なるのは57例中4例（7.0%）となった。

D．考察

本研究では 12 週間の保存療法での検討を行ったが、未だ最適な圧迫骨折への手術介入時期の検討は不十分である。手術適応時期はその手術の安全性や有効性とも関連がある。低侵襲で、合併症率が低く、さらに中長期成績も良好であるならば早めに手術を介入させ、早期離床により日常生活動作を拡大させ、要介護状態の高齢人口を減少させるという社会的ニーズにも応えることが可能となるかもしれない。しかし、保存療法で骨折が治癒し、日常生活に支障が出ない8割強の患者にむやみに手術を適応するとことがないように手術適応の選択が行われる指標作りが重要になる。

E．結論

本研究から当院における椎体形成術の適応を、現段階では、12週間の保存療法で偽関節となり、日常生活動作が障害される約７%の原発性骨粗鬆症性圧迫骨折症例には経皮的椎体形成術を適応し、日常生活動作が障害されていない約５%程度の偽関節例は椎体圧潰に進行しないか注意深く経過観察する方針としたい。

今後は2011年1月からのBKP施行から患者登録、臨床成績の検討を行う。

F．健康危険情報

保存療法における健康被害は存在しなかった。

G．研究発表

1.論文発表

- **戸川大輔.** 骨粗鬆症性脊椎圧迫骨折に対する低侵襲手術. 整形外科 2010;61:1231-8.
- **戸川大輔.** 骨粗鬆症性脊椎圧迫骨折に対するバルーン・カイフォプラスティー. 整・災外 2011;54:55-60.
- **戸川大輔.** 原発性骨粗鬆症性圧迫骨折に対する Balloon Kyphoplasty. - 日本の臨床試験成績. J Spinal Res 2011; in press.
- **戸川大輔.** Balloon Kyphoplasty. THE SPINE perspectives 2011; in press.
- **戸川大輔** 金山雅弘 重信恵一 大羽文博 長濱賢 橋本友幸仲村真実宇美由美 宇田聡子 田中静子. 骨粗鬆症性椎体骨折保存治療後の骨折治癒とEuroQOL (EQ-5D)の相関性. 日整会誌 2011; in press.

2.学会発表

- **戸川大輔**. 骨粗鬆症性椎体骨折 各種治療法の有用性と問題点 原発性骨粗鬆症性圧迫骨折に対する Balloon Kyphoplasty 日本の臨床試験成績. Journal of Spine Research 2010;1:420.
- **戸川大輔.** Balloon kyphoplasty 日本での治験成績と今後の課題. 日本整形外科学会雑誌 2010;84:S157.
- **戸川大輔**, LiebermanIsador H, Schlenk R, et al. 骨粗鬆症性圧迫骨折に対するballoon kyphoplasty 術中体位と手術手技による椎体高回復の比較. 日本整形外科学会雑誌 2010;84:S427.
- **戸川大輔**, 金山雅弘, 重信恵一, et al. 骨粗鬆症性椎体骨折の保存療法

骨粗鬆症性圧迫骨折の保存治療過程における骨折治癒とEuroQOL(EQ-5D)効用値の相関性. 日本整形外科学会雑誌 2010;84:S30.

- **戸川大輔**, 金山雅弘, 大羽文博, et al. 原発性骨粗鬆症性圧迫骨折に対する保存治療過程での骨折治癒状態とEuroQOL(EQ-5D)効用値. Journal of Spine Research 2010;1:1001.
- 金田清志, 伊東学, 金山雅弘, 橋本友幸, 重信恵一, **戸川大輔**, 須田浩太, 楫野知道, 斎田通則, 種市洋. 骨粗鬆症性椎体骨折　遅発性神経麻痺の病態と治療 骨粗鬆症性胸腰椎骨折後椎体圧潰による不安定性後彎と遅発性神経麻痺の病態と治療. Journal of Spine Research 2010;1-3:431.

H. 知的財産権の出願・登録状況

（予定を含む。）

1. 特許取得

特記なし

2. 実用新案登録

特記なし

3. その他

特記なし

Ⅲ. 研究成果の刊行に関する一覧表

研究成果の刊行に関する一覧表

書籍

著者氏名	論文タイトル名	書籍全体の編集者名	書　籍　名	出版社名	出版地	出版年	ページ
武政龍一	骨粗鬆症性脊椎圧迫骨折	国分正一ほか3名	今日の整形外科治療指針第6版	医学書院	東京	2010	545-547

研究成果の刊行に関する一覧表
【H22.4.1～H.23.3.31】

雑誌

発表者氏名	論文タイトル名	発表誌名	巻号	ページ	出版年
A. Okawa, K. Sakai, T. Hirai, T. Kato, S. Tomizawa, M. Enomoto, S. Kawabata, M. Takahashi, K. Shinomiya	Risk Factors for Early Reconstruction Failure of Multilevel Cervical Corpectomy With Dynamic Plate Fixation	Spine	in Press		2010
大川淳, 川端茂徳、加藤剛、富澤將司 榎本光裕、四宮謙一	【脊椎インストゥルメンテーションのリスクとベネフィット】 プレートを併用した頸椎広範囲前方除圧固定手術における留意点	整形・災害外科	53巻9号	1053-1061	2010
Kawasaki Y, Sotome S, Yoshii T, Torigoe I, Maehara H, Sugata Y, Hirano M, MochizukiN, ShinomiyaK, Okawa A.	Effects of gamma-ray irradiation on mechanical properties, osteoconductivity, and absorption of porous hydroxyapatite/collagen.	J Biomed Mater Res B Appl Biomater.	92(1)	161-167	2010
Yoshii T Hafeman AE Nyman JS Esparza JM Shinomiya K Spengler DM Mundy GR, Gutierrez GE Guelcher SA	A sustained release of lovastatin from biodegradable, elastomeric polyurethane scaffolds for enhanced bone regeneration.	Tissue Eng Part A.	16巻7号	2369-79	2010
Shimizu S Okuda N Kato N Rittling SR Okawa A Shinomiya K Muneta T Denhardt DT Noda M Tsuji K Asou Y	Osteopontin deficiency impairs wear debris-induced osteolysis via regulation of cytokine secretion from murine macrophages.	Arthritis Rheum.	62巻5号	1329-37	2010

Shinomiya K.	Envisioning the evolution of orthopedic surgery in the Twenty-first century.	J Orthop Sci.	15巻2号	161	2010
Ochi H Hara Y TagawaM Shinomiya K Asou Y.	The roles of TNFR1 in lipopolysaccharide-induced bone loss: dual effects of TNFR1 on bone metabolism via osteoclastogenesis and osteoblast survival.	J Orthop Res	28巻5号	657-63	2010
早乙女進一 四宮謙一 大川淳	骨のバイオマテリアル人工骨	総合臨床	59巻4号	544-547	2010
榎本光裕 榊経平 富澤將司 新井嘉容 川端茂徳 加藤剛 大川淳 四宮謙一	表面筋電計を用いた腰椎変性疾患を有する高齢者の腰背筋活動	臨床脳波	52巻8号	417-423	2010
網代泰充	椎体形成術	脊椎脊髄	23	469-473	2010
徳橋泰明 中村博亮 戸川大輔 松木健一	座談会「骨粗鬆症性脊椎骨折に対する椎体形成術NOW」	THE SPINE perspectives	7(1)	1-6	2010
上井　浩 徳橋泰明	椎弓根スクリュー固定後の脊椎骨折	整形・災害外科	53(9)	1037-1041	2010
武政龍一 谷俊一	骨粗鬆症性椎体骨折癒合不全に対するCPC椎体形成術の長所と短所	J. Spine Res	1	1260-1266	2010

