences in three repeated measurements (Table 3). Standard deviations of values were ≤3° for all values (range, 0.78–2.56°). Repeatability was very high for shoulder flexion (0.78°) and elbow extension (0.89°).

The system was next used to analyze motions for shampooing, washing the face, and eating a meal. Figure 3 shows the motion analysis for shampooing in a healthy volunteer (Case 1). When shampooing, the neck and upper limbs move in coordination, not separately. In Case 1, shampooing required 39° of flexion for the cervical spine, 61° of flexion for the shoulder, and 135° of flexion for the elbow. Maximum angles of flexion measured during these activities for the cervical spine, shoulder, and elbow are shown in Table 4. Maximum angle of flexion for each joint was almost constant for the three activities. The elbow required maximum elbow flexion for all activities, at 151° for shampooing, 140° for washing the face, and 146° for eating a meal. Conversely, the angle of flexion for the cervical spine varied for different activities, at 46° for shampooing, 16° for washing the face, and −8° for eating a meal. As maximum flexion angle for each joint was almost constant for these three activities, the sum of cervical spine, shoulder, and elbow flexions was defined as the total flexion angle (Table 5). Total flexion angle was almost constant for the three activi-

Table 2. Correlation between maximum angle of each joint measured using the Vicon 512 system and the universal goniometer

	Motion analyzer	Goniometer	γ
Cervical			
Flexion	47	50	0.90
Extension	64	56	0.89
Shoulder			
Flexion	161	160	0.94
Elbow			
Flexion	175	161	0.91
Extension	6	6	0.83
Forearm			
Pronation	75	76	0.76
Supination	100	93	0.78

γ, correlation coefficient

Table 3. Mean and standard deviations of maximum ranges of motion using the motion analyzer for three repeated measurements

		Mean	SD
Cervical	Flexion	47	2.03
	Extension	64	2.56
Shoulder	Flexion	161	0.78
Elbow	Flexion	175	1.81
	Extension	6	0.89
Forearm	Pronation	75	2.35
	Supination	100	2.12

Table 4. Maximum flexion angle measured during shampooing, washing the face and eating a meal for the cervical spine, shoulder and elbow flexion

	Shampooing	Washing the face	Taking a meal
Cervical			
Flexion	46 ± 10	16 ± 7	−8 ± 13
Shoulder			
Flexion	64 ± 9	50 ± 7	43 ± 6
Elbow			
Flexion	151 ± 9	140 ± 5	146 ± 5

Numbers are shown in degrees

Table 5. Sum of cervical spine, shoulder and elbow flexion (defined as total flexion angle) for shampooing, washing the face and eating a meal

Case	Shampooing	Washing the face	Taking a meal
1	244	215	195
2	288	209	186
3	242	202	181
4	264	199	172
5	264	209	194
Total flexion angle	261 ± 18	207 ± 8	185 ± 10

