

原著論文

脊損治療の医療経済に関する多施設共同研究

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脊損医療経済の現状を前向き多施設共同研究で調査した。脊損専門 (S), 救急 (E), リハ (R) 施設の脊損患者 94 例を対象に任意の 1 ヶ月間の保険点数と看護必要度, 麻痺の関連を調査した。看護必要度 B 得点 (B) は四肢麻痺 (T): 8.65 点, 対麻痺 (P): 5.09 点と有意差があり ($p < 0.001$), 保険点数 (H) は, T: 93,661 点, P: 109,423 点と差がなかった。施設別では S: 86,895 点, E: 296,860 点, R: 85,952 点と E が有意に高かった ($p < 0.001$)。受傷後期間と B, H の関係は, ≤ 1 ヶ月: 8.64 点・154,639 点, > 1 ヶ月: 7.37 点・84,627 点と B は期間による差はない ($p=0.189$) が, H は > 1 ヶ月で有意に低かった。 ($p < 0.001$)。受傷後 1 ヶ月以降では保険点数が有意に低下したが, 看護必要度は 1 ヶ月以降も引き続き高く, 診療報酬とのアンバランスが明らかとなった。

【緒言】

脊髄損傷は, すべての運動器機能を廃絶せしめうる重度外傷であり, その管理には多大な人的および物的医療資源を必要とする。本研究は, 日本脊髄障害医学会保険問題等検討委員会 (山岸正明委員長) において, 脊損医療の医療経済問題の実態調査を行うために発案・計画された。本研究の目的は, 急性期から慢性期までの脊損診療を一貫して行える脊損専門医療機関, 救命救急センター, および, リハビリテーション病院における看護必要度と保険診療報酬の実態を調査し, その問題点を明らかにすることである。

【対象と方法】

脊損診療を行っている脊損専門医療機関 (総合せき損センター, 北海道中央労災病院せき損センター, 国立病院機構村山医療センター), 救命救急センター (獨協医科大学病院), リハビリテーション病院 (熊本リハビリテーション病院) の計 5 施設を選定した。各施設にて倫理委員会の承認後, 入院加療中の脊髄患者に研究参加の同意を得た上で, 2010 年 12 月~2011 年 6 月における任意の 1 ヶ月間の看護必要度 (A 得点, B 得点) と保険点数を前向きに調査した。登録症例数は 94 例, 性別は男性: 80 例, 女性: 14 例, 年齢は平均 53.6 歳 (16~85 歳) であった。施設毎の症例数の内訳は, 総合脊損センター: 48 例, 北海道中央労災病院せき損センター: 28 例, 国立病院機構村山医療センター: 18 例, 獨協医科大学病院: 5 例, 熊本リハビリテーション病院: 3 例であった。

基本データとして入院時の麻痺型, 改良 Frankel 分類, 脊椎損傷型, 実施された治療法を調査した。看護必要度は「一般病棟用の重傷度・看護必要度に係わる評価票」(図 1) を用いて A 得点 (モニタリング及

Multicenter study for health economics of spinal cord injury treatment

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Key words: spinal cord injury (脊髄損傷), health economics (医療経済), multicenter study (多施設研究)

(配点)				
A	モニタリング及び処置等	0点	1点	2点
1	創傷処置	なし	あり	
2	血圧測定	0~4回	5回以上	
3	時間尿測定	なし	あり	
4	呼吸ケア	なし	あり	
5	点滴ライン同時3本以上	なし	あり	
6	心電図モニター	なし	あり	
7	シリンジポンプの使用	なし	あり	
8	輸血や血液製剤の使用	なし	あり	
9	専門的な治療・処置 (① 抗悪性腫瘍剤の使用, ② 麻薬注射薬の使用, ③ 放射線治療, ④ 免疫抑制剤の使用, ⑤ 昇圧剤の使用, ⑥ 抗不整脈剤の使用, ⑦ ドレナージの管理)	なし		あり
A得点				
B	患者の状況等	0点	1点	2点
10	寝返り	できる	両方につかまれば できる	できない
11	起き上がり	できる	できない	
12	座位保持	できる	支えがあれば できる	できない
13	移乗	できる	足回り・ 一握金具が不要	できない
14	口腔清潔	できる	できない	
15	食事摂取	介助なし	一部介助	全介助
16	衣服の着脱	介助なし	一部介助	全介助
B得点				

図 1 一般病棟用の重症度・看護必要度に係わる評価票

び処置等: 10 点満点), B 得点 (患者の状況等: 12 点満点) を毎日評価し, 1 ヶ月間の平均看護必要度を算出した。保険点数は, 医学管理等, 投薬料, 注射料, 処置料, 手術料, 検査料, 画像診断料, リハビリ等, 入院料の 1 ヶ月分の合計点数を調査した。統計検定には分散分析と Tukey-Kramer HSD 検定を用い, $p < 0.05$ を有意差ありとした。

【結果】

受傷から調査開始までの経過期間は, 平均 190.6 日 (0 日~10 年) であった。麻痺型は, 四肢麻痺: 68 例, 対麻痺: 23 例, 中心性頸髄損傷: 1 例, 馬尾損傷: 2 例であった。改良 Frankel 分類は, A (30 例) と C1 (21 例) が多く過半数を占めていた (図 2)。脊椎損傷型は, 脱臼骨折: 45 例 (48%), 非骨傷性頸損: 35 例 (37%), 骨折: 10 例 (11%), 上位頸椎損

