Spinal Injury in Athletes

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Disclosures: None

“The football fields of our nation have been a vast proving ground or laboratory for the study of tragic neurological sequelae of head and neck trauma in man”

Richard Schneider 1967

Hyperextension or Hyperflexion as Mechanisms for Catastrophic Cervical Spine Injuries

362 J.A.M.A., Aug. 12, 1961

Serious and Fatal Football Injuries Involving the Head and Spinal Cord

Richard C. Schneider, M.D., Edward Reifel, M.D., Herbert O. Crisler, S.B., and Bennie G. Oosterbaan, A.B., Ann Arbor, Mich.

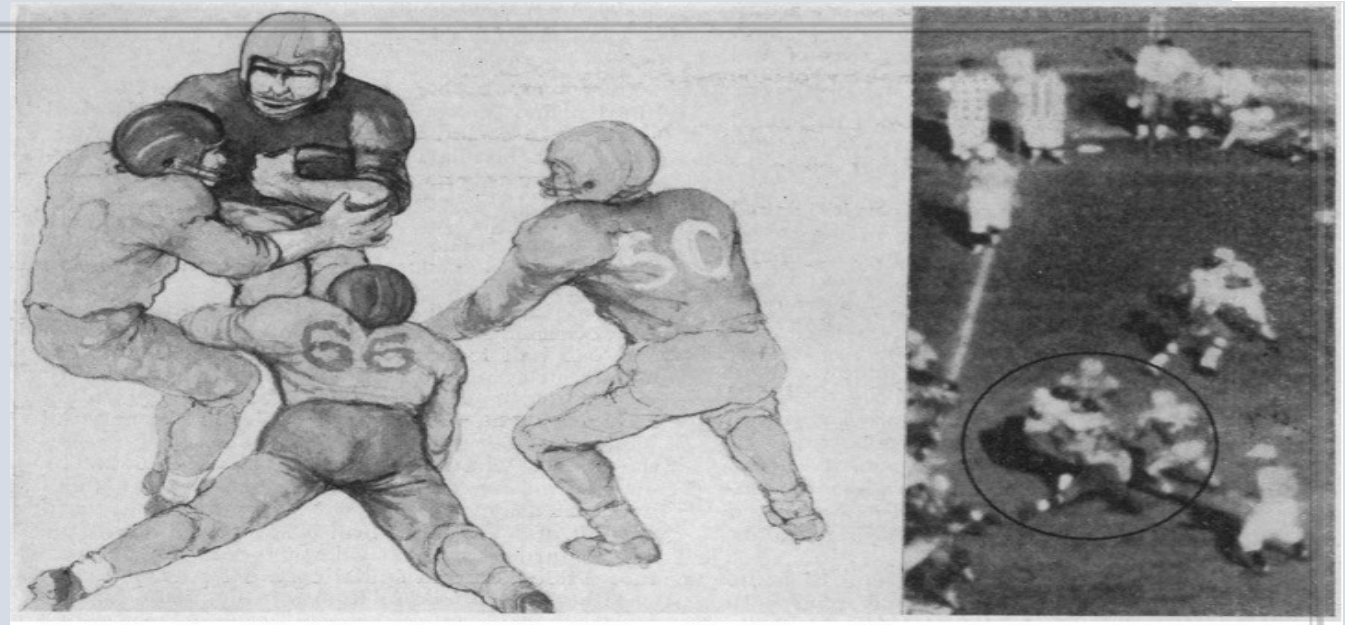

Fig. 1 (Case 3, p. 109).—Left guard's head (No. 66) is struck by ball carrier's knee as he dives to make tackle on second play prior to his retirement from game. (Courtesy Steve Sebo and Dr. F. Crescente.)

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AN EXPERIMENTAL STUDY OF CERVICAL SPINE AND CORD INJURIES

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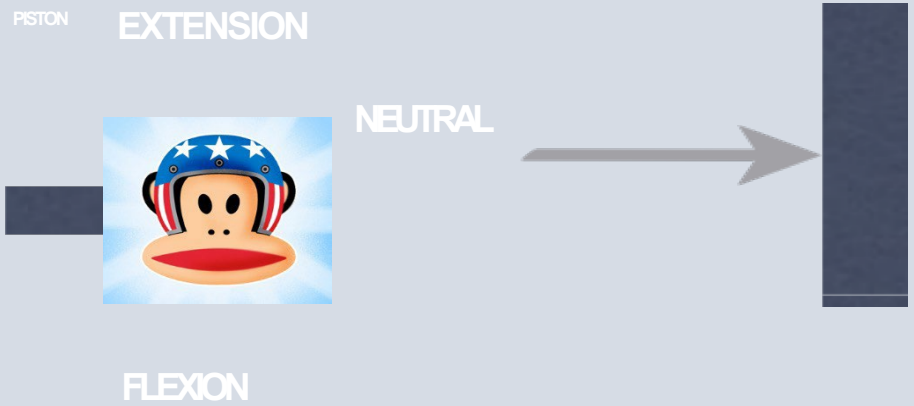
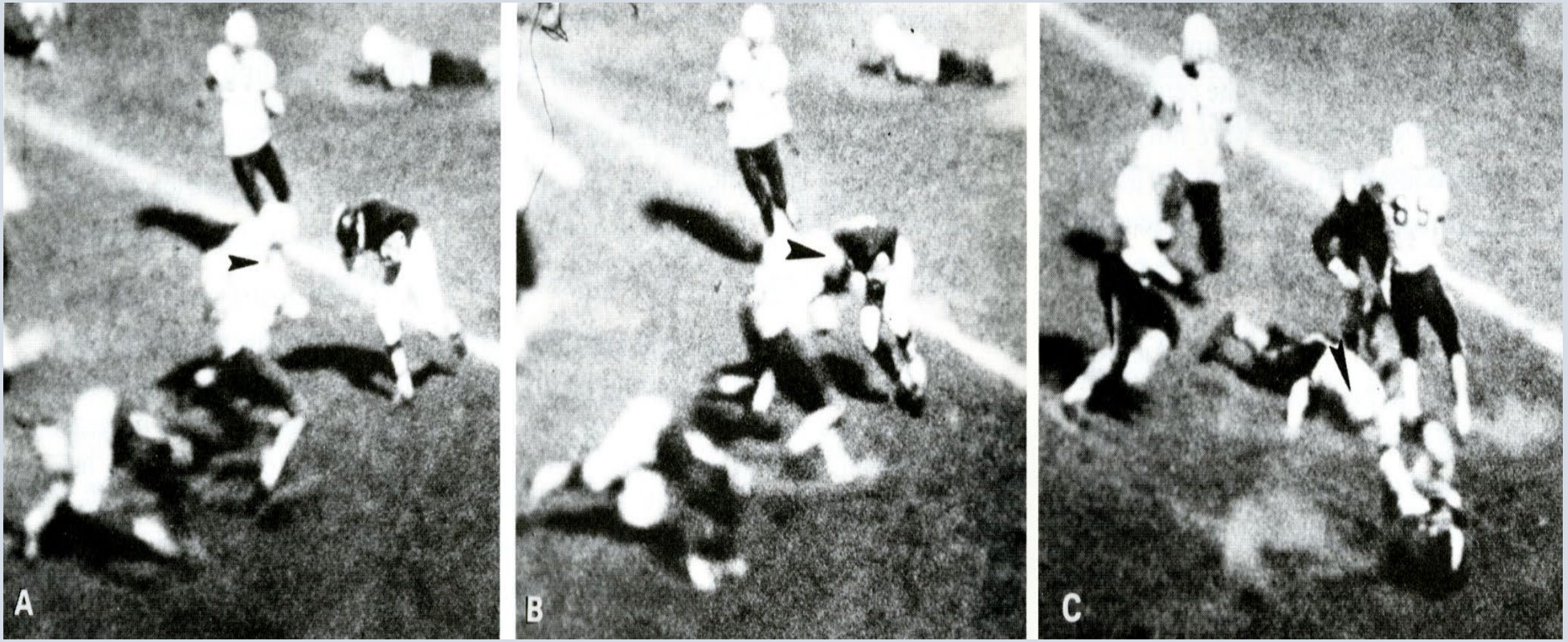
From the Section of Neurosurgery, University of Michigan Medical Center, Ann Arbor