Numbers are shown in degrees

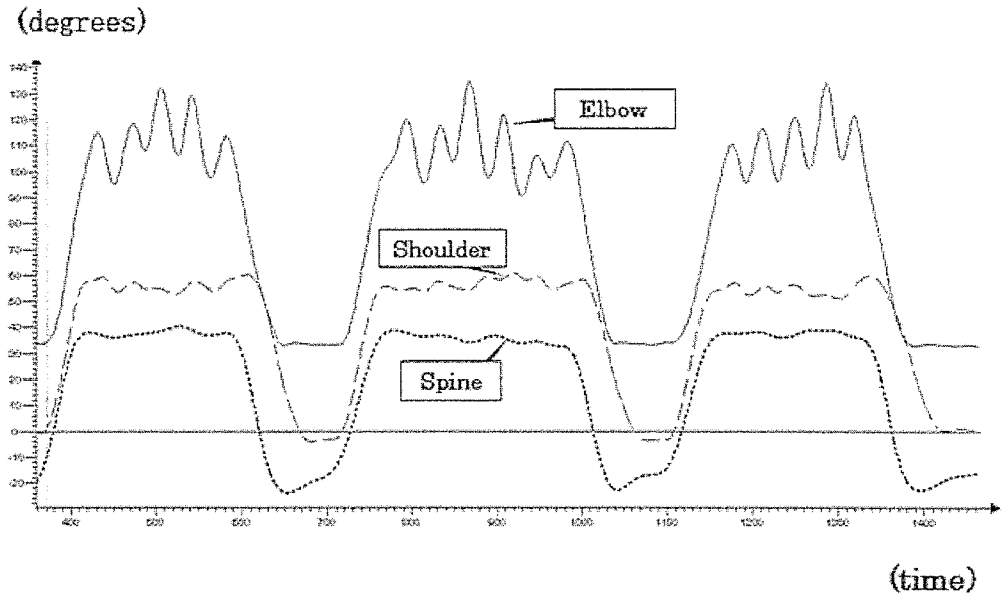

Fig. 3. Joint angles at cervical spine and upper limbs for shampooing in a healthy volunteer (Case 1)

ties, at 261° for shampooing, 207° for washing the face, and 185° for eating.

Discussion

Range of motion is typically evaluated using the universal goniometer. This method is simple, but large interexaminer differences can occur and simultaneous evaluation of multiple joints is not possible. While electrogoniometers are able to measure ROMs for multiple joints simultaneously, accuracy is considered low because of the bulkiness of the equipment.[11–13]

Electromagnetic motion analysis and optical 3D motion analysis systems are used for measurement of ROMs for multiple joints simultaneously. Both systems use markers for taking measurements and are highly accurate.[9,10] However, when markers are placed on the skin, accuracy may suffer because of skin motion.[2,5,14–20] In addition, the electromagnetic motion analysis system has a limited measuring area and metal can distort the magnetic field, while optical 3D motion analysis allows measurement of a wide area, but markers are sometimes measured incorrectly.

Accuracy of the Vicon 512 system has been evaluated using a gait analysis, revealing a high degree of accuracy.[9,10] As this system has not previously been used to evaluate movement of the neck and upper limbs, we assessed the accuracy of the system for movements of the neck and upper limbs. Error in measurements of ROMs for the neck and upper limbs using a universal goniometer have been reported in several studies.[21–26] A goniometric error at the elbow of 2.4°–3.4° was reported by Fish and Windgate.[21] In the present study, repeatability of the analyzer was examined by looking at differences over three repeated measurements. Standard deviation of the values was between 0.78° and 2.56°, almost equal to the standard deviation of measurements using a conventional goniometer. Next, maximum ROMs were examined by comparing angles calculated using this analyzer with those measured using a conventional goniometer. Correlation coefficient between the analyzer and goniometer was examined. Generally, a correlation coefficient >0.9 is very high, while <0.69 is considered low.[27] In this study, correlation coefficient between the analyzer and goniometer was >0.69 for all values. Maximum ROMs examined using this analyzer and the goniometer were closely correlated. The Vicon 3D motion analysis system thus appears useful for evaluating motion of the neck and upper limbs.

In activities of daily living that use the upper extremities, such as shampooing, washing the face, and eating, the neck and upper limbs move in a coordinated manner. Flexion angle for the shoulder and elbow in the three activities is almost constant, with the elbow requiring a maximum flexion angle for all activities. On the other hand, flexion angle for the cervical spine varies with different activities. The necessary angle of flexion for each activity varies for each joint. As the maximum angle of flexion for each joint was almost constant for each activity, the sum of the cervical spine, shoulder, and elbow flexion, defined as total flexion angle, was almost constant for the three activities, at 261° for shampooing, 207° for washing the face, and 185° for eating. The total flexion angle is suspected of having a minimum cumulative flexion angle to achieve the three activities. In this study shoulder abduction, rotation of forearm, and wrist flexion were not assessed, as the maximum angle varies over time. As these motions have a close relation to each activity, we intend to evaluate them in future.

For patients with multiple joint deterioration as in rheumatoid arthritis, surgical reconstruction is performed according to evaluation of each lesion, and this sometimes results in unsatisfactory improvements of disability. One reason for this is that the neck, shoulder, elbow, forearm, and wrist are not recognized as interrelated functional units. Analysis of impairments of neck and upper limb lesions in multiple arthropathies as changes in functional units

would enable us to determine appropriate multiple joint reconstruction plans to achieve maximum improvement in activities.