武政龍一	骨粗鬆症性椎体骨折の病態 -骨折急性期から骨癒合不全および遅発性神経麻痺発症の病態まで-	関節外科	**29(5)**	522-529	2010
武政龍一 谷俊一	胸腰椎陳旧性圧迫骨折患者への手術適応と手術の実際	関節外科	29(10)	212-222	2010
A. Okawa, K. Sakai, T. Hirai, T. Kato, S. Tomizawa, M. Enomoto, S. Kawabata, M. Takahashi, K. Shinomiya	Risk Factors for Early Reconstruction Failure of Multilevel Cervical Corpectomy With Dynamic Plate Fixation	Spine	in Press		2010
大川淳, 川端茂徳、 加藤剛、 富澤將司 榎本光裕、 四宮謙一	【脊椎インストゥルメンテーションのリスクとベネフィット】 プレートを併用した頸椎広範囲前方除圧固定手術における留意点	整形・災害外科	53巻9号	1053-1061	2010
Kawasaki Y, Sotome S, Yoshii T, Torigoe I, Maehara H, Sugata Y, Hirano M, MochizukiN, ShinomiyaK, Okawa A.	Effects of gamma-ray irradiation on mechanical properties, osteoconductivity, and absorption of porous hydroxyapatite/collagen.	J Biomed Mater Res B Appl Biomater.	92(1)	161-167	2010
早乙女進一 四宮謙一 大川淳	骨のバイオマテリアル人工骨	総合臨床	59巻4号	544-547	2010
榎本光裕 榊経平 富澤將司 新井嘉容 川端茂徳 加藤剛 大川淳 四宮謙一	表面筋電計を用いた腰椎変性疾患を有する高齢者の腰背筋活動	臨床脳波	52巻8号	417-423	2010

Nakamura M, Tsuji O, Fujiyoshi K, Watanabe K, Tsuji T, Ishii K, Matsumoto M, Toyama Y, Chiba K	Cordotomy for patients with thoracic malignant astrocytoma.	J Neurosurg Spine	13(4)	418-423	2010
Watanabe K, Lenke LG, Matsumoto M, Harimaya K, Kim YJ, Hensley M, Stobbs G, Toyama Y, Chiba K	A novel pedicle channel classification describing osseous anatomy: how many thoracic scoliotic pedicles have cancellous channels?	Spine (Phila Pa 1976)	35(20)	1836-1842	2010
Watanabe K, Matsumoto M, Tsuji T, Ishii K, Takaishi H, Nakamura M, Toyama Y, Chiba K	Ball tip technique for thoracic pedicle screw placement in patients with adolescent idiopathic scoliosis.	J Neurosurg Spine	13(2)	246-252	2010
Matsumoto M, Okada E, Ichihara D, Chiba K, Toyama Y, Fujiwara H, Momoshima S, Nishiwaki Y, Hashimoto T, Inoue T, Watanabe M, Takahata T	Prospective ten-year follow-up study comparing patients with whiplash-associated disorders and asymptomatic subjects using magnetic resonance imaging.	Spine (Phila Pa 1976)	35(18)	1684-1690	2010
Matsumoto M, Okada E, Ichihara D, Watanabe K, Chiba K, Toyama Y, Fujiwara H, Momoshima S, Nishiwaki Y, Hashimoto T, Takahata T	Age-related changes of thoracic and cervical intervertebral discs in asymptomatic subjects.	Spine (Phila Pa 1976)	35(14)	1359-1364	2010
Matsumoto M, Watanabe K, Ishii K, Tsuji T, Takaishi H, Nakamura M, Toyama Y, Chiba K, Imanishi Y, Kishi K, Kawana H	Complicated surgical resection of malignant tumors in the upper cervical spine after failed ion-beam radiation therapy.	Spine (Phila Pa 1976)	35(11)	E505-509	2010

Miyauchi Y, Ninomiya K, Miyamoto H, Sakamoto A, Iwasaki R, Hoshi H, Miyamoto K, Hao W, Yoshida S, Morioka H, Chiba K, Kato S, Tokuhisa T, Saitou M, Toyama Y, Suda T, Miyamoto T	The Blimp1-Bcl6 axis is critical to regulate osteoclast differentiation and bone homeostasis.	J Exp Med	207(4)	751-762	2010
T Uemura, Y Ohta, Y Nakao, T Manaka, H Nakamura, K Takaoka	Epinephrine accelerates osteoblastic differentiation by enhancing bone morphogenetic protein signaling through a cAMP/protein kinase A signaling pathway	Bone	47	756- 765	2010
Yamada K, Matsuda H, Nabeta M, Habunaga H, Suzuki A, Nakamura H	Clinical outcomes of microscopic decompression for degenerative lumbar foraminal stenosis: a comparison between patients with and without degenerative lumbar scoliosis	Eur Spine J	in Press		2010
Suzuki A, Matsumura A, Konishi S, Terai H, Tsujio T, Dozono S, Nakamura H	Risk Factor Analysis for Motor Deficit and Delayed Recovery Associated With L4/5 Lumbar Disc Herniation	J Spinal Disord Tech			2010
A Matsumura, T Namikawa, H Terai, T Tsujio, A Suzuki, S Dozono, H Yasuda, H Nakamura	The influence of approach side on facet preservation in microscopic bilateral decompression via a unilateral approach for degenerative lumbar scoliosis	J Neurosurg spine	13	758-765	2010
Matsumoto T, Okabe T, Ikawa T, Iida T, Yasuda H, Nakamura H Wakitani S.	Articular cartilage repair with autologous bone marrow mesenchymal cells	J Cell Physiol	Nov;225(2)	291-295	2010

H Toyoda, H Nakamura, S Konishi, S Dohzono, M Kato, H Matsuda.	Clinical Outcome of Microsurgical Bilateral Decompression via Unilateral Approach for Lumbar Canal Stenosis Minimum Five-Year Follow-up	Spine	in Press		2010
M Hoshi, S Taguchi, K Hayakawa, M Ieguchi, H Nakamura	Evaluation of clinical problems associated with bone matastases from carcinoma from unknown primary sites	Arch Orthop Trauma Surg	131	59-64	2011
M Tada, T Nakanishi, C Hirata, T Okano, Y Sugioka, S Wakitani, H Nakamura, T Koike	Use of infliximab in a patient with pyoderma gangrenosum and rheumatoid arthritis	Mod Rheumatol	20	598- 601	2010
鈴木亨暢 中村博亮	Vertebroplastyとkyphoplasty	骨粗鬆症治療	9 (3)	269-72	2010
寺井秀富 中村博亮.	高齢者・超高齢脊椎疾患(リウマチを除く)患者に対する手術適応と手術の実際　都会の腰椎疾患患者への手術適応と手術の実際	関節外科	(29)	186-193	2010
戸川大輔	骨粗鬆症性脊椎圧迫骨折に対する低侵襲手術	整形外科	61巻	1231-1238	2010
戸川大輔	骨粗鬆症性脊椎圧迫骨折に対するバルーン・カイフォプラスティー	整形・災害外科	54巻	55-60	2011
戸川大輔	原発性骨粗鬆症性圧迫骨折に対するBalloon Kyphoplasty.　－日本の臨床試験成績	J Spinal Res			2010

Ⅳ. 研究成果の刊行物・別刷

除再建術式(excisional procedure)と後方除圧と脊柱支持性再建により除痛と麻痺改善を図る姑息的な術式(palliative procedure)に大別できる。

前者の腫瘍脊椎骨切除再建術式の代表が腫瘍脊椎骨全摘術(total en bloc spondylectomy)で，後方単独法，前後合併法がある。後者の姑息的な術式の標準が，後方除圧固定術(posterior decompression and stabilization)で，後方からの神経除圧とインストゥルメンテーションを併用した脊柱再建を行う術式である。

術式選択は，単椎罹患(ときに連続した2椎)で予想予後1年以上の場合は，長期の局所コントロールを目的に腫瘍脊椎骨切除再建術式が望ましい。一方，多椎転移や予想予後1年以内ないし6ヵ月以内では，姑息的な(palliative)術式選択が一般的である。