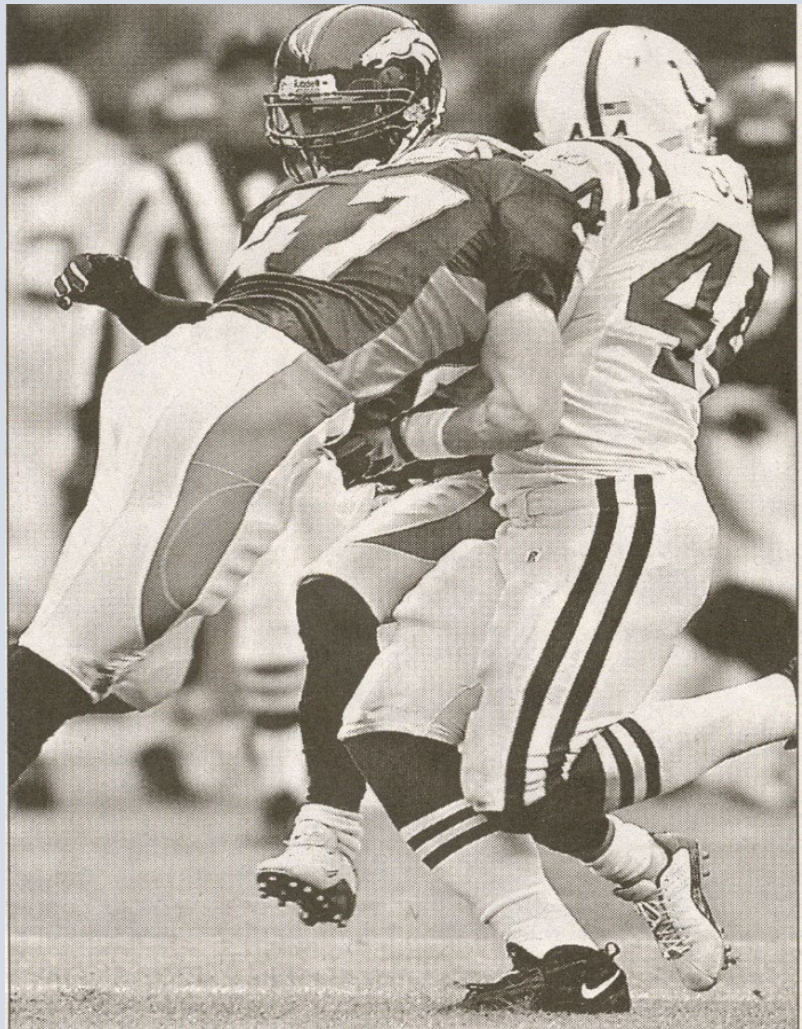


Established common mechanism of injury-head down axial contact

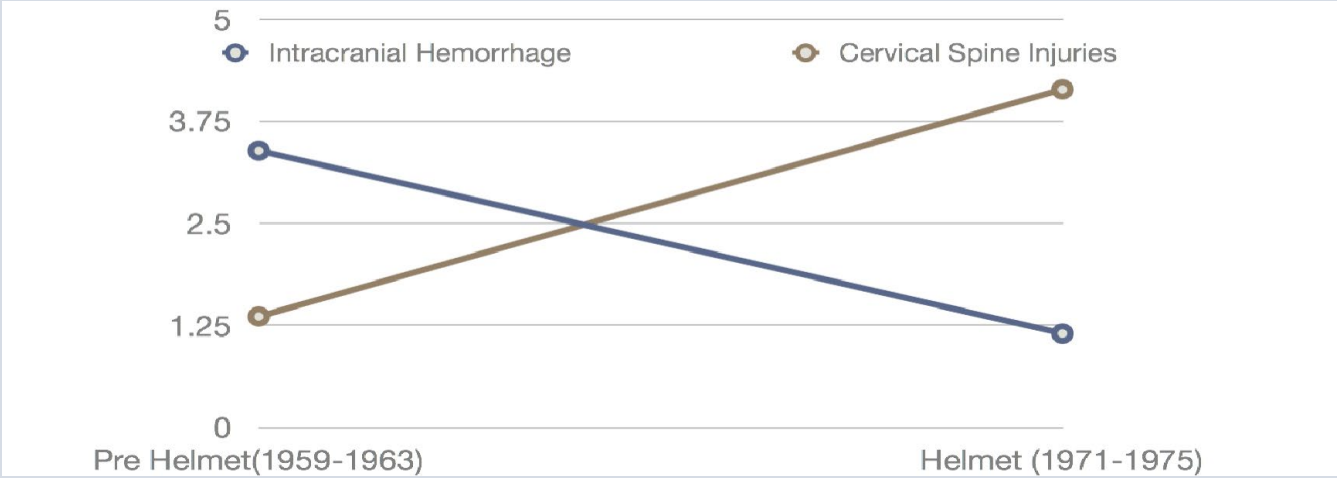


Mechanisms of Injury

- Football: Tackling– vertex impact
- Wrestling:Driving head into opponent/mat
- Ice hockey:Pushing/skating into boards
- Gymnastics: Fall during dismount
- Soccer: head to opponent or ground