References

1. Alexander EJ, Andriacchi TP. Correcting for deformation in skin-based marker systems. J Biomech 2001;34:355–61.
2. Reinschmidt C, van Den Bogert AJ, Murphy N, Lundberg A, Nigg BM. Tibiocalcaneal motion during running, measured with external and bone markers. Clin Biomech (Bristol, Avon) 1997;12: 8–16.
3. Hagio K, Sugano N, Nishii T, Miki H, Otake Y, Hattori A, et al. A novel system of four-dimensional motion analysis after total hip arthroplasty. J Orthoped Res 2004:22:665–70.
4. Chiu HY, Lin SC, Su FC, Wang ST, Hsu HY. The use of the motion analysis system for evaluation of loss of movement in the finger. J Hand Surg 2000:25B:195–9.
5. Yang N, Zhang M, Huang C, Jin D. Synergic analysis of upper limbs target- reaching movements. J Biomech 2002;35:739–46.
6. Yang N, Zhang M, Huang C, Jin D. Motion quality evaluation of upper limb target-reaching movements. Med Eng Phys 2002;24: 115–20.
7. Rab G, Petuskey K, Bagley A. A method for determination of upper extremity kinematics. Gait Posture 2002;15:113–9.
8. Vicon Clinical Manager User's Manual.
9. Ehara Y, Fujimoto H, Miyazaki S, Mochimaru M, Tanaka S, Yamamoto S. Comparison of the performance of 3D camera systems. Gait and Posture 1997:5:251–5.
10. Ehara Y, Fujimoto H, Miyazaki S, Tanaka S, Yamamoto S. Comparison of the performance of 3D camera systems. Gait Posture 1995;3:166–9.
11. Morrey BF, Askew LJ, An KN, Chao EY. A biomechanical study of normal function elbow motion. J Bone Joint Surg [A] 1981;3:872–7.
12. Chao EY, An KN, Askew LJ, Morrey BF. Electrogoniometer for the measurement of human elbow joint rotation. J Biomech Eng 1980;102:301–10.
13. Morrey BF, Chao EY. Passive motion of the elbow joint. A biomechanical analysis. J Bone Joint Surg [A] 1976;58:501–8.
14. Cappozzo A, Catani F, Leardini A, Benedetti MG, Croce UD. Position and orientation in space of bones during movement: experimental artifacts. Clin Biomech (Bristol, Avon) 1996;11:90–100.
15. Cappozzo A, Cappello A, Della Croce U, Pensalfini F. Surface-marker cluster design criteria for 3-D bone movement reconstruction. IEEE Trans Biomed Eng 1997;44:1165–74.
16. Andriacchi TP, Alexander EJ, Toney MK, Dyrby C, Sum J. A points cluster method for in vivo motion analysis: applied to a study of knee kinematics. J Biomech Eng 1998;120:743–9.
17. Lucchetti L, Cappozzo A, Cappello A, Della CU. Skin movement artifact assessment and compensation in the estimation of knee-joint kinematics. J Biomech 1998;31:977–84.
18. Lu TW, O'Connor JJ. Bone position estimation from skin marker co-ordinates using global optimisation with joint constraints. J Biomech 1999;32:129–34.
19. Spoor CW, Veldpaus FE. Rigid body motion calculated from spatial co-ordinates of markers. J Biomech 1980;13:391–3.
20. Reinschmidt C, van Den Bogert AJ, Murphy N, Lundberg A, Nigg BM. Tibiocalcaneal motion during running, measured with external and bone marker. Clin Biomech (Bristol, Avon) 1997;12: 8–16.
21. Fish DR, Wingate L. Sources of goniometric error at the elbow. Phys Ther 1985;65:1666–70.
22. Low JL. The reliability of joint measurement. Physiology 1976:62:227–9.
23. Rothstein JM, Miller PJ, Roettger RF. Goniometric reliability in a clinical setting. Elbow and knee measurements. Phys Ther 1983:63:1611–5.
24. Grohmann JE. Comparison of two methods of goniometry. Phys Ther 1983;63:922–5.
25. Boone DC, Azen SP, Lin CM, Spence C, Baron C, Lee L. Reliability of goniometric measurements. Phys Ther 1978;58:1355–90.
26. Youdas JW, Carey JR, Gareett TR. Reliability of measurements of cervical spine range of motion–comparison of three methods. Phys Ther 1991;71(2):98–104.
27. Norkin CC, White DJ. Measurement of joint motion. A guide to goniometry. 2nd ed. Philadelphia: Davis; 1995.