合併症と予後

手術治療による疼痛改善は良好で，いずれの術式でも80%以上で死亡直前まで維持できたと報告されている。麻痺の改善は，生命予後の影響が大きく，単純に術式相互間の比較はできない。後方除圧固定術では，術後早期(術後3週間)にFrankel 1段階以上の麻痺改善が約40～60%で得られるが，最終的には，そのうち約半数に麻痺再発が生じたと報告されている。

後療法のポイント

予後に応じた柔軟な対応が必要だが，残りの人生を有意義に過ごすため，できるだけ早く自宅に帰す。いたずらに医学的視点で治療を引き延ばしてはならない。

患者説明のポイント

がん告知と説明内容の問題もあり，原発科の主治医とともに説明が望ましい。いずれの治療法にも限界があること，QOL向上優先の治療であること，各治療法の利点，欠点を十分説明して，最終的に治療方針を決定する。

看護ケアとリハビリテーション上の注意

患者の置かれている生命予後と麻痺切迫程度を理解してもらう。特に痛みと麻痺進行の監視に配慮するよう指示する。脊椎支持性，麻痺状況に応じたリハビリテーション，看護を指示する。

参考文献

1) 徳橋泰明：脊椎腫瘍，戸山芳昭(編)：胸腰椎・腰椎・仙椎．最新整形外科学大系第12巻，pp313-9，中山書店，2006
2) 徳橋泰明，他：転移性脊椎腫瘍のMRI診断．伊藤博元(編)：図解よくわかる整形外科MRI診断実践マニュアル．pp90-9，全日本病院出版会，2007

骨粗鬆症性脊椎圧迫骨折

Osteoporotic vertebral compression fracture

武政 龍一　高知大学・講師

【疾患概念】 骨粗鬆症は骨密度の低下と骨質の劣化により骨強度が低下して，全身性に易骨折性を来す骨障害である。本症は，骨粗鬆症に起因する骨強度の低下を基盤として発生した脊椎椎体の圧潰型骨折である。

【臨床症状と病態】

転倒などの軽微な外力でも発生するが，外傷機転なしに発生することも少なくない。

急性期の臨床症状は骨折による腰背部痛が主体であり，椎体圧潰や脊柱後弯変形により身長も低下する。腰背部痛は臥位からの起き上がり動作や，座位からの臥床動作などの体位変換時に最も強く，臥床安静時には消失する。

痛みの部位は骨折部周辺の脊柱に限定して存在するとは限らず，むしろ骨折部よりも尾側および側方にまで痛みを訴える場合が多い。椎体の楔状化に伴い脊柱後弯変形が発生すると，骨癒合完了後も腰背部の慢性痛や易疲労感，日常生活動作の制限や抑うつ気分の助長，呼吸機能の低下，腹部膨満や胃食道逆流症などの消化器症状を招くことがある。さらに骨折部が癒合不全となり，偽関節を生じると寝起き動作の痛みや後弯由来の腰背部痛が持続する。一般的な保存療法では15%弱の症例に骨癒合不全が生じることが報告されている。椎体後壁損傷を有する症例は椎体骨癒合不全発生の危険因子となる。

神経麻痺を起こすことは通常ないが，高度の椎体圧潰や偽関節に至ると神経障害が遅発性に生じることがある。椎体の後壁が破綻して骨片が脊柱管内に突出し，脊髄や馬尾を圧迫して神経麻痺を生じさせると考えられているが，局所の後弯変形や偽関節部での椎体内不安定性の関与も大きい。

胸腰椎移行部椎体骨折では脊髄円錐や円錐上部症候群を呈する場合があり，T12では両側下垂足，L1では膀胱直腸障害を発症する場合があり下位腰椎部変性疾患と見誤ることがないように留意すべきである。

問診で聞くべきこと

ベッドや布団に寝るとき，あるいは寝た状態から起き上がるときに痛みが発生または増強するかどうかを必ずチェックする。これは急性期の未骨癒合時期や偽関節が生じた場合など，骨折部で可動性を認める場合の腰背部痛を示唆する所見である。そのほか受傷機転の有無，ステロイド薬内服歴などの2次性の骨粗鬆症

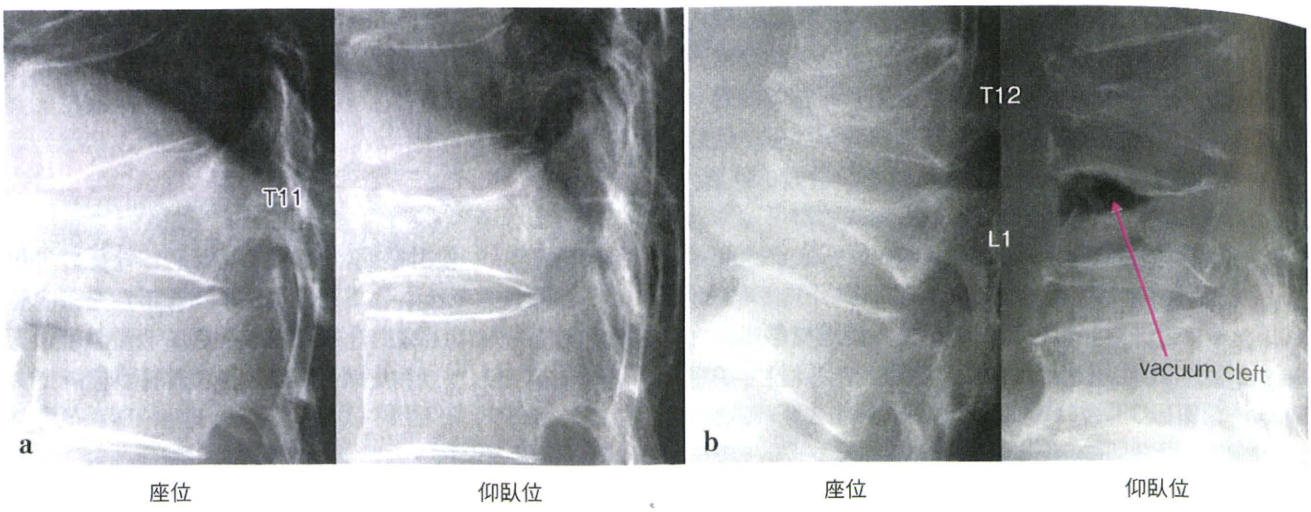

図 17-5　座位-仰臥位 X 線側面像比較による椎体圧迫骨折簡易画像診断法

a. T11 新鮮圧迫骨折。座位では T11 椎体が圧潰しているが，仰臥位になると椎体高が復元し，臨床経過と併せて椎体圧迫骨折の急性期であると診断した。

b. L1 椎体偽関節。座位 X 線像で T12，L1 椎体は圧潰像を示しているが，仰臥位側面像で T12 椎体には形態に変化なく，圧潰変形して骨癒合した陳旧性骨折と診断できるが，L1 椎体内には vacuum cleft が認められ，椎体偽関節の像を呈している。

の発症要因，膀胱直腸障害を含めた神経麻痺症状，悪性腫瘍などの病歴，多発性骨髄腫の鑑別のため発熱や貧血などの有無を聞く。

必要な検査とその所見

(1) 理学所見：棘突起の叩打痛，運動制限のチェック，および神経学的検査を行う。棘突起叩打痛の陽性率は必ずしも高くはなく，自験例では 38% であった。

(2) 画像診断：単純 X 線側面像で骨折椎体は，楔状椎，陥凹椎(魚椎)，扁平椎などを来し，旧厚生省長寿科学研究班により骨折椎体の判定基準が示されているが，新鮮骨折ではこの判定基準に満たない場合も多く，症状と局所所見を総合して診断する。また偽関節椎体の診断には椎体内 cleft の出現が参考になる。陳旧性の変形治癒椎体と，急性期新鮮骨折もしくは偽関節などのまだ骨癒合していない椎体との鑑別は単純 X 線では困難であるが，立位あるいは座位での側面像と，仰臥位での側面像を比較することが鑑別に有用である。両者の比較で椎体高が変化している椎体は，その時点では少なくとも骨癒合に至っていない椎体と判定できる(図 17-5)。