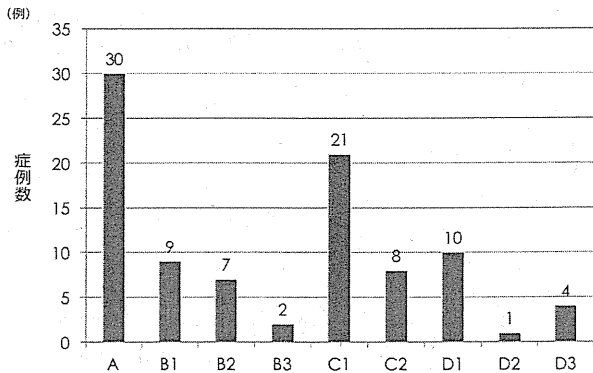


図2 改良 Frankel 分類

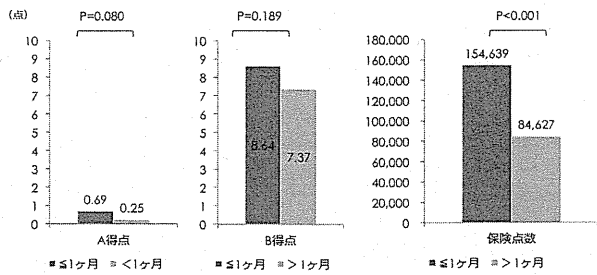


図3 受傷からの期間と看護必要度 (A,B 得点)・保険点数 (合計) の関係

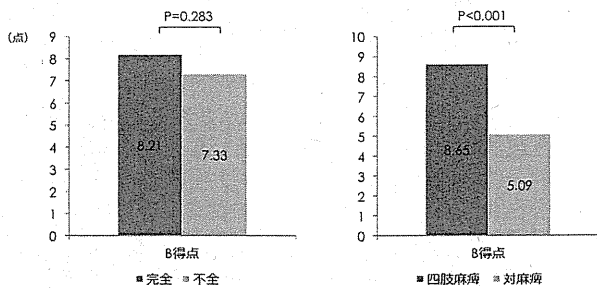


図4 麻痺型と看護必要度 B 得点の関係

傷：5例 (4%) であった。調査期間内 (1ヶ月間) に行われた治療は、手術治療：13例、保存治療：81例であった。一方、受傷から調査終了時まで手術治療が施行されていたのは、46例 (49%) であった。保険種別では労災保険は全体の28%にとどまり、国保と社保を合わせた28%と同比率であった。

看護必要度は A 得点：平均 0.337 点 (0-6 点)、B 得点：平均 7.609 点 (0-12 点) と A 得点が低く B 得点が高い、すなわち全身管理に係わる看護必要度が低いのに対し、患者の移動介助などに係わる看護必要度が著しく高くなっていた。受傷からの期間と看護必要度の関係は、A 得点は ≤1ヶ月：0.69 点、>1ヶ月：0.25 点と有意差なく ($p=0.080$)、B 得点も ≤1ヶ月：8.64 点、>1ヶ月：7.37 点と有意差はなかった ($p=0.189$)。一方、要した保険点数 (合計) は、≤1ヶ月：154,639 点であったのに対し、>1ヶ月：84,627 点と1ヶ月以内の保険点数が有意に高かった ($p<0.001$) (図3)。

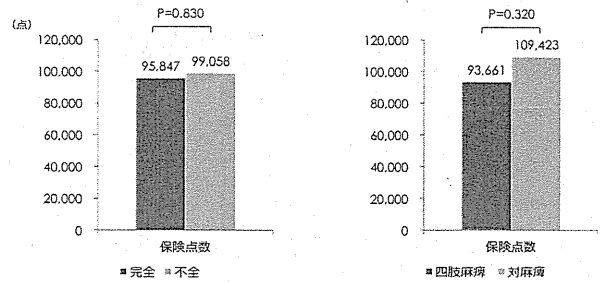


図5 麻痺型と保険点数 (合計) の関係

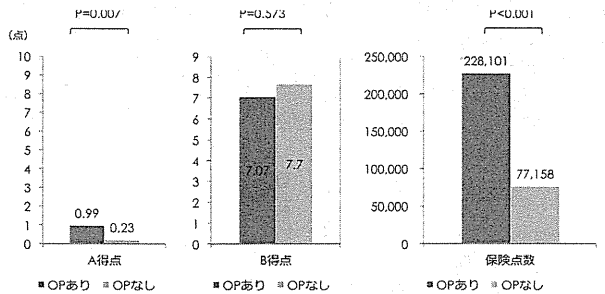


図6 手術の有無と看護必要度 (A,B 得点)・保険点数 (合計) の関係

麻痺と看護必要度 B 得点の関係は、完全麻痺 (改良 Frankel A)：8.21 点、不全麻痺 (改良 Frankel B1-D3)：7.33 点と有意差がなかった ($p=0.283$) のに対し、四肢麻痺：8.65 点、対麻痺：5.09 点と四肢麻痺の看護必要度が有意に高かった ($p<0.001$) (図4)。一方、保険点数 (合計) は完全麻痺：95,847 点、不全麻痺：99,058 点 ($p=0.830$)、四肢麻痺：93,661 点、対麻痺：109,423 点 ($p=0.320$) といずれも有意差はなかった (図5)。

手術の有無と看護必要度の関係は、A 得点は手術あり：0.99 点、手術なし：0.23 点と手術有りが有意差に高かったがいずれもきわめて低得点であった ($p=0.007$)。一方、B 得点は手術あり：7.07 点、手術なし：7.70 点と有意差はなかった ($p=0.573$)。要した保険点数 (合計) は、手術あり：228,101 点であったのに対し、手術なし：77,158 点と手術ありの保険点数が有意に高かった ($p<0.001$) (図6)。

医療機関の種類による看護必要度 B 得点は、脊損専門医療機関：7.54 点、リハビリテーション病院：6.67 点、救命救急センター：9.38 点と各群間に有意差はなかった (図7)。また、医療機関による保険点数 (合計) は、脊損専門医療機関：86,895 点、リハビリテーション病院：85,952 点、救命救急センター：296,860 点と救命救急センターが他の2つに対し、有意に高かった ($p<0.001$) (図8)。

症例数が最多であった脊損専門医療機関 (障害者病棟 10：1看護) での保険点数の内訳 (平均) をみると保険点数に占める入院料と手術点数の割合が高く、それぞれ 55.1%と 38.8%で合計 93.9%を占めた (図9)。

【考察】

21 世紀に入り、脊損治療の医療経済的問題に着目した調査・研究がなされるようになってきた¹⁾²⁾³⁾⁴⁾⁵⁾⁶⁾⁷⁾⁸⁾⁹⁾¹⁰⁾。

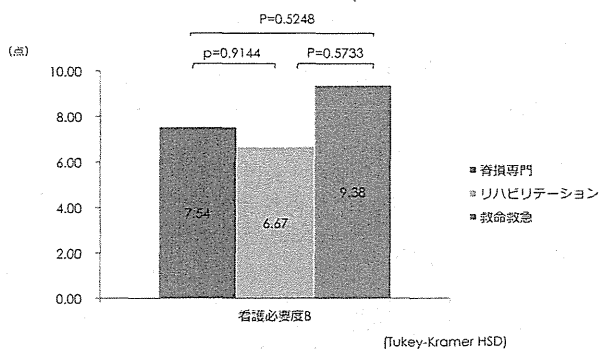


図7 医療機関の種類による看護必要度 (B 得点)

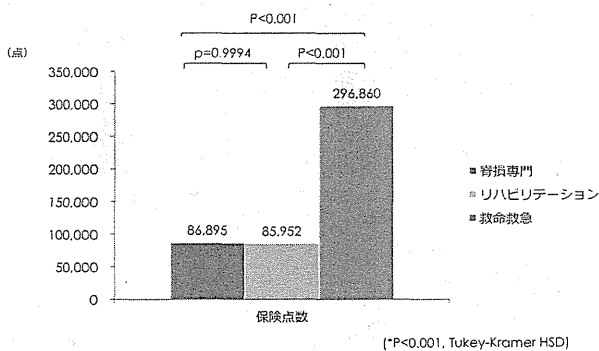


図8 医療機関の種類による保険点数 (合計)