SPINE Volume 31, Number 12, pp 1332–1337

Open-Door Laminoplasty for Cervical Myelopathy Resulting From Adjacent-Segment Disease in Patients With Previous Anterior Cervical Decompression and Fusion

Morio Matsumoto, MD,* Kenya Nojiri, MD,† Kazuhiro Chiba, MD,† Yoshiaki Toyama, MD,† Yasuyuki Fukui, MD,‡ and Michihiro Kamata, MD§

Study Design. This is a retrospective study of patients with cervical myelopathy resulting from adjacent-segment disease who were treated by open-door expansive laminoplasty.

Objectives. The purpose of this study was to evaluate the effectiveness of laminoplasty for cervical myelopathy resulting from adjacent-segment disease.

Summary of Background Data. Adjacent-segment disease is one of the problems associated with anterior cervical decompression and fusion. However, the optimal surgical management strategy is still controversial.

Methods. Thirty-one patients who underwent open-door expansive laminoplasty for cervical myelopathy resulting from adjacent-segment disease and age- and sex-matched 31 patients with myelopathy who underwent laminoplasty as the initial surgery were enrolled in the study. The pre- and postoperative Japanese Orthopedic Association scores (JOA scores) and the recovery rate were compared between the two groups.

Results. The average JOA scores in the patients with adjacent-segment disease and the controls were 9.2 ± 2.6 and 9.4 ± 2.3 before the expansive laminoplasty and 11.9 ± 2.8 and 13.3 ± 1.7 at the follow-up examination, respectively; the average recovery rates in the two groups were 37.1 ± 22.4% and 50.0 ± 21.3%, respectively (P = 0.04). The mean number of segments covered by the high-intensity lesions on the T2-weighted magnetic resonance images was 1.87 and 0.9, respectively (P = 0.001).

Conclusions. Moderate neurologic recovery was obtained after open-door laminoplasty in patients with cervical myelopathy resulting from adjacent-segment disc disease, although the results were not as satisfactory as those in the control group. This may be attributed to the irreversible damage of the spinal cord caused by persistent compression at the adjacent segments.

Key words: open-door expansive laminoplasty, adjacent-segment disease, cervical myelopathy, anterior cervical decompression and fusion. **Spine 2006;31:1332–1337**

From the Departments of *Uniden Musculoskeletal Reconstruction and Regeneration Surgery and †Orthopaedic Surgery, School of Medicine, Keio University, Tokyo, Japan; the ‡Department of Orthopaedic Surgery, Mita Hospital, International University of Health and Welfare, Tokyo, Japan; and the §Department of Orthopaedic Surgery, Keiyu Hospital, Yokohama, Japan.

Acknowledgment date: January 26, 2005. First revision date: April 1, 2005. Second revision date: April 14, 2005. Third revision date: August 2, 2005. Acceptance date: August 2, 2005.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

Address correspondence and reprint requests to Morio Matsumoto, MD, Department of Uniden Musculoskeletal Reconstruction and Regeneration Surgery, School of Medicine, Keio University, 35 Shinanomachi, Shinjuku-ku, Tokyo, 160-8582, Japan; E-mail: morio@sc.itc.keio.ac.jp