① MRI：一般に椎体骨折では骨折部分が T1 強調で低輝度，T2 強調で高～等輝度となる。さらに T2 強調像の脂肪抑制や STIR 法を行うと骨折部の浮腫性変化が高輝度に描出される。骨折が治癒過程にある椎体では，圧縮され骨硬化した部分を除いて，受傷後約 6 ヵ月程度を経て椎体内骨髄が等輝度に復する。偽関節では滲出液が偽関節腔に貯留することが多く，そのため T1 強調で低輝度，T2 強調で超高輝度領域が偽関節腔に相当する部分に認められることが多い。

② CT：椎体後壁損傷が疑われる場合の質的診断などに有用である。

診断のポイント

高齢者で急性に発症した腰痛をみればまず本症を疑う必要がある。理学所見と座位および仰臥位単純 X 線側面像の比較が有用だが，変形が明らかでない骨折もあり，その場合 MRI が極めて有用な診断手段となる。MRI が利用できない場合，骨折の疑いがあれば時間的な間隔を開けて X 線検査を再度行う。

保存療法

高齢者が多く，臥床による下肢深部静脈血栓，廃用性筋萎縮などを作らないためには，早期に離床を促し運動療法を開始すべきである。しかし骨折の急性期には疼痛が著しく，実際には困難な場合が多く，四肢骨折と同様にまずは仮骨形成を促進するため初期の安静をとるべきとの意見もある。筆者は採型した体幹装具が完成するまでの約 1 週間は自宅または入院で原則的には臥床安静とし，以後外固定を行って離床を促している。疼痛対策として筆者は鎮痛作用のあるカルシトニン製剤の筋注を好んで用いており，NSAIDs の使用は最小限としている。

装具は硬性装具を原則とするが，患者のコンプライアンスによりやむをえず軟性装具にせざるをえない場合もある。座位と仰臥位 X 線側面像の比較で骨折可

動性が著しく大きいものには体幹ギプス固定を勧めている。座位と仰臥位X線像比較で骨折椎体に明らかな動きがなくなれば軟性装具に変更し，合計で約3〜6ヵ月間程度の外固定を継続している。装具は骨折部をカバーする十分な長さが必要である。

いったん椎体骨折が発生すると連鎖的に椎体骨折が続発するリスクが高くなることが知られており，基盤となる骨粗鬆症に対する薬物治療を併用して，新規骨折を予防することが大切である。

手術療法

骨癒合不全を来した椎体圧潰・偽関節例で神経麻痺を来した症例，保存療法に反応せず腰背部痛が持続する症例は手術療法の適応となる。筆者はリン酸カルシウムセメントを用いた椎体形成術を低侵襲性に行い優れた除痛効果を実感している。神経麻痺を生じた症例には椎体形成術に神経除圧操作と脊椎インストゥルメンテーションを併用した後方再建術も施行している。楔状椎体変形のための脊柱後弯変形の矯正には脊椎後方短縮骨切り術も適応がある。前方除圧前方再建術や，前方除圧後前方および後方一期的再建術なども良好な手術成績が報告されているが，高齢者には侵襲が大きな手術であり，合併症も問題となる。

ナース，PT・OTへの指示

易骨折性であり，転倒予防策を徹底する。装具の正しい装着法を指導してもらいコンプライアンスの向上に努めてもらう。

透析性脊椎症

Dialysis-related spondylosis, Destructive spondyloarthropathy

下出 真法 NTT東日本関東病院・部長〔東京都品川区〕

〔疾患概念〕 透析患者アミロイド沈着性病変(dialysis-related amyloidosis；DRA)が脊椎に発生したもので，長期の人工透析に関連して起こる脊椎変性疾患である。1984年Kuntzにより報告された破壊性脊椎関節症(destructive spondyloarthropathy；DSA)が代表的なものであるが，脊椎の破壊性病変を伴わず後縦靱帯や黄色靱帯へのアミロイド沈着が原因となって脊髄圧迫症状を呈するEAD(extradural amyloid deposit)と呼ばれる病態もこれに含まれる。

なお，透析患者アミロイド沈着性病変とは，透析膜で濾過されないβ_2-microglobrinが組織親和性のある靱帯，腱，椎間板，軟骨，関節滑膜などに沈着し，それらの組織の肥厚や変性を来した結果起こる病変の総称である。透析性脊椎症のほか，手根管症候群，手指腱鞘炎，アミロイド骨嚢胞，アミロイド関節症，滑液包炎などの病変がある。

〔臨床症状と病態〕

DSAは，椎間板・椎骨・椎間関節の破壊性変性により脊柱管の破綻が起こり，脊髄や馬尾神経や神経根に圧迫が生じることより，頚椎罹患では非透析例の頚髄症・神経根症と同様の症状を呈し，腰椎罹患では腰部脊柱管狭窄症や変性すべり症と同様の症状を呈するが，その症状はいずれも非透析例のものより高度で進行性であることが一般的である。好発部位は，非透析例における変形性脊椎症と同様で，中下部頚椎と中下部腰椎で，胸椎罹患は稀である。このような破壊性病変の発生機序は，椎間板や脊柱靱帯群を主とした軟部組織へのアミロイド沈着がその部位の変性と脆弱性を生じ，脊椎に破壊性病変を起こすというのが現在の一般的な理解であるが，椎体終板から始まる骨吸収や椎間関節の破壊性骨病変の進行過程には長期透析による腎性骨症をはじめとした骨代謝異常の存在が大きく関与していることが推測されている。

EADは，脊椎の破壊性変化を伴わず後縦靱帯および黄色靱帯へのアミロイド沈着蓄積による靱帯肥厚が高度の脊柱管狭窄状態を生じ，頚椎罹患では頚髄症，腰椎罹患では腰部脊柱管狭窄症の症状を呈する。頚椎罹患例は上中位頚椎に好発し進行性で重症な麻痺を起こしやすいが，腰椎罹患例では比較的軽症で推移する傾向がある。

必要な検査とその所見

DSAの単純X線像での特徴的所見は化膿性脊椎炎に酷似することである。すなわち，①椎間板腔の著しい狭小化または消失，②隣接する椎体終板の不整化と骨吸収像と骨硬化像，③加齢変化による変形性脊椎症にみられる骨棘の欠如，などの所見が認められる。化膿性脊椎炎との鑑別にはMRI検査が有用で，DSAではT1，T2強調像ともに低信号であることが一般的である。DSAと脊椎炎症性疾患の鑑別には血液検査所見，骨生検による組織所見が有用なこともある。

EADでは単純X線像に特異的な所見がなく，MRI，脊髄造影，脊髄造影下CTにて脊柱靱帯肥厚による脊柱管狭窄所見が確認される(**図17-6**)。

診断のポイント

①長期透析歴を有すること。透析歴10年以下で発生することは稀で，20年以上の透析歴を有することが一般的である。

②頚髄症または腰部脊柱管狭窄症の症状を呈していること。典型的な画像所見を呈していても症状がな

SPINE Volume XX, Number XX, pp 000–000

Risk Factors for Early Reconstruction Failure of Multilevel Cervical Corpectomy With Dynamic Plate Fixation

Atsushi Okawa, MD, PhD, Kenichiro Sakai, MD, PhD, Takashi Hirai, MD, Tsuyoshi Kato, MD, PhD, Shoji Tomizawa, MD, PhD, Mitsuhiro Enomoto, MD, PhD, Shigenori Kawabata, MD, PhD, Makoto Takahashi, MD, PhD, and Kenichi Shinomiya, MD, PhD

Study Design. Retrospective case series.

Objective. To investigate risk factors for early reconstruction failure of multilevel cervical corpectomy with dynamic plate fixation.

Summary of Background Data. For anterior cervical decompression and fusion, reinforcement by plate fixation was performed to decrease early reconstruction failure and to increase the fusion rate. However, a relatively high complication rate such as graft dislodgement, has been reported in patients undergoing multilevel corpectomy and reconstruction. Risk factors associated with early reconstruction failure have not been explicitly described.