その多くが指摘するのは、麻痺により大きく自立性が損なわれた患者管理に要する膨大な看護必要度を反映した適切な医療収入が得られない点である。特に看護必要度 B 得点に反映される「寝返り」「起き上がり」「食事摂取」など、自立した生活に必要な最低限の ADL ができない患者の介助に多くの人的資源を要するにもかかわらず、それに見合った人件費を捻出できる医療収入がえられないという現在の保険診療の構造的な問題が指摘されている^{1) 2) 3) 9) 10)}。

本研究結果では、受傷から1ヶ月以内の急性期とそれ以降の亜急性期～慢性期の看護必要度は A, B 得点ともに変化がないことが明らかとなった。特に B 得点は高いレベルが持続した。これに対し、保険点数は受傷後1ヶ月を過ぎると急性期の半分程度にまで落ち込むのが現状である。一方、麻痺型との関係を見ると、四肢麻痺では上肢機能が温存された対麻痺に対し看護必要度は有意に高いにもかかわらず、保険点数には差がないことが明らかとなった。これは、脊損の全医療収入の4割を手術料に依存している現行の保険制度によることが大きい。たとえば、四肢麻痺を引き起こす頸椎の脱臼骨折と対麻痺の原因となる胸腰椎脱臼骨折では同様の脊柱再建術の適応となるため、必然的に手術に要する保険点数は同等となる。四肢麻痺は多くの人的資源が必要になるにもかかわらずそれに見合った入院料が設定されていないことが問題である。手術の有無と看護必要度の関係では、手術例で看護必要度 A 得点が有意に高かったが、いずれも1点未満の低いレベルで、全身管理の面では「手のかからない手術」であった。これに対し、麻痺の程度やレベルに大きく影響される B 得点は手術の有無にかかわらず

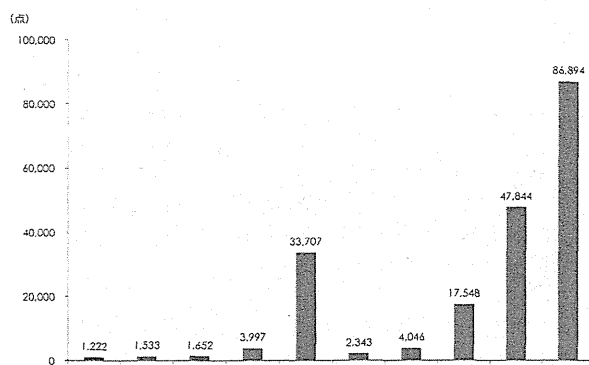


図9 脊損専門医療機関における保険点数の内訳(1ヶ月)

	1-7日	8-14日	15-30日	31日	1ヶ月計 1月目	1ヶ月計 2月目
脊損専門病院 障害者病棟10:1	1,612	1,612	1,467	1,300	46,040	39,000
救命救急センター 特定機能病院7:1 (救急医療管理加算)	3,067	2,267	1,762	1,555	65,530	46,650

(平成22年)

図10 現行医療制度での脊損専門医療機関と救命救急センターでの入院料 (試算)

高かった。一方、保険点数は手術を行わない場合は手術例の約1/3程度にとどまることが明らかとなった。

脊損専門医療機関では、入院基本料は障害者病棟(10:1看護)で算定されており、入院から14日目までは1,612点である。一方、今回対象とした救命救急センターでは特定機能病院(7:1看護)入院基本料と救急医療管理加算で7日目までは3,067点、14日目までは2,267点などとなり、最初の1ヶ月での入院料で約1.4倍の格差が生じることが試算された。この傾向は、1ヶ月以降もつづき、1ヶ月あたりの入院料は1.2倍の開きが生じている(図10)。

本研究では、社会保険診療報酬点数が脊損医療の現状とはかけ離れている事実が明らかとなった。この解決策として、頸髄損傷(四肢麻痺)の看護必要度(B得点)に応じた適正な人員配置と保険診療報酬のバランスを考慮した入院基本料の設定があげられる。たとえば脊損病棟(7:1看護)入院基本料や頸髄損傷(四肢麻痺)管理加算などの設定である。現状では、構造的な不採算部門として脊損病棟の存続は危機的な状況となっており、早急な解決が望まれる^{1) 2) 3)}。保険制度の改革を待つゆとりがない状況とも考えられ、当面は補助金などでの専門医療機関の存続を行う必要があるかもしれない。一方、脊損患者を受け入れている各地の救命救急センターでは、急性期治療終了後の脊損患者の受け入れ先医療機関を見つけることがきわめて困難な状況であることも指摘され、脊損患者の医療難民化が危惧される³⁾。脊髄損傷の発生件数そのものは増加していないものの、受傷年齢の高齢化や保険上有利な労災患者の減少など、脊損医療を取り巻く状況の変化に柔軟に対応する必要に迫られていることを

強調したい。

【結語】

脊損治療の医療経済的問題を明らかにするために、94例を対象に多施設共同研究を行った。看護必要度は発症からの経過期間にかかわらず、高い値で推移しているにもかかわらず医療収入は経時的に減少した。脊損に特化した入院基本料や特別加算の接待など医療保険制度の改革が望まれる。

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千葉県における脊髄損傷疫学調査 (2008) 第1報

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【目的】

本学会脊髄損傷予防委員会からの補助を受けて、2008年における千葉県の脊髄損傷発生状況を調査する。1990年～1992年に本学会が実施した、全国疫学調査時に演者が集計した千葉県データとの比較も行う。

【方法】

2007年の福岡県の調査法に準じ、県内の2次および3次救急病院に調査票を送付した。調査項目は、年齢、性別、診断(骨傷の有無、頸損or胸腰損)、受傷原因麻痺の程度(Frankel)、急性期治療内容、である。このほかに受傷日、生年月日、居住市町村、頭部外傷合併の有無、リハ実施の有無と場所など千葉県独自の質問も追加した。

【結果・考察】

調査票は2009年4月に第1回を郵送後、未回収施設には合計3回送付し、さらに電話で回答を依頼した。10月末までに回収できたのは、表1で示すように調査対象177施設中165施設であり回収率は93.2%であった。