Anterior cervical decompression and fusion (ACDF) is an effective and widely used surgical procedure for degenerative diseases or trauma of the cervical spine. The short-term surgical outcome of this procedure has been reported to be satisfactory in a majority of the patients. However, degeneration of the intervertebral discs adjacent to the fused segments could be accelerated after ACDF, causing symptoms such as neck pain, radiculopathy, and myelopathy.[1–6] Hilbrand *et al*[5] reported the results of a long-term follow-up study conducted on 374 consecutive patients who underwent anterior cervical arthrodesis for cervical spondylosis with radiculopathy, myelopathy, or both. They found that symptomatic adjacent-segment disease occurred at a relatively constant incidence of 2.9% per year during the 10 years after the operation, and that symptomatic adjacent-segment disease affected more than one fourth of all the patients within 10 years after anterior cervical arthrodesis. Ishihara *et al*[6] reported the development of symptomatic adjacent-segment disease in 19 of 112 patients (19%). Thus, much effort has been directed toward preventing adjacent-segment disease, including that which led to the recent development of artificial cervical discs.[7]

Among the various manifestations of adjacent-segment disease, cervical myelopathy is one of the most problematic, and the optimal management strategy for this complication remains controversial. Repeated fusion surgery may be effective but can result in further adjacent-segment lesions and, according to Hilibrand *et al*,[8] achieving fusion is more difficult when anterior cervical arthrodesis is performed for segments adjacent to a prior fusion. Moreover, scars in the anterior neck involving the esophagus and internal carotid artery and vein make a repeated anterior approach to the cervical spine hazardous and complicated.[9] Therefore, a posterior approach would seem to be more reasonable for dealing with cervical myelopathy resulting from adjacent-segment disease.

Open-door expansive laminoplasty (ELAP) developed by Hirabayashi *et al*[10] is believed to expand the whole cervical spinal canal and to spare but restrain intersegmental motion of the cervical spine. This surgical method has been widely used for the treatment of cervical compression myelopathy caused by spondylosis, soft disc herniation, and ossification of the posterior longitudinal ligament.[11–13] The advantages and disadvantages of the treatment of cervical compression myelopathy in patients without previous surgery have been frequently

Table 1. Demographics of Patients

Group	Group A	Group B
Age (years) (range)	60 (39–83)	58 (42–77)
Gender		
Male	26	26
Female	5	5
Interval between ACDD and ELAP (range)	12 y 3 m (1 y 4 m to 36 y 11 m)	—
No. of fused levels		
Single	12	
Two	14	—
Three	5	

ACDF indicates anterior cervical decompression and fusion; ELAP, expansive laminoplasty.

discussed; however, reports of treatment in those who have undergone previous ACDF have been rather scarce. The purpose of this study was to elucidate the effectiveness of ELAP for cervical myelopathy resulting from adjacent-segment disease by a retrospective review of the surgical outcomes for this condition.

Materials and Methods

Thirty-one patients with a history of previous ACDF who underwent ELAP for cervical myelopathy resulting from adjacent-segment disease were enrolled in this study (group A) (Table 1). There were 26 males and five females with a mean age of 60 years (range: 39–83 years) and a mean follow-up duration after ELAP of 45 months (range: 25–60 months). The average interval between the ACDF and ELAP was 12 years 3 months (range: 1 year 4 months to 36 years 11 months). Fusion was conducted at a single level in 12 patients (C3–C4 in one, C4–C5 in four, C5–C6 in seven patients), over two levels in 14 patients (C3–C5 in two, C4–C6 in five, and C5–C7 in seven patients), and over three levels in five patients (C3–C6 in one and C4–C7 in four patients). Twenty-nine patients had undergone ACDF once, whereas two patients had undergone the surgical procedure twice as a result of a history of adjacent-segment disease. The ACDF had been performed at our hospital in 26 patients and at other hospitals in five patients. The indications for ACDF included disc herniation in 14 patients, spondylotic myelopathy in 15 patients, and spinal injury in two patients. The preoperative symptoms before ACDF were myelopathic symptoms in 24 patients, nonmyelopathic symptoms in five patients, and unknown in two patients. The adjacent lesions were spondylosis in 27 patients and disc herniation in four patients, and they occurred in the superior segment in 21 patients and in the inferior segment in 10 patients. Thirty-one age- and sex-matched patients with cervical spondylotic myelopathy who underwent ELAP during the same period, who gave no history of surgery on the cervical spine, were enrolled as controls (group B; 26 males, five females; mean age: 58 years). Matching was made by a third person who had no information on the patients, by choosing 31 of 108 patients who underwent ELAP, who were stratified by the age group and gender.