Catastrophic Spinal Injuries in Football



RATE INJURY PER 100,000 PARTICIPANTS IN 5YR PERIOD

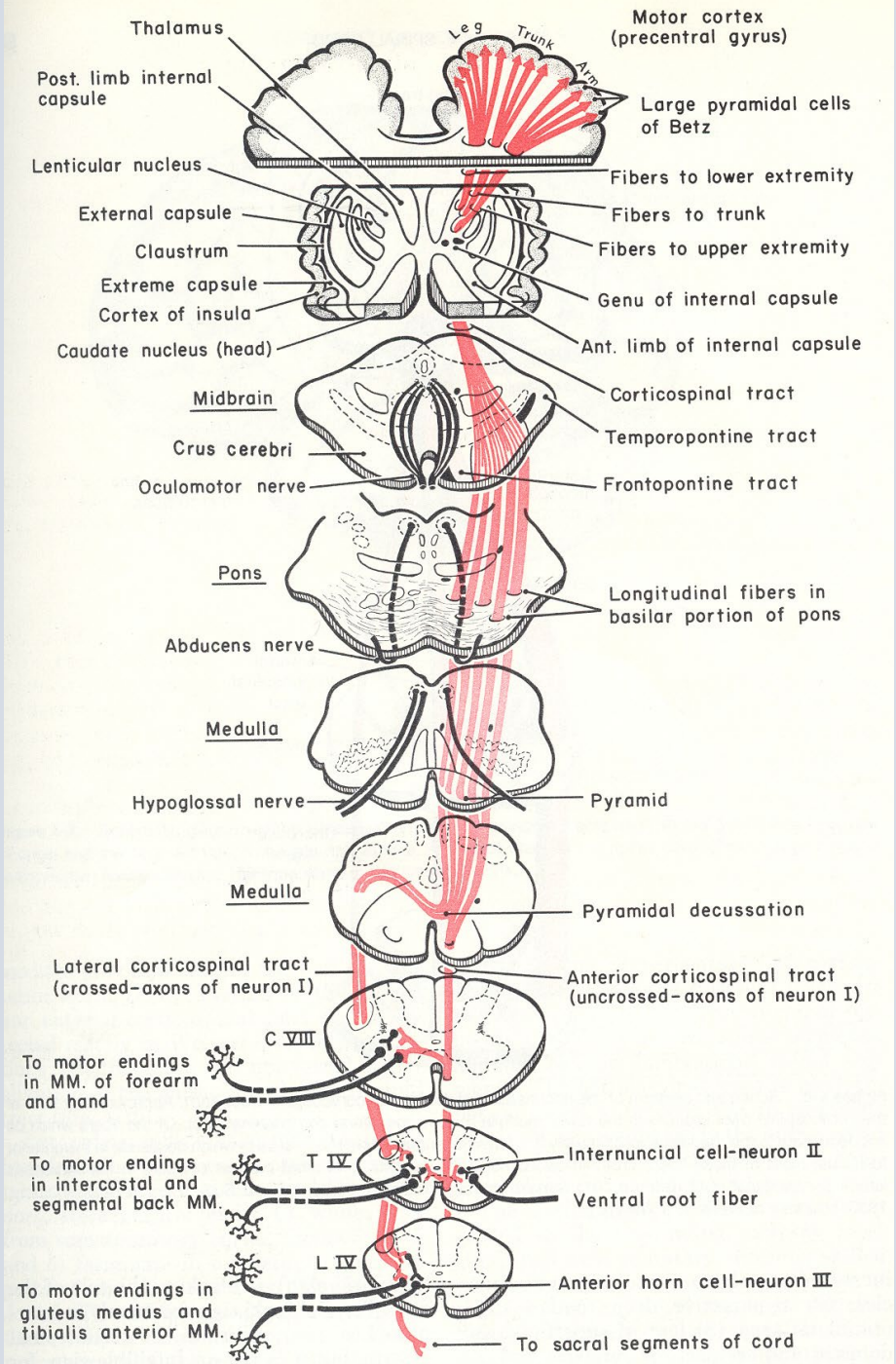
Schneider-6/year 1959-63

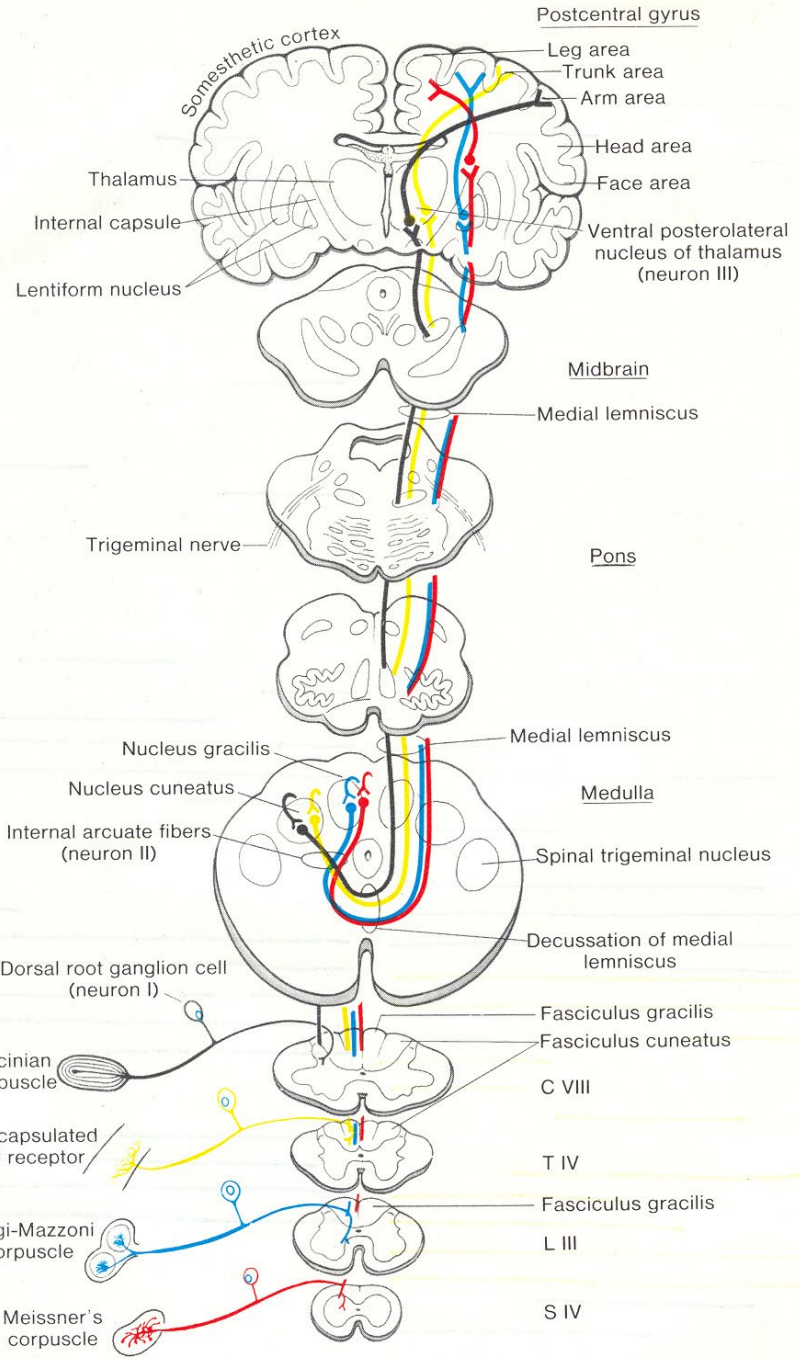
Torg-20/year 1971-75, peaked in 1976 with 34 permanent injuries in 1976