Methods. In 30 instrumented multilevel corpectomy and reconstruction, medical records and radiographic studies were reviewed to investigate risk factors with regard to sagittal alignment of the cervical spine, graft subsidence, screws used in fixation, endplate preparation, and intermediate screw for fibular graft.

Results. Reconstruction failures included anterior slipping at the bottom of the graft in 2 cases, fracture of the C7 vertebral body in 2 cases, and pullout of a screw in 2 cases. Four patients were found to have nonunion of the graft at the final follow-up, but none had experienced early reconstruction failure.

On radiologic measurement, the fusion area lordotic angle after surgery in the patients with reconstruction failures was significantly larger than that of the patients with no complications. The postoperative C2–C7 lordotic angles of the patients with reconstruction failure were also larger, but this trend was not statistically significant. No other factor, such as age and gender, type of screw used, intermediate screw or preservation of the endplates was related to reconstruction failures in this study.

Conclusion. Postoperative cervical hyperlordosis may adversely affect graft stability in the early postoperative period of the surgery of corpectomy and reconstruction with dynamic plate fixation.

Key words: anterior cervical fusion, anterior cervical plate, complication, cervical myelopathy, ossification of longitudinal ligament. **Spine 2010;XX:000–000**

Corpectomy and reconstruction are the treatment of choice in patients with ossification of the posterior longitudinal ligament (OPLL) or spondylotic myelopathy with a kyphotic alignment of the cervical spine. We have previously reported that the anterior floating method appears to yield adequate long-term outcomes when used to treat OPLL.[1] However, a relatively high complication rate, which includes complications such as respiratory distress and graft dislodgement, has been reported in patients undergoing multilevel corpectomy and reconstruction. Previous studies have found that graft reinforcement with anterior plate fixation is expected to decrease early reconstruction failure and to increase the fusion rate in patients undergoing multilevel corpectomy.[2,3]

However, Sasso *et al* reported a 71% failure rate after 3-level fixed plated reconstruction.[4] Daubs also reported an extremely high early failure rate (75%) with the use of a titanium mesh cage and a fixed anterior plate for reconstruction in patients undergoing multilevel corpectomies.[5] Interestingly, in a biomechanical experiment, Brodke *et al* found that a static plate loses its load-sharing capacity after 10% subsidence has occurred.[6] In contrast, with regard to the choice of the type of fixation that is used (*i.e.*, a constrained *vs.* a semiconstrained plate), most recent studies have reported that dynamic plate designs provide a faster fusion of the cervical spine in comparison to rigid plate designs.[7–10] In these reports, however, the authors did not include a detailed discussion of the complications associated with early reconstruction failure in multilevel corpectomy.[11]

This article details the results of a retrospective study of the factors associated with early reconstruction failure in patients undergoing multilevel corpectomy with dynamic plate fixation. Specifically, we review the preoperative and postoperative sagittal alignment of the cervical spine, the screws used in fixation, the use (or lack of use) of an intermediate screw for fibula grafts, the methods that were used for endplate preparation, and the characteristics of patients who required repeat surgery in the early postoperative period.

From the Department of Orthopedic and Spinal Surgery, Graduate School of Medicine, Tokyo Medical and Dental University, Tokyo, Japan.

Acknowledgment date: October 28, 2009. First revision date: February 12, 2010. Second revision date: March 12, 2010. Acceptance date: March 12, 2010.

The device(s)/drug(s) is/are FDA-approved or approved by corresponding national agency for this indication.

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 Atsushi Okawa, MD, PhD, Department of Orthopedic and Spinal Surgery, Tokyo Medical and Dental University, Yushima 1-5-45, Bunkyo-Ku, Tokyo 113-8519, Japan; E-mail: okawa.orth@tmd.ac.jp

Table 1. Characteristics of 30 Patients

Median age (range)	59 (44–79)
Gender (male:female)	27:3
Segments fused (cases)	
3	14
4	13
5	3
Type of fusion (fibula: hydroxyapatite)	
Long (LF)	25
Hybrid (HF)	5

LF indicates multilevel corpectomy and fusion; HF, a combination of segmental fusion and multilevel corpectomy with fusion.

Table 2. Complication

Neurological deterioration	
C5 palsy	2
Myelopathy	1
Reconstruction failure	
Graft migration	2*
C7 body fracture	2*
Screw pullout	2 (4)†

*One of the patients with graft migration and one of the patients with a C7 fracture had screws that had dislodged.
†Two patients showed only dislodged screws; this event coincided with graft migration and C7 fracture in other 2 patients.

■ Materials and Methods

Materials

Between 2000 and 2008, 31 patients with myelopathy caused by multilevel cervical spondylosis (n = 7) or OPLL (n = 24) underwent multilevel corpectomy and reconstruction with autologous fibula and anterior cervical plate placement. One patient with spondylotic amyotrophy was included in the group of patients with cervical spondylosis. Our patients were divided into 2 groups based on the operative methods we used: long fusion (LF) was defined as multilevel corpectomy and reconstruction without segmental fusion, and a hybrid group (HF) was defined as a combination of segmental fusion and multilevel corpectomy and reconstruction (Table 1). One patient treated with LF was lost to follow-up after within 1 year of surgery. Therefore, a total of 30 patients (3 female, 27 male) were observed for a minimum of 1 year after surgery. The average follow-up period was 3.5 years in this patient population. When we define a disc-level as "1 segment," we performed 3-segment (n = 14), 4-segment (n = 13), and 5-segement fusion (n = 3). In the LF group, there were 14 cases of 2-level corpectomy and reconstruction, 10 cases of 3-level corpectomy and reconstruction, and 1 case of 4-level corpectomy and reconstruction. In the HF group, there were 3 cases of 4-segment fusion (a discectomy and 2-level corpectomy), and 2 cases of 5-segment fusion (1- or 2-level discectomy and 3- or 2-level corpectomy, respectively).

Clinical results were evaluated using the Japanese Orthopedic Association (JOA) scoring system for cervical myelopathy, and the JOA score recovery rate was calculated using Hirabayashi 's method.[1]

The surgical procedure we used consisted of a standard anterior approach to the cervical spine with intraoperative spinal cord monitoring using motor-evoked potentials while the patient was under general anesthesia. No traction was used during the procedure. Lordosis of the cervical spine was maintained with a contoured foam pillow that was placed beneath the neck during the operation. Osteophytes that were compressing the spinal cord were removed using the microscope, and ossification of the posterior ligament was treated using an air drill such that the ligament was thinned and was allowed to migrate anteriorly (this is known as the "floating" method).[1,12] The endplates of the adjacent vertebral bodies were retained whenever possible but were sometimes removed to decompress areas of ossification behind the vertebral body or to better fit the vertebral column to the shape of the graft.

For reconstruction, a fibular bone graft reinforced by a rotationally dynamic plate was typically used. We used a fixed-type screw for the bottom and a variable-type screw for the top of the graft. This configuration allows the screws to pivot while preventing screw pullout.[7] A fibular bone graft reinforced by an anterior plate was used in 30 cases, and in 18 of these cases intermediate screws were added. The length and shape of the grafts were chosen such that the decompressed cervical column was extended slightly by mild manual distraction or with a Casper distractor.