患者の性別では男性82%、女性22%であり、男女比は前回(82%対18%)同様、約4対1であった。

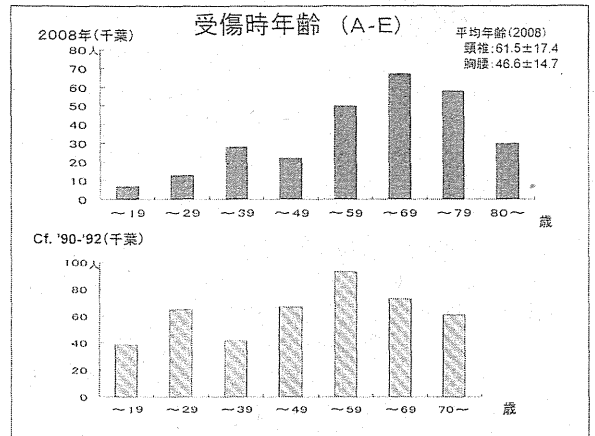


図1 受傷時年齢

受傷時年齢は、今回調査でも前回調査のように2峰性がみられたが全体に発生が高齢に移行し、そのピークは前回の20代と50代から、今回は30代と60代に移っており高齢者での発生が多くなっていった(図1)。なお、頸椎損傷の平均年齢は61.5歳、胸・腰椎損傷では46.6歳であり、頸椎損傷の方が15歳高かった。

・ 調査用紙回収(10月末迄)	
回収施設 165施設(／177)	回収率 93.2%
うち症例あり 37施設	症例なし 128施設
・ 登録患者数	県内推定発生率(/百万人)
275名 (A-E)	48.0
224名 (A-D)	39.1
cf. '90-'91 全国 (A-D)	39.8
'90-'92 千葉県(A-D)	38.5
(参考:'08年末の千葉県人口 約615万人)	

表1 回収率・推定発生率

複数病院から報告のあった4症例を整理したうえで、登録された患者数はFrankel A～Eで275名、A～Dで224名であった。回収率および千葉県人口615万人を考慮して計算した推計発生率は、人口百万に対しFrankel A～Dで39.1人で、この値は前回調査における全国(39.8)および千葉県(38.5)の発生率とほぼ同じとなった。

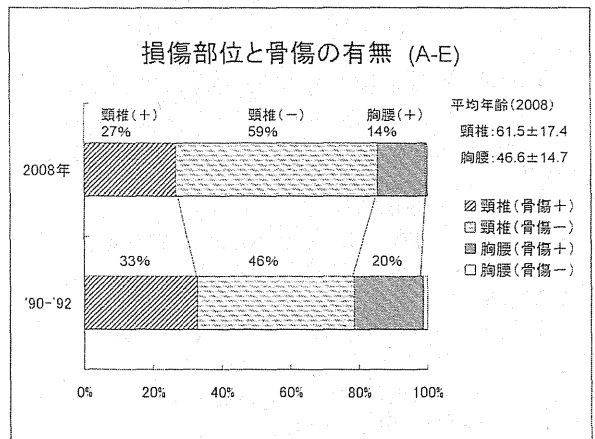


図2 損傷部位と骨傷の有無

頸椎損傷と胸・腰椎損傷の割合は、前回調査では頸椎損傷が全体の79%であったのに対し、今回は86%と頸椎損傷の割合が増え、特に骨傷の無い頸椎損傷が全体の59%に達していた。また胸・腰椎損傷では前回同様にほとんどの症例で骨症を伴っていた(図2)。

Epidemiological study of spinal cord injury in Chiba prefecture (2008)

K. Yoshinaga, et al.

Key words : spinal cord injury (脊髄損傷), incidence (発生頻度), cause (発生原因)

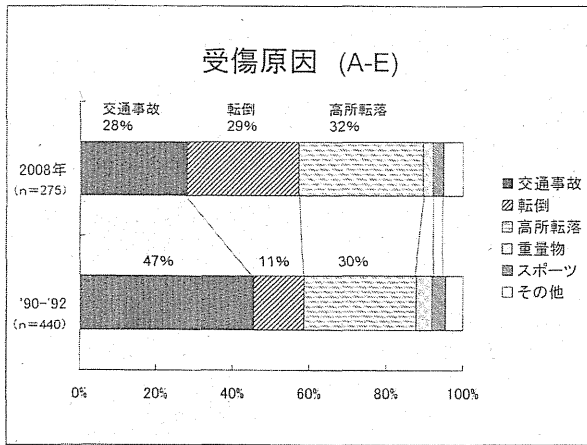


図3 受傷の原因

Frankel分類に基づく脊髄損傷の程度は、頸椎損傷ではA8%、B12%、C27%、D39%、E14%であり、胸・腰椎損傷ではA21%、B3%、C15%、D13%、E48%であった。前回との比較で特に目立つのはEの割合が頸椎では減り、胸・腰では増加していたことであるが、骨症のタイプについて調査していないこともあり、その理由については十分な検討ができなかった。

全体の受傷原因としては、高所からの転落が32%と最も多く、ついで転倒29%であり、前回49%を占めていた交通事故は今回28%に減っていた(図3)。なお損傷部位別にみると、頸椎損傷では転倒34%、高所転落29%、交通事故28%の順であり、胸・腰椎では高所転落54%、交通事故26%、重量物による打撲・下敷き15%の順となった。またスポーツによる受傷は8例全例が頸椎損傷であった。

交通事故の種類でみると、四輪車に乗車中が今回40% (前回60%)、バイク運転中28% (同24%)、自転車運転中24% (同10%)、歩行者8% (同6%)であった。四輪車運転中の事故割合が前回調査の3分の2に減少していて、このことが交通事故による脊髄損傷が減った主な理由であり、車の安全性や向上や酒酔い運転取締り強化等による効果の可能性が考えられた。それと反対に自転車の割合増加が顕著であった。

スポーツ事故の種類では、前回の調査で登録数の上位を占めた水飛び込みとラグビーが今回調査では見られず、関係団体等による事故予防策等が講じられた結果である可能性も示唆された。今回はスポーツ事故の登録数は8例で、内訳はサーフィン4例、ボディボード3例、スノーボード1例であり、千葉県を地理的条件を反映して海の事故が大半を占めた。

月別発生数とその原因の検討では、6月が少ないことを除けば春から秋にかけての発生が多い傾向にあった。原因については、海のスポーツが7月から10月にかけて発生している以外は特徴的な傾向は認められなかった。

【まとめ】

- 1、2008年における千葉県の脊髄発生疫学調査を行い前回調査(1990~1992)と比較した。
- 2、推定発生率はFrankel A-Dで人口百万対39.1人であり、前回調査とほぼ同じであった。
- 3、高齢者で骨症の無い頸髄損傷例が著しく増加して

いた。

4、原因としては交通事故が減り、転倒が増加していた。また交通事故では四輪車に乗車中の事故の減少と自転車事故の増加が顕著であった。

5、スポーツでは飛び込みとラグビーが著減し、サーフィンとボディボードが多かった。

6、今後の脊損予防対策では、高齢者の転倒等による頸髄損傷を防ぐことが最重要課題と考えられた。

CERVICAL SPINE

Soft-Tissue Damage and Segmental Instability in Adult Patients With Cervical Spinal Cord Injury Without Major Bone Injury

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Study Design. A retrospective imaging and clinical study.

Objective. To evaluate the extraneural soft-tissue damage and its clinical relevance in patients with traumatic cervical spinal cord injury (SCI) without major bone injury.