In 1950's without face masks shoulder was main area of initial contact

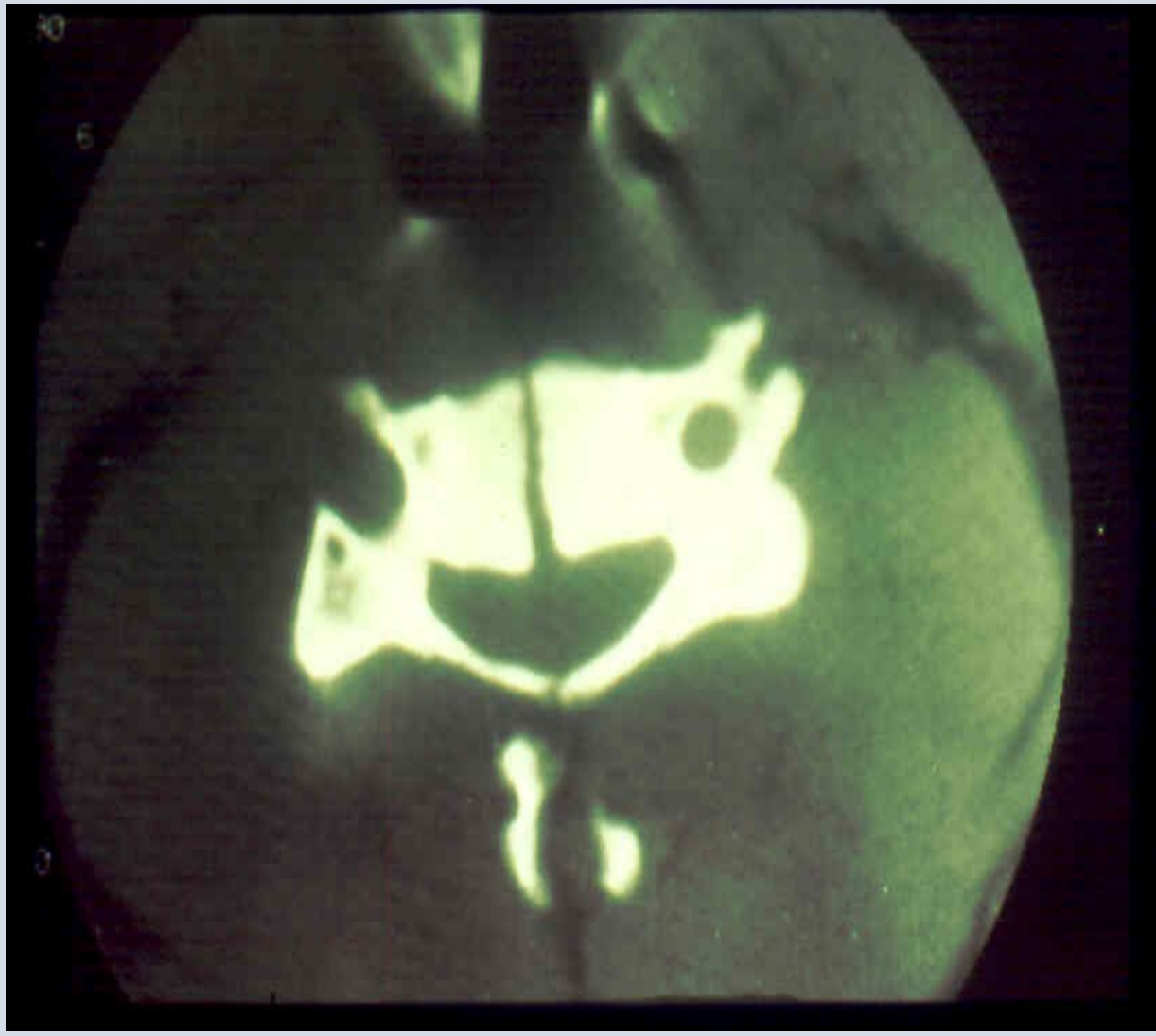
1976: NCAA & NFHSA-prohibited using head as initial point of contact when blocking/tackling