The average operation time was 6 hours 3 minutes and ranged from 3 hours 25 minutes to 9 hours 15 minutes. The mean estimated blood loss during the operation was 440 mL (range: 70–2885 mL). Patients were permitted to walk 2 to 5 days after surgery and were placed in Philadelphia-type collars for 3 months. The length of admission ranged from 15 to 79 days (mean: 29 days). Patients' JOA scores before the operation ranged from 6 to 14.5 points with a mean of 11.0 ± 2.6 points. The JOA scores at the final follow-up appointment were 14.7 ± 2.3 points in the LF group and 14.9 ± 1.7 points in the HF group. The recovery rates of the JOA scores were 64.8% ± 27.9% in the LF group and 58.5% ± 50.5% in the HF group. Clinical outcomes did not differ significantly between the groups. Three patients experienced neurologic complications; 2 developed C5 palsy and 1 developed myelopathy (Table 2). One of the patients with C5 palsy also showed evidence of graft migration and screw pullout. All of the patients with neurologic complications had repeat surgery within 1 week after the initial surgery and had regained normal function by their 1-year follow-up appointment. Two of these patients displayed evidence of nonunion of the graft at their final follow-up appointment, which was most likely due to the fact that the graft was shortened somewhat during the second operation for neurologic complication. An additional 2 patients who had no particular risk factors also displayed evidence of nonunion at their 1-year follow-up appointments.

The clinical outcomes of these patients were not statistically significantly inferior to those of the patients who did not experience nonunion, but none of these 4 patients did exhibit early reconstruction failure.

Methods

This study is a case series of 30 patients who underwent multilevel corpectomy and reconstruction. Their medical records and radiographic studies were reviewed to investigate their individual risk factors for reconstruction failure.

We defined early reconstruction failure as graft migration, vertebral body fracture, or screw extrusion within 1 month of the index surgery regardless of whether it required repeat surgery. We examined the patients' surgical records to collect data regarding the type of screws that were used as well as whether the endplates were preserved. A series of lateral plain radiographs of the cervical spine were obtained to identify the presence of any implant or graft movement as well as to evaluate

fusion status. Postoperative radiologic evaluation was performed on the radiographs that were taken within 1 week of surgery on the first day that patients were allowed to ambulate. Graft subsidence was defined as a >2 mm graft sinkage and was assessed by comparing lateral radiographs taken at 1 week and 1 month after the surgery. When either abnormal graft movement or screw pullout was suspected, a computer-assisted tomography (CT) scan was performed. This approach allowed us to detect fine fracture lines and anterior slippage at the bottom of the graft. Reformatted CT views that were obtained just after the surgery were also used for radiologic measurements when the borders of the C7 vertebral body were not clearly visible.

Sagittal alignment of the cervical spine was evaluated by measuring the C2–C7 angle between the tangential lines drawn from the posterior border of the C2 and C7 vertebral bodies. The lordotic angle of the fusion area was determined in a similar manner. The C7 horizontal angle was defined as the upper endplate angle of the C7 vertebral body viewed from the horizontal plane of the neutral lateral view. This angle was assessed with a radiograph that was taken with the patient in a sitting position. The graft was determined to have fused if there was absence of motion of the adjacent vertebral bodies and spinous processes in flexion-extension radiographs. We used the χ^2 test and Student's unpaired t test for our statistical analyses. All $P < 0.05$ were considered to be statistically significant.

■ Results

The causes of reconstruction failures for which the patients underwent secondary operations included graft migration (n = 2), fracture of the C7 vertebral body (n = 2), and screw pullout (n = 2) (Table 2). Because one of the patients who experienced graft migration and one of the patients who experienced a C7 fracture also presented with screw pullout, a total of 4 patients had screws that had protruded. Four patients who had experienced graft migration or C7 fracture were treated by posterior spinous process wiring. Two patients with screw pullout had their implants removed after fusion was completed.

Reconstruction failures were observed in 5 patients in the LF group and in 1 patient in the HF group. A total of 1 of 14 patients who underwent 3-segment fusion, 3 of 13 patients who underwent 4-segment fusion, and 2 of 3 patients who underwent 5-segment fusion eventually presented with reconstruction failures. The number of segments that were fused was found to be statistically significantly related to the risk of reconstruction failures ($P < 0.05$). The following factors were not associated with reconstruction failure; nor with age, gender, the preservation of the vertebral endplates, screw type, the occurrence of postoperative graft subsidence within 1 month of surgery, and the use of intermediate screws for fibular grafting (Table 3).

With regard to radiologic measurements, the mean preoperative C2–C7 lordotic angle of patients who experienced reconstruction failure was 13.5° ± 10.9°, and that of the patients who did not experience any complications was 13.5° ± 17.1°. The fusion area lordotic angle of the patients who experienced reconstruction failure was 9.6° ± 13.1°, and that of the patients who did not experience complications was 7.4° ± 9.1°. There were no significant differences observed between the preoperative C2–C7 lordotic angles or the fusion area lordotic angles of these 2 groups.

Table 3. Factors Related to Reconstruction Failures

	Reconstruction Failures (6)	No Complication (24)	P
Average number of fused segments	4.2	3.5	$P < 0.05$
Removal of the top endplate of the fused area	4	6	$P < 0.1$
Removal of the bottom endplate of the fused area	4	13	n.s.
Fixed screw used at both ends	1	4*	n.s.
Intermediate screw	3/6	15/24†	n.s.
Subsidence	3	12	n.s

*No documentation about the screw in the 2 operative records.
†Excluding HA graft.

The postoperative C2–C7 lordotic angle of the patients who experienced reconstruction failures tended to be larger than those of patients who did not experience reconstruction failure, but this trend was not significant. The fusion area lordotic angle of the patients who experienced reconstruction failure was 15.6° ± 8.4°, which was significantly ($P < 0.05$) larger than that of the patients who did not experience reconstruction failure (8.6° ± 6.4°) (Figure 1). The C7 horizontal angle did not differ between these 2 groups. We did not observe any statistically significant differences between the groups with regard to changes in the C2–C7 lordotic angle or the fusion area lordotic angle (Table 4).

■ Discussion

Anterior cervical decompression and fusion is a valuable method for treating patients with cervical myelopathy caused by spondylosis or OPLL. However, among this procedure, a multilevel corpectomy and reconstruction are frequently accompanied by complications like plate

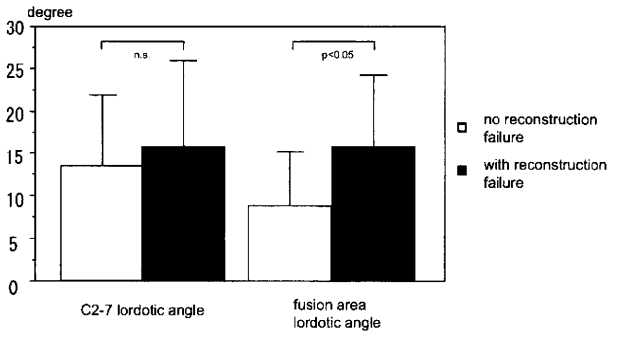

Figure 1. The postoperative C2–C7 lordotic angles and fusion area lordotic angles tended to be larger in patients who experienced reconstruction failure than they were in patients who did not experience reconstruction failure. The postoperative fusion area lordotic angles were statistically significant ($P < 0.05$).

Table 4. Radiological Measurements (Degrees)

	Reconstruction Failures (6)	No Complication (24)	*P*
C2–C7 lordotic angle	13.5 ± 17.1	13.5 ± 10.9	n.s
Fused area lordotic angle	9.6 ± 13.1	7.4 ± 9.1	n.s
PO C2–C7 lordotic angle	15.6 ± 10.2	13.3 ± 8.5	n.s
PO fused area lordotic angle	15.6 ± 8.4	8.6 ± 6.4	$P < 0.05$
C7 horizontal angle	22.7 ± 7.0	22.0 ± 6.8	n.s.
Change in C2–C7 lordotic angle	2.1 ± 11.8	−0.23 ± 7.4	n.s.
Change in fused area lordotic angle	3.1 ± 9.0	0.9 ± 8.9	n.s.

dislodgement and graft migration.[5,6,13] Figure 2 shows a typical case of graft subsidence and migration with screw pullout that occurred in the early postoperative period. Figure 3 shows images from another patient who also experienced early reconstruction failure. The original cervical curve of this patient was slightly lordotic, and we tried to change the alignment of the cervical spine more lordotic to decompress the spinal cord. However, screw pullout and fracture of C7 vertebra occurred during the early postoperative period. Reformatted CT views showed that the C2–C7 lordotic angle had increased after surgery and that C7 fracture had occurred.