Summary of Background Data. To date, various kinds of cervical discoligamentous injuries have been demonstrated on magnetic resonance images in patients with SCI without bony injury. However, it has not been clear whether these magnetic resonance imaging abnormalities are actually related to spinal segmental instability and the patients' neurological status.

Methods. Eighty-eight adult patients with acute traumatic cervical SCI without major bone injury were examined by flexion-extension lateral radiographs and magnetic resonance images within 2 days after trauma. We excluded patients with flexion recoil injury; therefore, most of the patients included were considered to have sustained a hyperextension injury. Instability of the injured cervical segment was defined when there was more than 3.5-mm posterior translation and/or more than a 11° difference in the intervertebral angle between the site of interest and adjacent segments. The neurological status was evaluated according to the American Spinal Injury Association motor score.

Results. On magnetic resonance images, the damage to the anterior longitudinal ligament and intervertebral disc were apparent in 44 and 37 patients, respectively. Various degrees of prevertebral fluid collection (vertebral hyperintensity) were demonstrated in 76 patients. These magnetic resonance imaging abnormalities were significantly associated with initial cervical segmental instability as judged by flexion-extension radiographs. Interestingly, the American

Spinal Injury Association motor score had a significant association with either magnetic resonance imaging abnormalities or segmental instability but not with the cervical canal diameter.

Conclusion. A considerable proportion of the patients with traumatic cervical SCI without major bone injury were shown to have various types of soft-tissue damage associated with cervical segmental instability at the early stages of the injury. The severity of paralysis greatly depended on these discoligamentous injuries.

Key words: cervical spinal cord injury, MRI, segmental instability.
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A substantial number of adult patients experiencing acute traumatic cervical spinal cord injury (SCI) do not show any noticeable bony injury or dislocation on initial radiological survey.^{1–4} Although some of these cases are due to flexion-distraction injury, which has been spontaneously reduced (recoil flexion injury),⁵ most of the cases are thought to be neck extension-type injuries.^{1,2,6–9} If patients have pre-existing cervical canal stenosis caused by either cervical spondylosis or ossification of the posterior longitudinal ligament (PLL), sudden neck extension may produce severe cord compression between the bulging *ligamentum flavum* and the posterior osteophytes of the vertebral body. This kind of cervical SCI typically shows central cord syndrome, and it is not necessarily accompanied by extraneural soft-tissue damage, such as a disruption of the anterior/posterior longitudinal ligament (ALL/PLL) or the intervertebral disc.^{7,8} The other type of neck extension injury is caused by more intense extension force applied to the cervical spine, in which the SCI takes place by momentary nipping between the posteroinferior border of the posteriorly displaced vertebral body above and the edge of the subjacent lamina.^{6,10,11} Displaced vertebra is usually spontaneously reduced, leaving either no abnormality or only a subtle roentgenographic abnormality.⁶

Many previous studies have been published concerning adult cervical SCIs without major bony injury or dislocation, using various nomenclatures—hyperextension-dislocation,¹¹ SCI without radiographical abnormality in adults,^{3,4,12–14} SCI without radiographical evidence of trauma,^{2,15,16} cervical SCI without bony injury,^{17,18} occult cervical spine injury,¹⁹ cervical

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SCI without bone and disc injury,²⁰ and so forth. In addition, at least part of the distraction/extension injury of the cervical spine in the classification of Allen *et al*²¹⁻²³ would be included in this category, in which various extents of discoligamentous failure of the injured segment are thought to occur. More recently, Bono *et al*²⁴ defined cervical hyperextension injury with destruction of the anterior tension band as an anterior distraction injury in their subaxial cervical injury description system. Thus, along with various nomenclature, a broad spectrum of injury patterns and clinical symptoms was included in these studies, but it is often difficult to infer the amount of stress present at the time of trauma as well as the resultant damage of soft-tissue structures by the plain lateral radiographs or computed tomographic scan of the cervical spine.

Magnetic resonance imaging (MRI) is the most powerful tool to assess discoligamentous injuries of the spine in the patients with SCI without bony injury. ALL, PLL, and intervertebral disc disruptions, as well as disc herniation have been reported in patients with cervical hyperextension injury.^{11,12,14,19,25-27} Some studies have also demonstrated prevertebral hyperintensity by T2-weighted MRI, which presumably reflects prevertebral edema, fluid collection, or hemorrhage.^{11,19,25,27} However, the clinical relevance of these MRI abnormalities of the cervical soft tissues has not yet been clearly demonstrated. The purpose of this study was to evaluate whether the cervical soft-tissue abnormalities detected on magnetic resonance (MR) images are actually associated with segmental instability as judged by flexion/extension lateral radiographs obtained just after the trauma, and, to examine whether the damage to these extraneural soft tissues and the resultant segmental instability affect the severity of paralysis in the patients with cervical SCI without any major bone injury or dislocation.

MATERIALS AND METHODS

Patients experiencing acute SCI with no or minor bony injury who were admitted to our hospital within 2 days after trauma were included in this study. A small avulsion fracture of the vertebral body, spinous process fracture, or bone bruise in the vertebral body without noticeable vertebral collapse was considered to be minor bony injury. Any patients who had undergone previous cervical surgery and those who were likely to have recoil flexion injury were excluded. We also excluded patients who had no cord signal changes on MR images to rule out the patients with just a cervical concussion or hysteria. From 1998 to 2009, 88 consecutive patients who met the aforementioned criteria were included in this study. The age of patients at the time of trauma ranged from 33 to 89 years (average, 64 yr), and there were 79 men and 9 women. Although, the reason for the marked male predominance was unclear, various environmental factors, such as the occupations, sports activities, driving style, and alcohol consumption by the men, may have influenced their susceptibility.

All patients were examined by careful flexion-extension lateral radiographs by spine surgeons at the time of hospital admission using a roentgen fluoroscope. All patients were awake during this procedure, and no neurological

deterioration associated with this procedure was noted. By applying gentle flexion force to the patient's neck, spontaneously reduced flexion-distraction injury (recoil flexion injury) was easily reproduced as an abnormal local kyphosis and slippage of the injured segment. These initial dynamic radiographs therefore enabled us to exclude recoil flexion injury in the differential diagnosis. Posterior translation of the cephalad vertebral body at the site of injury in the neck extension position as well as sagittal angulation of 2 consecutive vertebrae at the site of injury were measured. According to the criteria of White *et al*,²⁸ posterior translation of more than 3.5 mm and/or more than 11° angular difference compared with adjacent segments was considered to indicate clinical segmental instability. MRI was also performed in all the patients at hospital admission. We routinely performed serial MRIs for more than a month to identify clearly the delayed spinal cord signal changes after SCI. The level of cord signal change, as well as any apparent discoligamentous damage, was used to identify the level of the injured segment(s). Attention was focused on ALL disruption, intervertebral disc disruption, and prevertebral hyperintensity (Figure 1A). The area of prevertebral hyperintensity was measured using the ImageJ software program (National Institute of Health, Bethesda, MD; Figure 1B).