1977-2001: 10/year—71% defense, tackling 69%, defensive back

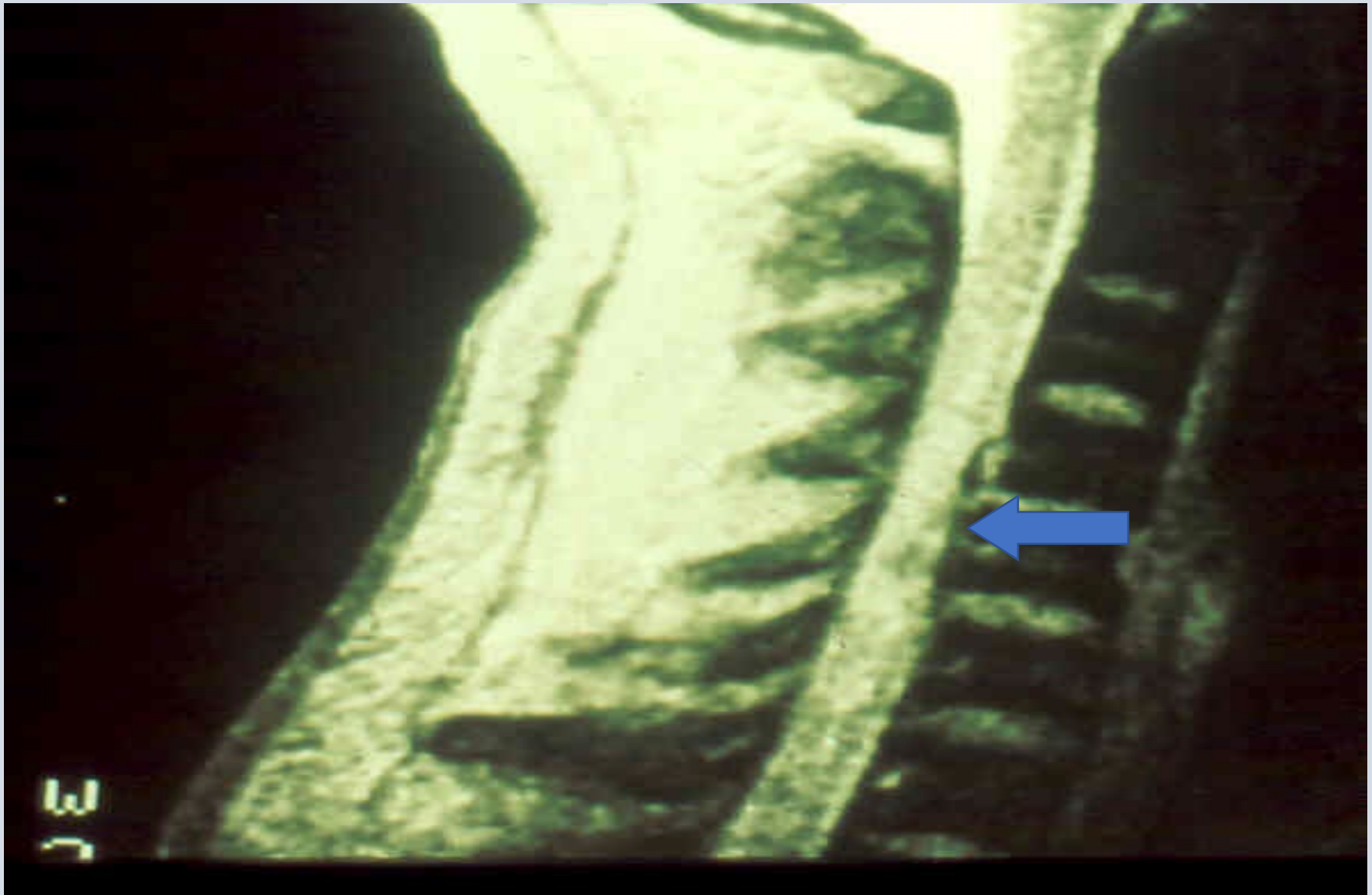

Thalamus
Post. limb internal capsule
Lenticular nucleus
External capsule
Claustrum
Extreme capsule
Cortex of insula
Caudate nucleus (head)
Midbrain
Crus cerebri
Oculomotor nerve
Pons
Abducens nerve
Medulla
Hypoglossal nerve
Medulla
Lateral corticospinal tract (crossed-axons of neuron I)
C VIII
To motor endings in MM. of forearm and hand
T IV
To motor endings in intercostal and segmental back MM.
L IV
To motor endings in gluteus medius and tibialis anterior MM.
Leg
Trunk
Arm
Motor cortex (precentral gyrus)
Large pyramidal cells of Betz
Fibers to lower extremity
Fibers to trunk
Fibers to upper extremity
Genu of internal capsule
Ant. limb of internal capsule
Corticospinal tract
Temporopontine tract
Frontopontine tract
Longitudinal fibers in basilar portion of pons
Pyramid
Pyramidal decussation
Anterior corticospinal tract (uncrossed-axons of neuron I)
Internuncial cell-neuron II
Ventral root fiber
Anterior horn cell-neuron III
To sacral segments of cord