ELAP was performed from C3–C7 according to the method originally reported by Hirabayashi *et al*[10] with some modifications. Because two or three adjacent laminae showed osseous fusion at the levels of the ACDF, they were opened up en bloc after making a gutter on the hinge side and cutting the laminae on the open side. A single stay suture was placed on a block of laminae and also on the paravertebral muscles around the laminae, and the block of laminae was held open by tying the suture. Adhesions between the laminae and the dura matter did not compromise the decompression procedure in any of the patients. The open side was usually on the left side and the hinge side was on the right unless spinal cord compression was significantly more severe on the right side than on the left side.

The pre- and postoperative Japanese Orthopedic Association scores (JOA scores, Table 2)[14] and the recovery rates were compared between the two groups. The recovery rate was calculated as follows; (JOA score at follow up − preoperative JOA score)/(17 − preoperative JOA score) × 100 (%),[15] and the surgical outcomes were classified into four grades based on the calculated recovery rate; excellent: recovery rate 75% or higher, good: 50–75%, fair: 25–50%, and poor: lower than 25%. Evaluation was made on radiographic findings, including the range of motion and the jaw diameter (a measured line from the posteroinferior corner of the vertebral body to the anterior aspect of the subjacent lamina) at the adjacent levels in group A and the affected levels in group B and the spinal canal diameter at the C4 level in both groups. The C4 level was chosen for this measurement, because the spinal canal is usually narrowest at this level. On magnetic resonance imaging, the cross-sectional

Table 2. Evaluation System for Cervical Myelopathy (JOA scoring system)

Category	Score (points)
Motor function	
Upper extremity	
Unable to feed oneself with any tableware including chopsticks, spoon, or fork, and/or unable to fasten button of any size	0
Can manage to feed oneself with spoon and/or fork but not with chopsticks	1
Either chopsticks feeding or writing is possible but not practical, and/or large button can be fastened	2
Either chopsticks feeding or writing is clumsy but practical, and/or cuff button can be fastened	3
Normal	4
Lower extremity	
Unable to stand and walk by any means	0
Unable to walk without a cane or other support on a level	1
Walks independently on a level but needs support on stairs	2
Capable of fast but clumsy walking	3
Normal	4
Sensory function	
Upper extremity	
Apparent sensory disturbance	0
Minimal sensory disturbance	1
Normal	2
Lower extremity	
Apparent sensory disturbance	0
Minimal sensory disturbance	1
Normal	2
Trunk	
Apparent sensory disturbance	0
Minimal sensory disturbance	1
Normal	2
Bladder function	
Urinary retention and/or incontinence	0
Sense of retention and/or dribbling and/or thin stream and/or incomplete continence	1
Urinary retardation and/or pollakiuria	2
Normal	3

Table 3. Clinical Results

	JOA Scores			Outcome Classification			
	Preoperative	Postoperative	Recovery Rate	Excellent	Good	Fair	Poor
Group A (range)	9.2 ± 2.6 (4–14)	11.9 ± 2.8 (6–15)	37.1 ± 22.4 (0–81)*	1	11	11	8
Group B (range)	9.4 ± 2.3 (4–14)	13.3 ± 1.7 (10–16)	50.0 ± 21.3 (14–90)	4	15	7	5

*Statistically significant ($P = 0.04$).

area of the spinal cord was measured at the adjacent levels in group A and at the level at which compression of the spinal cord was maximal in group B. For the measurements, hard copies of magnetic resonance images were photographed using a high-resolution digital camera (Cybershot; Sony, Tokyo), and the cross-sectional area of the spinal cord was measured on a personal computer using the Scion software (Scion Inc., MD). The measurement was conducted twice, and the average of the two values was used for the analyses. The presence or absence of high-signal-intensity lesions on T2-weighted magnetic resonance images was also evaluated.