The patients' neurological status was evaluated by the American Spinal Injury Association (ASIA) motor score at hospital admission, 1 month after trauma, and at the final

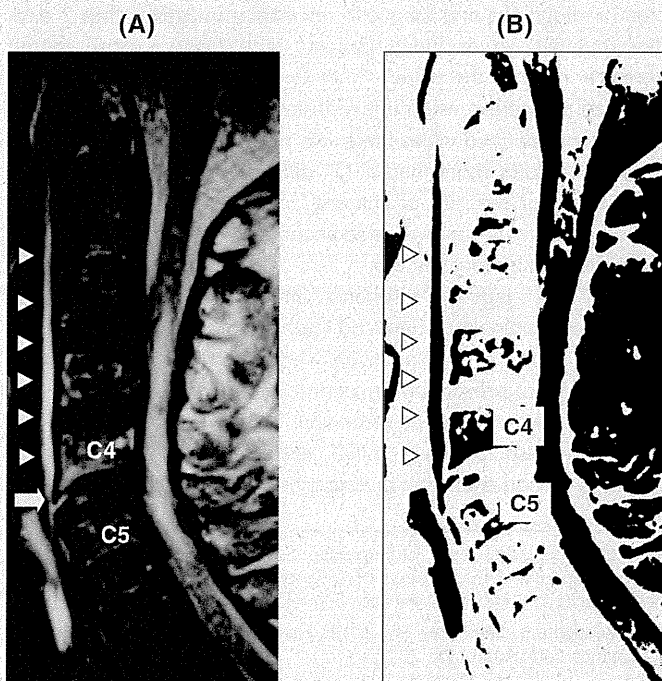


Figure 1. (A) A T2-weighted magnetic resonance image obtained a day after trauma. The anterior longitudinal ligament and disc disruptions are evident at the C4–C5 segment (arrow). There is prevertebral hyperintensity, presumably reflecting fluid collection or hemorrhage (arrowheads). (B) The area of prevertebral hyperintensity (arrowheads) was measured using the ImageJ software program.

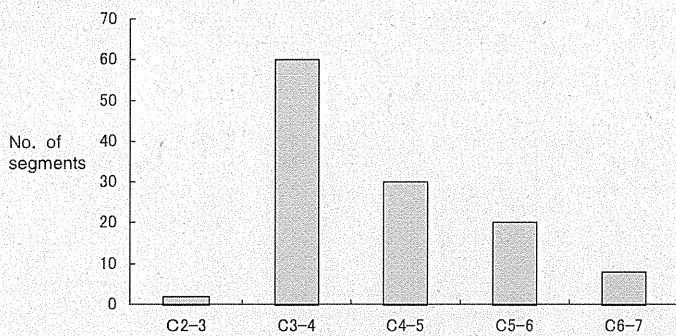


Figure 2. The cervical segment that was suspected to be injured was examined by magnetic resonance image (the site of spinal cord intensity change and/or the apparent discoligamentous damage). C3–C4 was the most frequently injured segment.

follow-up. The average follow-up period was 6 months (range, 1–17 mo) after trauma. All neurological evaluations were done by spinal surgeons.

The relationship between each MRI finding and segmental instability was analyzed using the χ^2 test. Comparisons of the ASIA motor scores among patients regarding the presence/absence of each MRI finding and segmental instability were performed using Student *t* test. The relationships between the ASIA motor scores and either the area of prevertebral hyperintensity or the spinal canal diameter of the injured segment were analyzed using Pearson product moment correlation coefficient (*r* value). All data were analyzed using the JMP 8.0.2 software program (SAS Institute Inc., Cary, NC) and significance was set at 5%.

RESULTS

MRI Findings

The levels of SCI determined on the basis of cord signal change or apparent discoligamentous injuries on MR images are shown in Figure 2. C3–C4 was the most frequently injured segment, followed by C4–C5 and C5–C6. Among the 88 patients, ALL disruption and intervertebral disc disruption were identified in 44 patients (50%) and 37 patients

(42%), respectively. Prevertebral hyperintensity was identified in 76 patients (86%). The area of prevertebral hyperintensity ranged from 0 cm² to 11.5 cm² (average, 2.6 cm²). All patients presenting with either ALL disruption or disc damage were shown to have prevertebral hyperintensity.

Radiographical Findings

Forty-two patients (48%) showed more than 2-mm posterior translation in the neck extension position. Twenty-eight patients (32%) exhibited more than 3.5-mm posterior translation and/or more than 11° angular deformity than in adjacent segments, indicating that about one-third of the patients were considered to have cervical segmental instability, according to the criteria of White *et al.*²⁸

Relationship Between MRI Abnormalities and Segmental Instability

As shown in Table 1, among the 44 patients who were demonstrated to have ALL disruption on MR images, 23 patients were shown to have segmental instability, whereas only 5 of the 44 patients without ALL disruption were shown to have segmental instability. Thus, ALL disruption confirmed by MRI was significantly associated with segmental instability as judged by flexion-extension radiographs (*P* < 0.001). A similar association was found between intervertebral disc damages on MR images and segmental instability (*P* < 0.01). The average area of prevertebral hyperintensity in patients who had segmental instability was 4.0 cm², whereas that in the patients who did not have segmental instability was 2.0 cm². The difference in the area of prevertebral hyperintensity between the 2 groups was significant (*P* < 0.001), thus suggesting that the area of prevertebral hyperintensity reflects the severity of discoligamentous injuries.

Impact of Cervical Soft-Tissue Damage on the Patients' Neurological Status

As shown in Figure 3A, patients in whom ALL disruption was detected on MR images had significantly lower ASIA motor scores than those without ALL disruption on admission and at 1 month after trauma. Similarly, patients showing disc damage on MR images had significantly lower ASIA

TABLE 1. Associations Between Cervical Segmental Instability and MRI Findings of Soft Tissue Damages

		ALL Disruption (No. of Patients)		Disc Damage (No. of patients)		Average Area of Prevertebral Hyperintensity (cm ²)
		+	–	+	–	
Segmental instability	+	23	5	18	10	4.0
	–	21	39	19	41	2.0
		44	44	37	51	

The cervical segmental instability of the injured segment was defined as follows: more than 3.5-mm posterior translation of the superior vertebral body and/or a more than 11° angular difference compared with adjacent intervertebral spaces. The presence of either ALL disruption or disc damage on magnetic resonance image was significantly associated with that of the cervical segmental instability (*P* < 0.001, *P* < 0.01; χ^2 test). The area of prevertebral hyperintensity in patients with segmental instability was significantly larger than that in patients without segmental instability (*P* < 0.001; Student *t* test).

ALL indicates anterior longitudinal ligament.