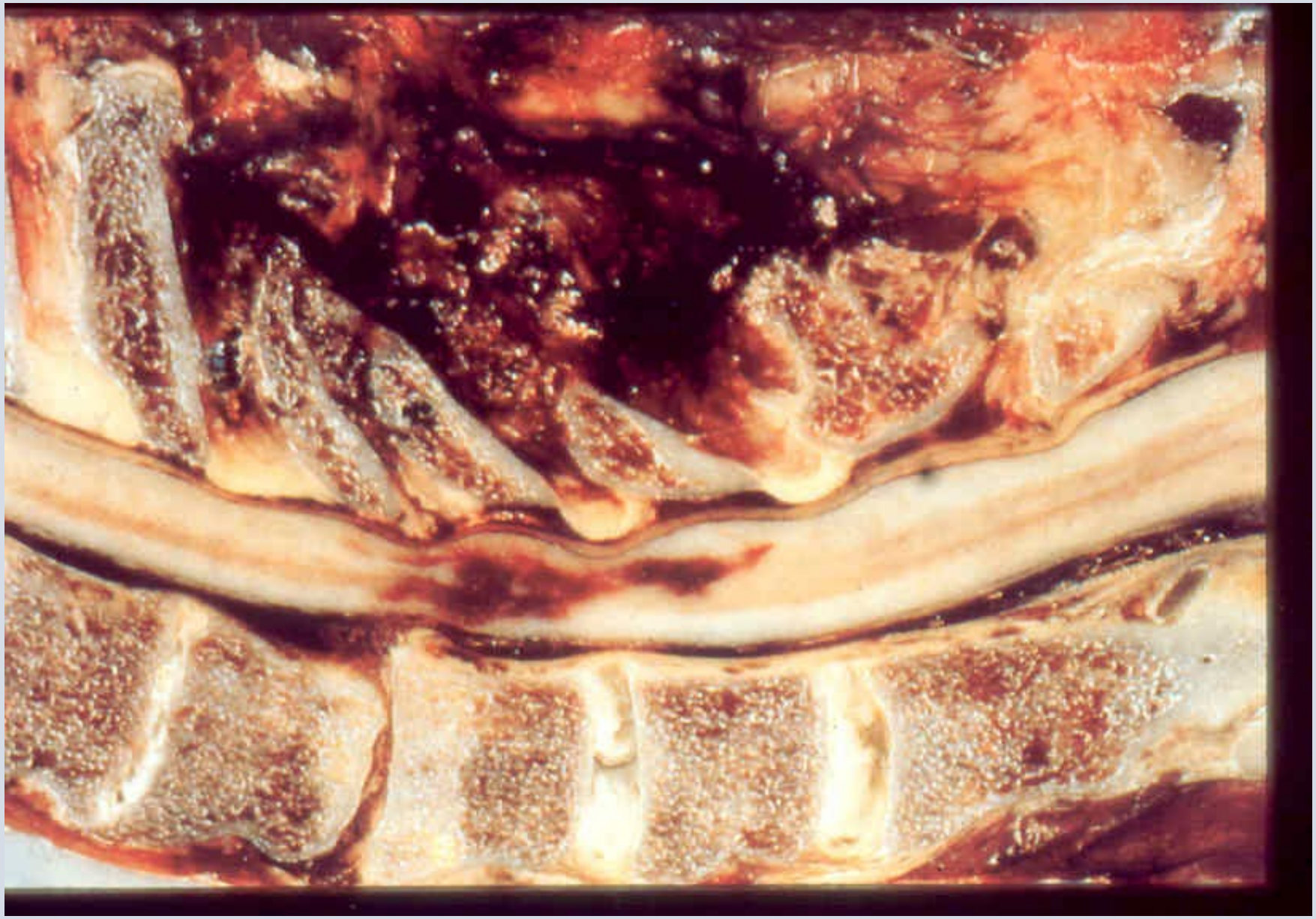

Somesthetic cortex
Postcentral gyrus
Leg area
Trunk area
Arm area
Head area
Face area
Thalamus
Internal capsule
Lentiform nucleus
Ventral posterolateral nucleus of thalamus (neuron III)
Midbrain
Medial lemniscus
Trigeminal nerve
Pons
Medial lemniscus
Nucleus gracilis
Nucleus cuneatus
Internal arcuate fibers (neuron II)
Medulla
Spinal trigeminal nucleus
Decussation of medial lemniscus
Dorsal root ganglion cell (neuron I)
Fasciculus gracilis
Fasciculus cuneatus
Pacinian corpuscle
C VIII
Unencapsulated joint receptor
T IV
Fasciculus gracilis
Golgi-Mazzoni corpuscle
L III
Meissner's corpuscle
S IV