In this study, 6 of 30 (20%) patients who underwent mutlilevel corpectomy and reconstruction without the use of a halo brace experienced reconstruction failures. The postoperative fusion area lordotic angle of the patients who experienced reconstruction failure was significantly larger than that of the patients who did not experience reconstruction failure (Figure 1). As seen in the scatter graph (Figure 4), 3 of the 6 patients who experienced early reconstruction failure exhibited postoperative fusion area lordotic angles of >15°. Although it is not easy to determine a cut-off with regard to the fusion area lordotic angle at which it is no longer advisable to perform this procedure, the risk of reconstruction failure may increase in patients with postoperative fusion area lordotic angles of >15°. In our study, this value (15°) was equal to the mean postoperative fusion area lordotic angle of the patients who did not experience reconstruction failure plus 1 standard deviation. Hyperlordosis of the cervical spine yields to high shear stress at the bottom of the fused segment, which can lead to anterior slippage of the construct. Herrmann and Geisler has pointed out that both device failure and pseudarthrosis have been observed with greater frequency at the inferior end of long-segment constructs than the top of the fused segment.[13,14] They speculated that the long lever arm of the anterior plate transmitted unacceptably high forces to the inferior level of the fusion area. They observed that shear stress increased at the bottom of the fusion area, especially in patients with a hyperlordotic alignment and continuing micromotion of their cervical spines, both of which can lead to reconstruction failure. These findings were similar to our results.

Additional factors that affected the 3 patients who experienced early reconstruction failure but did not have excessive lordosis of their cervical spines were not elicited in this study. We postulate that overdistraction during grafting could have been one of the causes of recon-

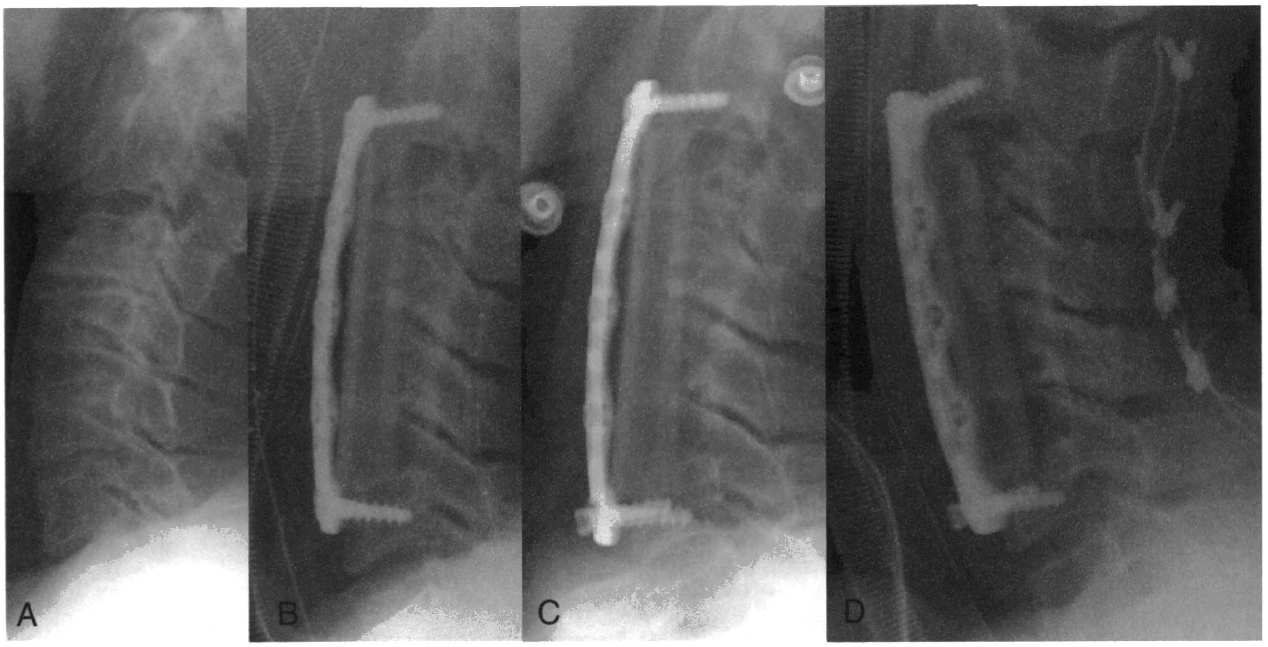

Figure 2. Preoperative radiograph of a 61-year-old man shows mixed-type OPLL with a fusion area lordotic angle of 25.8° (**A**). C2–C6 fusion was performed using an autologous fibular graft and a rotationally dynamic plate. Note the retention of the C6 endplate just after the operation (**B**). Graft subsidence and migration with screw pullout occurred 3 weeks after surgery (**C**). After in situ spinous process wiring, the degree of the patient's cervical lordosis decreased. However, solid fusion was observed (**D**).

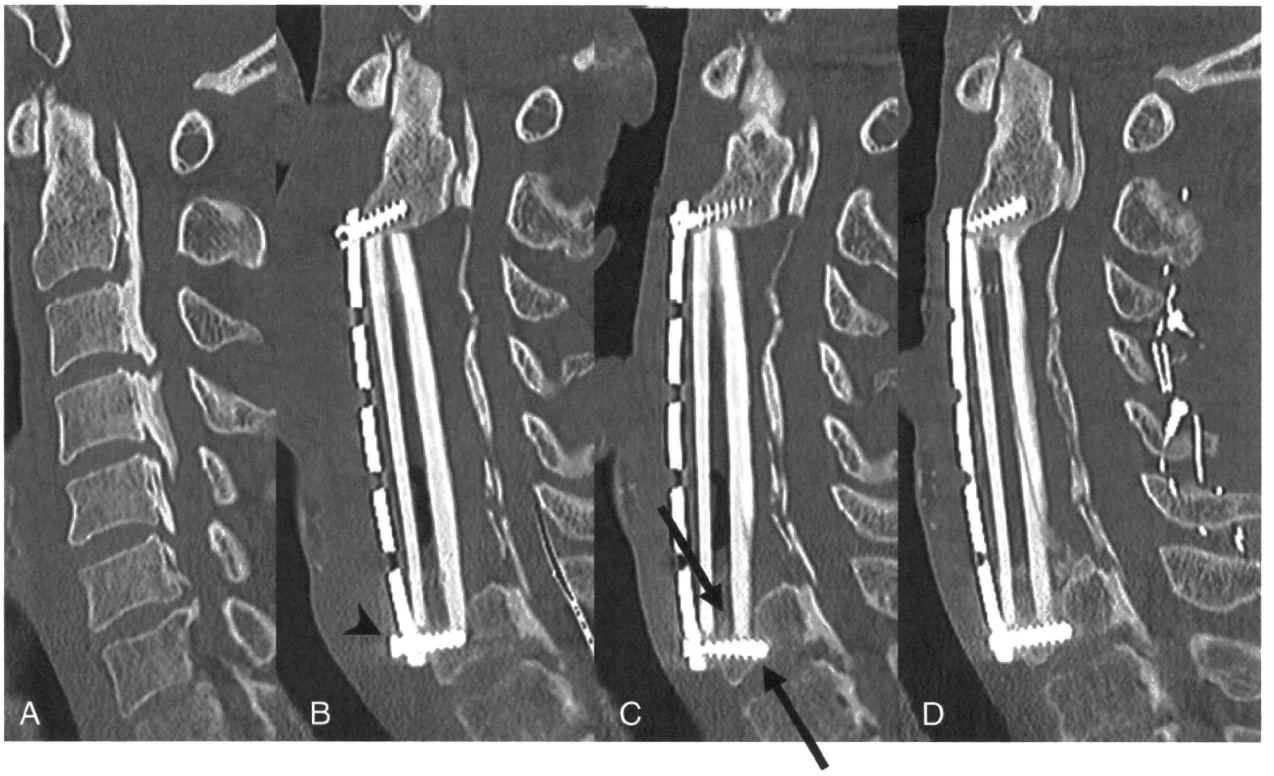

Figure 3. Preoperative radiograph of a 51-year-old man shows mixed-type OPLL with a slight lordosis (**A**). Postoperative scan taken 3 weeks after the surgery revealed screw pullout (arrow head) (**B**). Note cervical lordosis seemed to increase after the surgery. The screw was retightened, but graft subsidence and C7 fracture occurred (arrows) (**C**). After *in situ* spinous process wiring, the degree of the patient's cervical lordosis decreased. However, solid fusion was observed (**D**).

struction failure in these patients. We distracted the neck carefully while the graft was being inserted, but the distraction force was not controlled precisely.