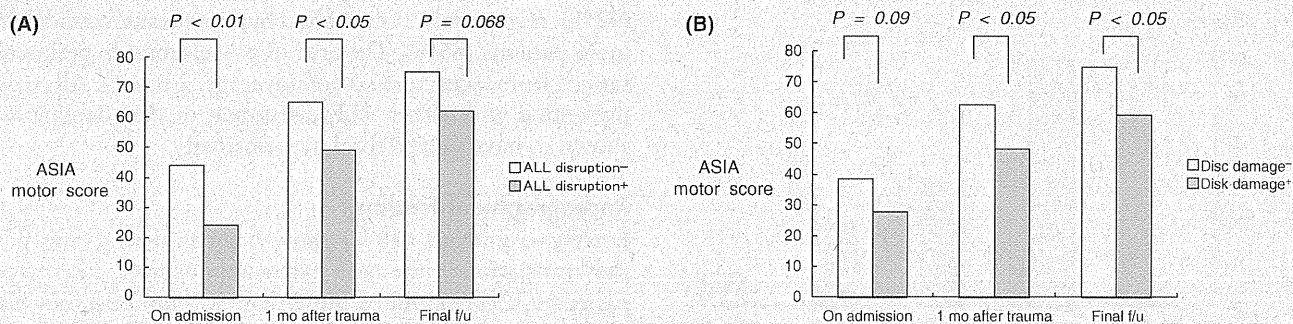


Figure 3. (A) The average ASIA motor score of the patients with or without ALL disruption. A statistically significant difference in the ASIA motor score was seen on admission and 1 month after trauma. (B) The average ASIA motor score of the patients with or without disc damage. A statistically significant difference in the ASIA motor score was seen 1 month after trauma and at the final follow-up. ASIA indicates American Spinal Injury Association; ALL, anterior longitudinal ligament.

motor scores than those without disc damage (Figure 3B). In addition, the area of prevertebral hyperintensity had a significant negative correlation with the ASIA motor score, indicating that patients who had larger prevertebral hyperintensity tended to show severe paralysis (Figure 4). All these findings indicate that the soft-tissue damage present at the time of trauma strongly affected the patients' neurological status.

In accordance with these findings, patients showing cervical segmental instability on admission had a significantly lower ASIA motor score at each time point than those without segmental instability (Figure 5).

Relationship Between the ASIA Motor Score and Cervical Canal Diameter

Next, we investigated the relationship between the ASIA motor score and the cervical canal diameter at the injured site to see how cervical canal stenosis affects a patient's neurological status. As shown in Figure 6, there was no relationship between the cervical canal diameter and the ASIA motor score at 1 month after trauma. The same was true of the ASIA motor score on admission and at the final follow-up (data not shown).

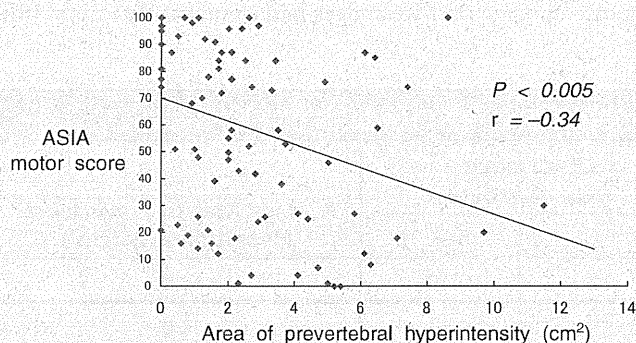


Figure 4. The relationship between the ASIA motor score and the area of prevertebral hyperintensity. There was a significant negative relationship between the 2 parameters, indicating that a higher prevertebral hyperintensity area on magnetic resonance image was associated with more severe paralysis. ASIA indicates American Spinal Injury Association.

DISCUSSION

In patients experiencing acute traumatic cervical SCI without any major bone injury or dislocation on the initial radiographical survey, 2 possible pathomechanisms are thought to be involved; extension-type injury and flexion-type injury (recoil flexion injury). By obtaining careful flexion-extension radiographs at the time of admission, we could exclude patients with spontaneously reduced recoil flexion injury. Therefore, the 88 patients investigated in this study were considered to have sustained neck extension injury. This extension-type cervical SCI can then be further divided into 2 categories. One is patients with pre-existing cervical canal stenosis in whom the spinal cord is compressed between the posteroinferior edge of the vertebra (or protruded disc) and the wrinkled ligamentum flavum in the neck hyperextension position.⁷ In this situation, sudden (but physiological) motion of the neck may produce spinal cord compression severe enough to cause SCI without causing any substantial damage to the discoligamentous structures. The other type of hyperextension injury is caused when patients receive more intense neck extension force resulting in various extents of momentary vertebral displacement with discoligamentous injuries. Taylor and Blackwood⁶ first described this type of injury as the hyperextension-type "recoil injury," and Harris and Yeakley¹¹ called this type of injury hyperextension-

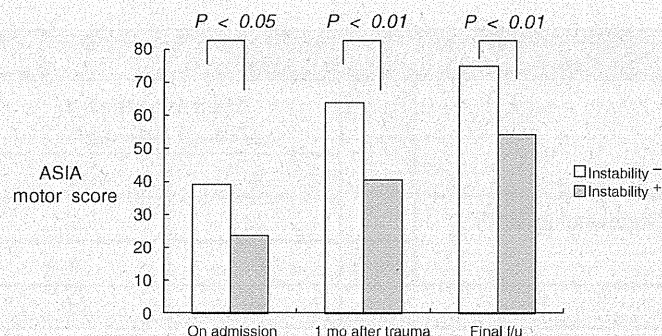


Figure 5. The average ASIA motor score of the patients with or without segmental instability. A statistically significant difference in the ASIA motor score was seen at each time point. ASIA indicates American Spinal Injury Association.

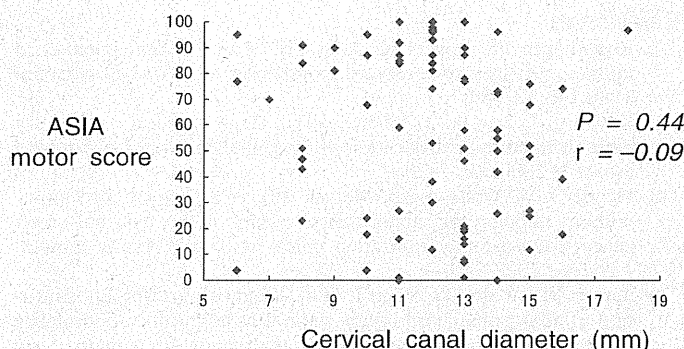


Figure 6. The relationship between the ASIA motor score and the cervical canal diameter at the injured segment. There was no relationship between the 2 parameters, indicating that the severity of the patient's paralysis was independent of cervical canal stenosis. ASIA indicates American Spinal Injury Association.

dislocation without gross displacement on lateral radiographs. In the actual clinical setting, however, there would be many cases in between these 2 categories, and the neurological manifestations would vary from typical central cord syndrome to more severe transverse cord syndrome, depending on the patients' pre-existing conditions and the type of trauma sustained. This heterogeneity concerning traumatic cervical SCI without bony injury is one of the reasons why there has been some confusion about the nomenclature and definition of this type of injury.