Cervical fracture or fracture-dislocation

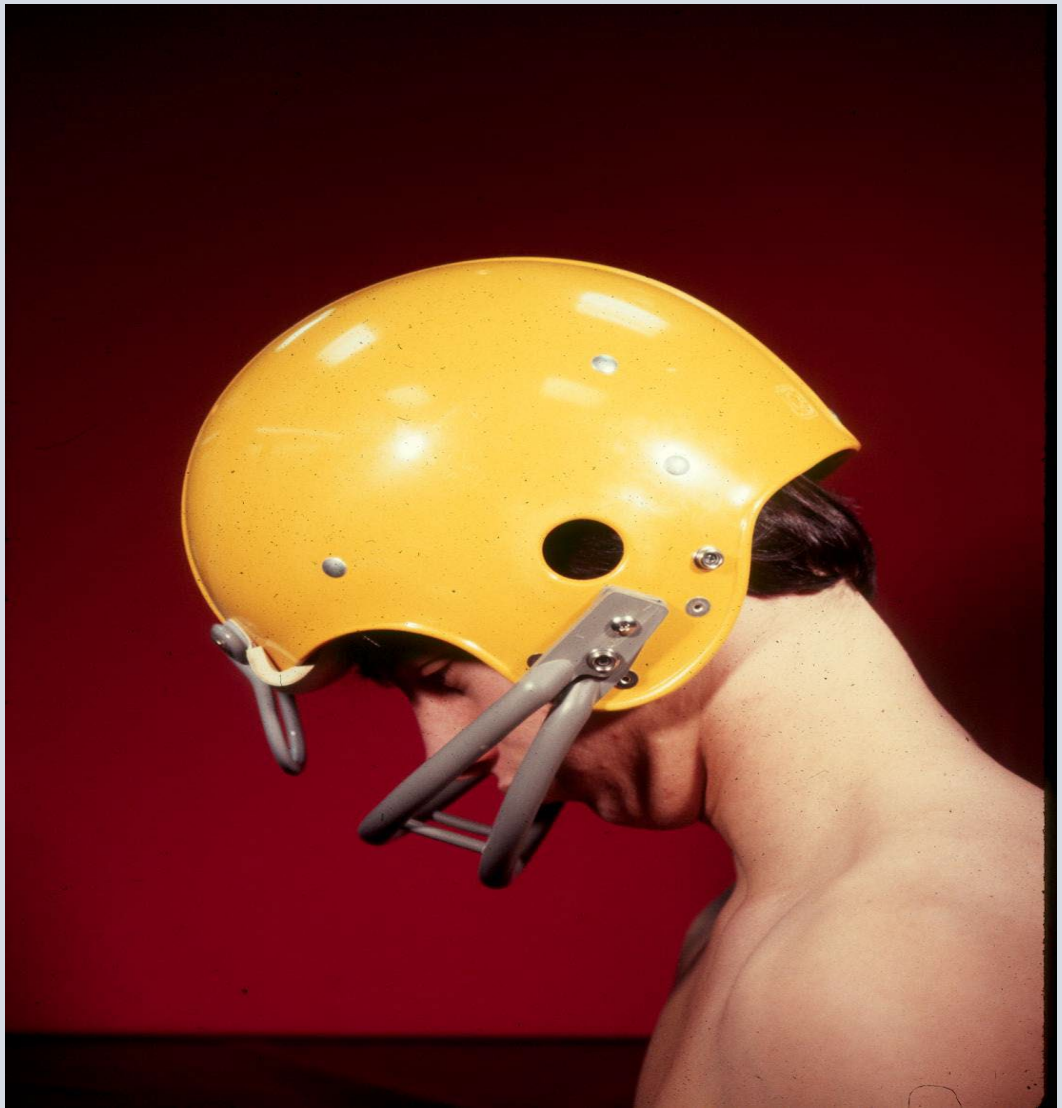


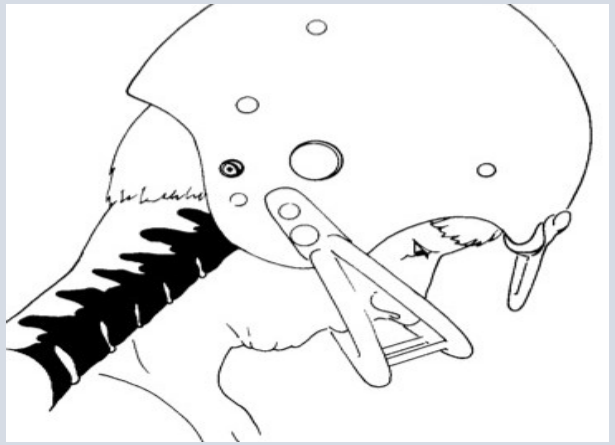
MRI spinal cord injury

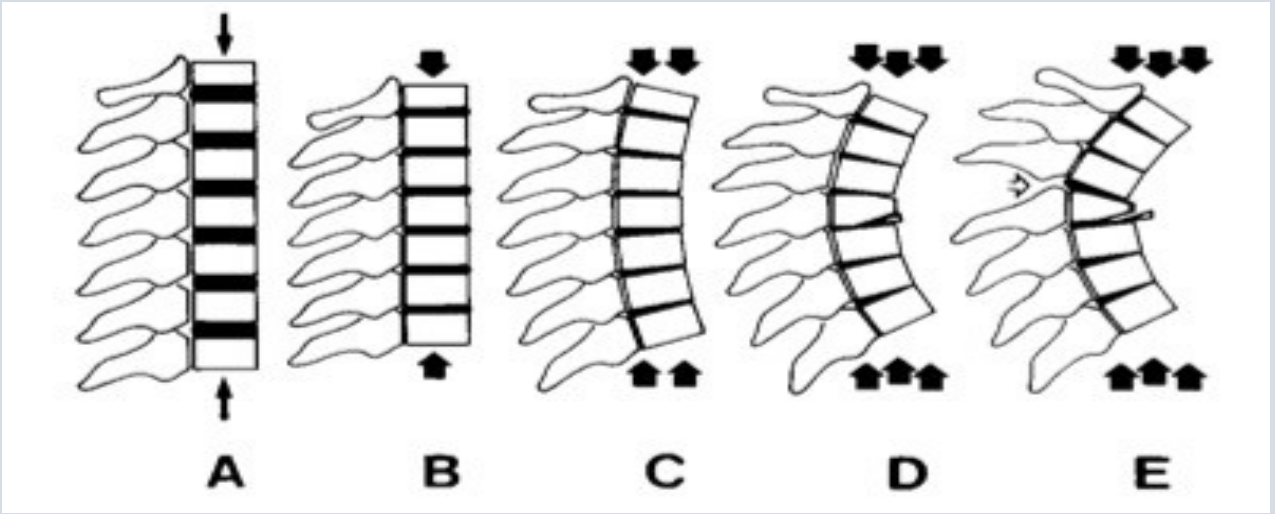




Striking with crown or vertex of helmet-straightened cervical spine-less absorption







Upright position is protective because of normal cervical lordosis. Slight flexion converts spine into a segmented column that bears brunt of impact forces.

TORG ET AL. AM J SPORTS MED 18(1):50-57

Surg Neurol
1990;34:155–8

Diving Injuries of the Cervical Spine

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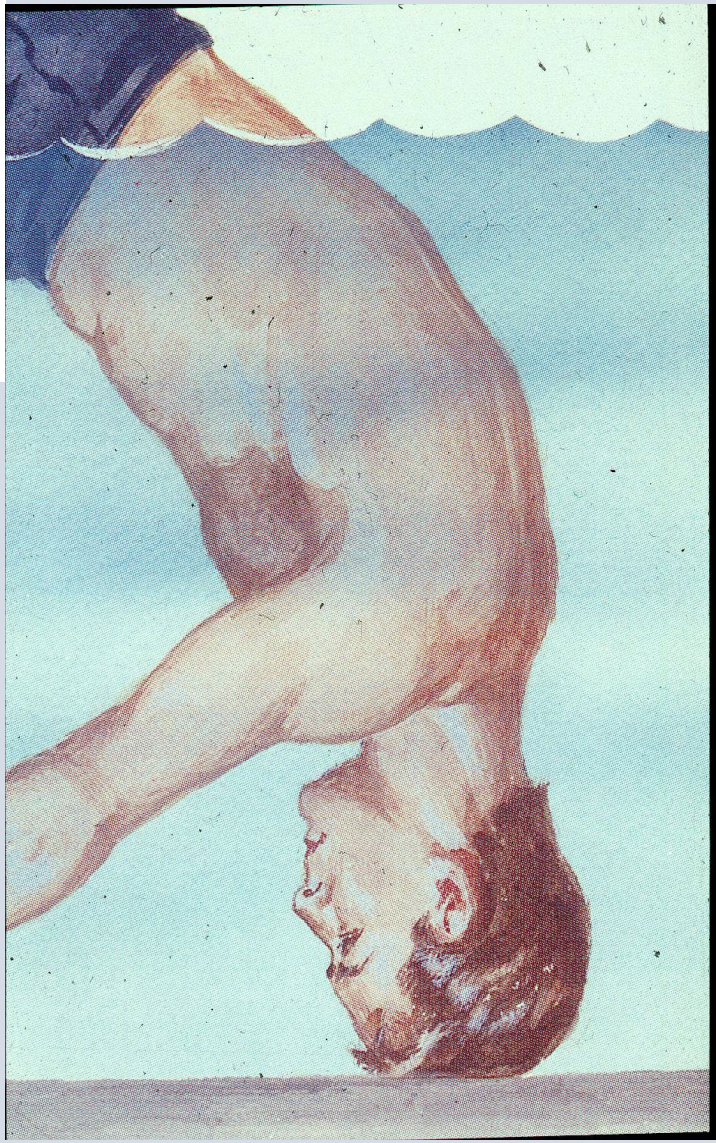
Leonard J. Cerullo, M.D., and Paul R. Meyer, Jr., M.D.

Department of Neurosurgery, Allegheny General Hospital and The Medical College of Pennsylvania, Pittsburgh, Pennsylvania, and Division of Neurological Surgery and Department of Orthopedic Surgery, Northwestern University Medical School, Chicago, Illinois



Ice Hockey-cervical injuries hitting boards, usually driven into from behind

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Experimental and clinical studies