The following factors were not associated with reconstruction failure: age, gender, preservation of the vertebral endplate, screw type, the occurrence of postoperative graft subsidence within 1 week of surgery, and the use of intermediate screws for fibular grafting. However, preservation of the vertebral endplate is thought to be important in patients with osteoporosis. In a biomechanical study, Lim *et al* confirmed that load to failure tended to decrease with incremental removal of the endplate and the risk of failure tended to increase.[15]

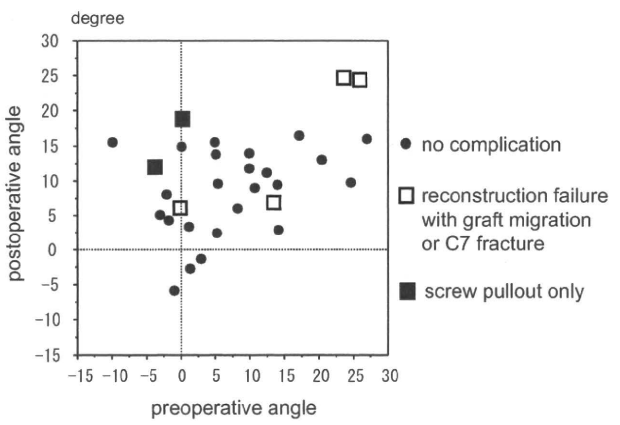

Figure 4. The preoperative and postoperative fusion area lordotic angles of the included patients have been plotted. Of the 6 patients, the 4 who experienced early reconstruction failure exhibited postoperative fusion area lordotic angles of >10°. Additional factors that affected the remaining 2 patients without excessive lordosis of their cervical spines were not elicited in the current study.

When the alignment of the cervical spine is lordotic, laminoplasty is normally performed. However, the clinical outcomes of patients with massive OPLL or with a kyphotic cervical alignment treated by anterior cervical decompression and fusion have been previously shown to be better than those of patients treated with posterior decompression.[16] Thus, some patients with cervical myelopathy respond well to multilevel corpectomy and reconstruction.[17] Cervical lordosis is also normally thought to be important for preventing long-term fusion-related problems such as adjacent segment degeneration. However, we hypothesized that postoperative cervical hyperlordosis may adversely affect graft stability in the early postoperative period.

When graft migration is discovered, posterior wiring can provide solid union. When the graft dislodges completely, reinforcement by screw fixation is needed. Because some authors recommend simultaneous anterior and posterior fixation for patients with hyperlordotic cervical spine alignments,[18,19] a combined surgical plan should be used to decrease the rate of early reconstruc-

tion failure in the limited number of patients this type of alignment.

The limitations of this study include its retrospective nature and the fact that only a small number of cases are included. A prospective study is, therefore, needed to further examine this paradoxical hypothesis that we generated based on the results of our study.

■ Key Points

- A retrospective study was conducted to investigate risk factors for early reconstruction failure of multilevel cervical corpectomy and reconstruction with dynamic plate fixation.
- Six of 30 cases experienced reconstruction failures, including graft migration at the bottom of the graft in 2 cases, fracture of the C7 vertebral body in 2 cases, and pullout of a screw in 2 cases.
- On radiologic measurement, the fusion area lordotic angle after surgery in patients with reconstruction failures was significantly larger than that of the patients with no complication.

References

1. Matsuoka T, Yamaura I, Kurosa Y, et al. Long-term results of the anterior floating method for cervical myelopathy caused by ossification of the posterior longitudinal ligament. *Spine* 2001;26:241–8.
2. Epstein NE. The value of anterior cervical plating in preventing vertebral fracture and graft extrusion after multilevel anterior cervical corpectomy with posterior wiring and fusion: indications, results, and complications. *J Spinal Disord* 2000;13:9–15.
3. Daffner SD, Wang JC. Anterior cervical fusion: the role of anterior plating. *Instr Course Lect* 2009;58:689–98.
4. Sasso RC, Ruggiero RA, Reilly TM, et al. Early reconstruction failures after multilevel cervical corpectomy. *Spine* 2003;28:140–2.
5. Daubs MD. Early failures following cervical corpectomy reconstruction with titanium mesh cages and anterior plating. *Spine* 2005;30:1402–6.
6. Brodke DS, Klimo P Jr, Bachus KN, et al. Anterior cervical fixation: analysis of load-sharing and stability with use of static and dynamic plate. *J Bone Joint Surg Am* 2006;88:1566–73.
7. Dipaola CP, Jacobson JA, Awad H, et al. Screw orientation and plate type (variable- vs. fixed-angle) effect strength of fixation for in vitro biomechanical testing of the Synthes CSLP. *Spine J* 2008;8:717–22.
8. Nunley PD, Jawahar A, Kerr EJ 3rd, et al. Choice of plate may affect outcomes for single versus multilevel ACDF: results of a prospective randomized single-blind trial. *Spine J* 2009;9:121–7.
9. Stulik J, Pitzen TR, Chrobok J, et al. Fusion and failure following anterior cervical plating with dynamic or rigid plates: 6-months results of a multicentric, prospective, randomized, controlled study. *Eur Spine J* 2007;16:1689–94.
10. Pitzen TR, Chrobok J, Stulik J, et al. Implant complications, fusion, loss of lordosis, and outcome after anterior cervical plating with dynamic or rigid plates: two-year results of a multi-centric, randomized, controlled study. *Spine* 2009;34:641–6.
11. Koller H, Hempfimg A, Ferraris L, et al. 4- and 5-level anterior fusions of the cervical spine: review of literature and clinical results. *Eur Spine J* 2007;16:2055–71.
12. Yamaura I, Kurosa Y, Matsuoka T, et al. Anterior floating method for cervical myelopathy caused by ossification of the posterior longitudinal ligament. *Clin Orthop Relat Res* 1999;359:27–34.
13. Herrmann AM, Geisler FH. Geometric results of anterior cervical plate stabilization in degenerative disease. *Spine* 2004;29:1226–34.
14. Mourning D, Reitman CA, Heggeness MH, et al. Initial intervertebral stability after anterior cervical discectomy and fusion with plating. *Spine J* 2007;7:643–6.
15. Lim TH, Kwon H, Jeon CH, et al. Effect of endplate conditions and bone mineral density on the compressive strength of the graft-endplate interface in anterior cervical spine fusion. *Spine* 2001;26:951–6.
16. Iwasaki M, Okuda S, Miyauchi A, et al. Surgical Strategy for cervical myelopathy due to ossification of the posterior longitudinal ligament. *Spine* 2007;32:654–60.
17. Masaki Y, Yamazaki M, Okawa A, et al. An analysis of factors causing poor surgical outcome in patients with cervical myelopathy due to ossification of the posterior longitudinal ligament. Anterior decompression with spinal fusion versus laminoplasty. *J Spinal Disord Tech* 2007;20:7–13.
18. Suda K, Abumi K, Ito M, et al. Local kyphosis reduces surgical outcomes of expansive open-door laminoplasty for cervical spondylotic myelopathy. *Spine* 2003;28:1258–62.
19. Hilibrand AS, Fye MA, Emery SE, et al. Increased rate of arthrodesis with strut grafting after multilevel anterior cervical plating. *Spine* 2002;27:146–51.