Statistical Methods. Statistical analyses were conducted using the SPSS software (SPSS Japan Inc., Tokyo). χ^2 test or Mann-Whitney U was used for categorical or ordinal data, and the t test and analysis of variance (ANOVA) were used for interval data with normal distribution.

In all tests, a P value of less than 0.05 was considered to denote statistical significance.

Results

Clinical Outcomes

The average JOA scores in group A and group B were 9.2 ± 2.6 and 9.4 ± 2.3 before the ELAP and 11.9 ± 2.8 and 13.3 ± 1.7 at the follow-up examination, respectively, and the average recovery rates in the two groups were 37.1 ± 22.4% and 50.0 ± 21.3%, respectively (Table 3). Thus, the recovery rate in group A was significantly lower than that in group B ($P = 0.04$; unpaired t test). Clinical results of group A and group B were classified into excellent in one patients (3.2%) and four patients (12.9%), good in 11 (35.5%) and 15 (48.4%), fair in 11 (35.5%) and seven (22.6%), and poor in eight (25.8%) and five (16.1%), respectively. In regard to stratification of the recovery rates according to diagnosis before ACDF in group A, the rate was 41.1 ± 21.5% in cases with soft disc herniation, 35.9 ± 23.0% in cases of spondylotic myelopathy, and 20.8 ± 29.4% in cases of spine injury ($P = 0.48$, ANOVA). A weak correlation was observed between the recovery rate and the interval between the initial ACDF and the ELAP (correlation coefficient, 0.33, $P = 0.062$).

Complications associated with ELAP included postoperative hematoma with the development of quadriplegia in one patient from group A, which was treated by emergency revision surgery, and C5 palsy in one patient from group B. Although neck pain was not a major problem in either group before the ELAP, one patient from group A and two patients from group B experienced intractable axial pain after ELAP, which necessitated the use of nonsteroidal antiinflammatory drugs.

Radiologic Findings

The mean preoperative anterior–posterior diameter at the C4 vertebral level was 12.7 ± 1.4 mm in group A and 13.7 ± 1.2 mm in group B ($P = 0.03$, unpaired t test) (Table 4). The mean angular motion at the adjacent levels in group A was 10.5 ± 5.6 degrees before the ELAP and decreased significantly to 7.0 ± 6.6 degrees at the follow-up evaluation ($P = 0.008$, paired t test). The preoperative angular motion *and* the jaw diameter at the adjacent levels in group A and at the affected levels in group B was not significantly different ($P = 0.66$ and 0.15, respectively, unpaired t test). On magnetic resonance imaging, the mean cross-sectional area of the spinal cord at the adjacent segments in group A was 30.9 ± 12.2 cm^2 and at the most compressed level in group B was 31.2 ± 9.0 cm ($P = 0.95$, unpaired t test). High-intensity lesions in the spinal cord were observed on the T2-weighted magnetic resonance images in 30 of the 31 patients (97%) in group A and in 27 of the 31 patients (87%) in group B ($P = 0.35$, χ^2 test). The mean number of segments covered by the high-intensity lesions on the T2-weighted magnetic resonance images was 1.87 (range: 0–5) in group A and 0.9 (range: 0–2) in group B ($P = 0.001$, Mann-Whitney U test).

Table 4. Radiologic Findings

	Spinal Canal Diameter (mm)	Jaw Diameter (mm)	Angular Motion of Affected Segment (degree)		Spinal Cord Area (mm^2)	T2 High-Intensity Lesion	
			Preoperative	Postoperative		No. of Patients	No of Levels (range)
Group A	12.7 ± 1.4*	12.7 ± 2.1	10.5 ± 5.6	7.0 ± 6.6	30.9 ± 12.2	30 (97%)	1.87 (0–5)†
Group B	13.7 ± 1.2	11.7 ± 2.7	9.8 ± 6.0	4.7 ± 5.1	31.2 ± 9.9	27 (87)	0.9 (0–2)

*$P = 0.03$.
†$P = 0.001$.