For the patients with traumatic cervical SCI without noticeable bony injury on initial radiographs, information on potential discoligamentous injuries and resultant segmental instability, as well as its clinical implications, is important for treatment decision making and the prediction of a patient's prognosis. In this study, we clearly showed that many of the patients without bony injury actually had discoligamentous injuries that were associated with segmental instability. The percentages of patients in whom ALL disruption and disc injury were detected on MR images were 50% and 42%, respectively. These percentages may be underestimated, because it is difficult to accurately identify ALL and/or disc disruptions by MRI. Malham *et al*²⁹ compared the MRI findings of cervical discoligamentous injuries with surgical findings and found that the sensitivity of ALL and disc injury were only 0.48 and 0.81, thus indicating that only 48% of ALL injuries and 81% of disc injuries detected surgically were evident on MR images. As a result, even more cases with discoligamentous injuries in our study would thus be expected to be difficult to identify by MRI. The fact that 86% of the patients in this study had prevertebral hyperintensity, which was thought to reflect prevertebral fluid collection or hemorrhage due to soft-tissue damage, would support this idea, and it seems plausible that most of the patients with traumatic cervical SCI without any major bone injury experience various degrees of discoligamentous injuries at the time of trauma. The high frequency of prevertebral hyperintensity observed in this study is in marked contrast to previous studies evaluating patients who sustained whiplash injury without paralysis.^{30,31} Kongsted *et al*³¹ reported that only 3

of 178 patients (1.7%) who had acute neck symptoms without paralysis after a rear end or frontal car collision showed prevertebral edema on MRI. These facts indicate that if there is no prevertebral hyperintensity in the patients with hyperextension neck injury, the amount of extension force applied to the cervical segments at the time of injury is considered to be relatively small, resulting in no or minimal clinical damage to discoligamentous structures. If a patient who sustained neck injury has an apparent neurological deficit but no prevertebral hyperintensity on MRI, it is necessary to carefully re-evaluate the patient's history and neurological status to rule out acute deterioration of pre-existing cervical spondylosis.

Obtaining flexion-extension radiographs of the patients with cervical SCI without major bone injury can be completely safe as long as the patients are awake and the physicians handle the patients' neck carefully while watching a C-arm monitor. We have already used this protocol to examine more than 200 patients who did not have major bone injury, and no neurological worsening related to this procedure has occurred so far. The main advantage of obtaining flexion-extension radiographs is not only that it allows us to identify patients with recoil dislocation injury, which would otherwise have been overlooked even with MRI evaluation, but also that it allows us to evaluate less severe cervical segmental instability precisely. We used a part of the criteria of White *et al*²⁸ (>3.5-mm translation and/or 11° of angulation compared with adjacent segments) for evaluating cervical segmental instability. Their original criteria include other items such as the presence or absence of cord damage, abnormal disc narrowing, positive stretch test, and so forth. Using only a part of their criteria may not be an appropriate manner to evaluate clinical segmental instability. However, the threshold of 3.5-mm translation and/or 11° of angulation were derived from their vigorous experimental studies, and these numbers (3.5 and 11) themselves are considered to have clinical significance. There is currently no better way radiographically to evaluate cervical segmental instability, and all of the patients in our study had varying degrees of cord damages. Therefore, it is a plausible way to use these radiographical criteria for evaluating cervical segmental instability.

By obtaining careful flexion-extension lateral radiographs in the early phase of injury, we could demonstrate that 48% of the patients had more than 2-mm posterior translation of the cephalad vertebral body at the injured segment and 32% of the patients had more than 3.5-mm posterior translation and/or more than 11° of angulation in comparison with the adjacent segments. Considering that patients exhibit some defensive reaction against dynamic neck examination immediately after trauma and because it is difficult for the examiners to ensure that the patients are in the maximum neck flexion and extension positions, it is plausible that there were actually more patients who potentially had initial cervical segmental instability than we identified. Nevertheless, our study clearly demonstrated that the above-mentioned MRI findings of discoligamentous injuries were significantly related to initial cervical segmental instability. Patients with

either ALL disruption or disc damage on MR images had a significantly higher risk of segmental instability. Furthermore, the area of prevertebral hyperintensity was strongly associated with segmental instability. Of note was the finding that each of these MRI findings, and segmental instability judged by flexion-extension radiographs, had a strong association with the ASIA motor score. In support of this, Song *et al*³² demonstrated relationship between cervical soft-tissue damage on MR images and presence or absence of SCI in the patients with cervical extension injury. Thus, as more cervical discoligamentous structures are affected at the time of trauma, more spinal cord damage occurs. On the contrary, there was no association between the cervical canal diameter as determined by lateral radiographs and the ASIA motor score. This is in accordance with our previous study of ossification of posterior longitudinal ligament patients with traumatic cervical SCI at C3–C4 level, showing no relationship between the cervical canal diameter of C3–C4 and the ASIA motor score.³³ We recently conducted MRI evaluations on the width of the cervical spinal cord in the patients with cervical SCI without major bone injury and found that there was no relationship between spinal canal compromise as judged by a sagittal view MR image and the ASIA motor score (manuscript in preparation), thus suggesting that the size of the cervical spinal canal has less of a predictive value in evaluating patients' neurological prognosis in the patients with cervical SCI without major bone injury. Taken together, these findings indicate that the severity of paralysis in the patients with cervical SCI without major bone injury mainly depends on the severity of cervical discoligamentous injuries that occur at the time of trauma, and that momentary abnormal displacement of the vertebral body, rather than cervical canal stenosis, is important for determining the patients' prognosis.

In conclusion, this study provides an important perspective concerning the pathophysiology of cervical hyperextension SCI without major bone injury. Eighty-six percent of the patients had varying degrees of prevertebral hyperintensity, and about half of them were shown to have ALL and/or disc injury, both of which were significantly associated with cervical segmental instability. Patients with such discoligamentous insufficiency showed more severe paralysis than those without it, thus suggesting that the severity of paralysis greatly depends on the amount of stress that was given to the injured segment at the time of trauma.

➤ Key Points

- Eighty-eight adult patients with acute traumatic cervical SCIs without major bone injury were evaluated using MR images and flexion-extension lateral radiographs.
- A substantial number of patients showed cervical discoligamentous injuries on MRI, which were associated with cervical segmental instability.
- The patients' neurological status greatly depended on these discoligamentous injuries that occurred at the time of trauma.

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