Management of Athletic Injuries of the Cervical Spine and Spinal Cord

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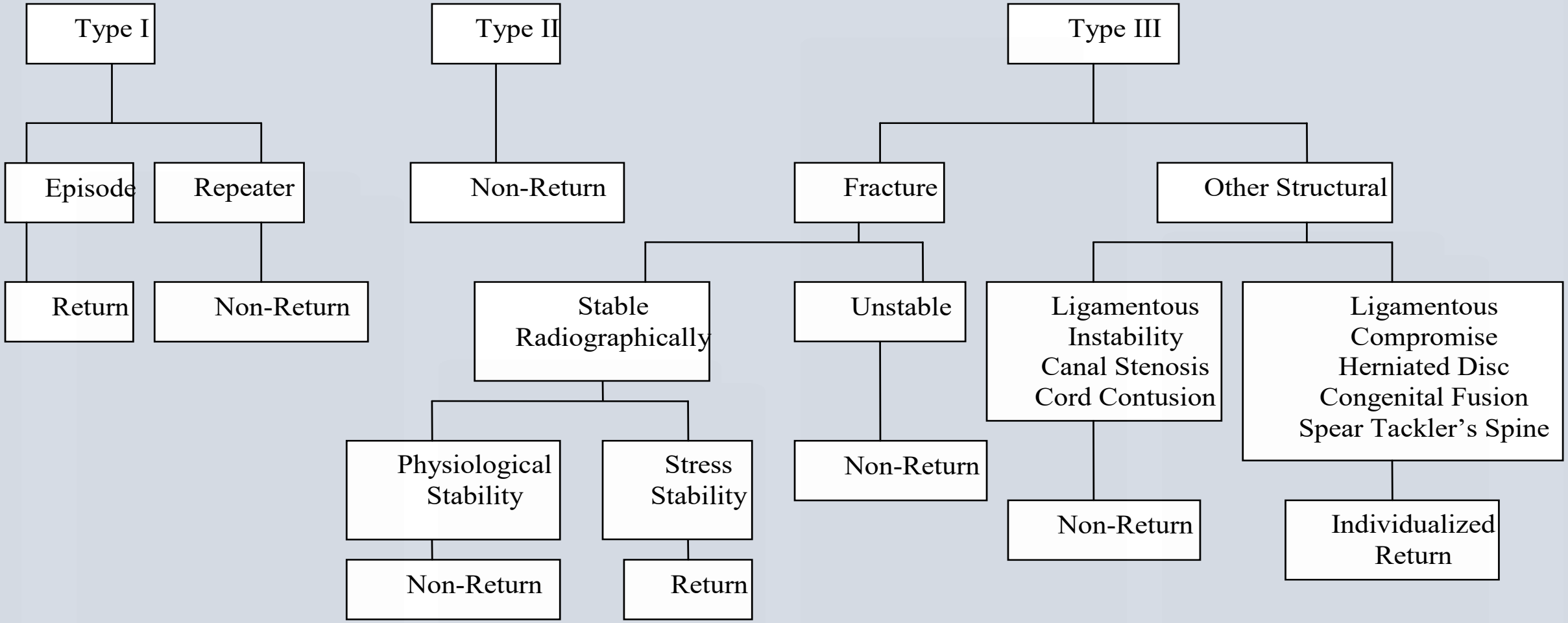
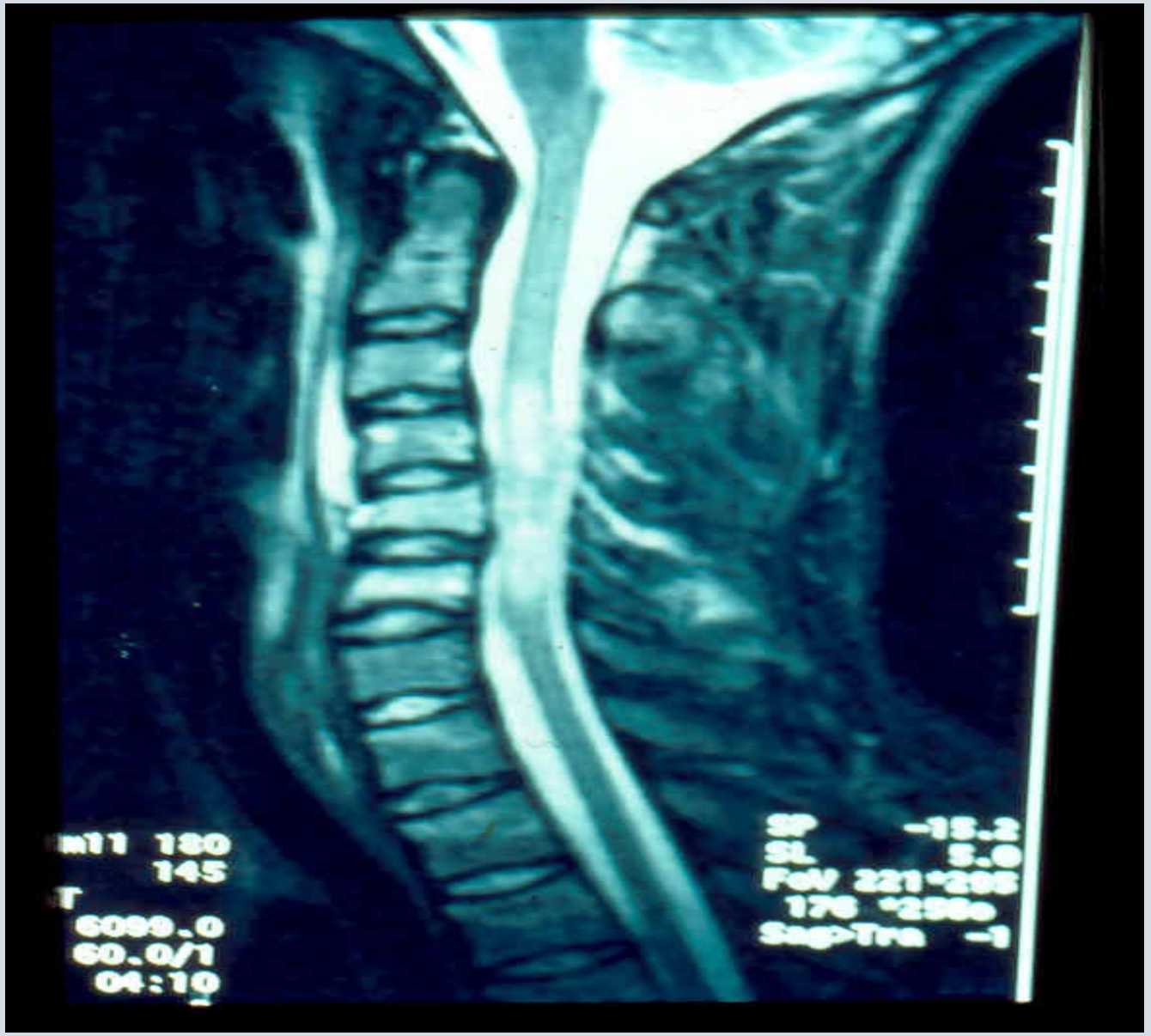
Department of Neurosurgery, Allegheny General Hospital (JEB, MRQ), Pittsburgh, Pennsylvania; Division of Neurosurgery, Barrow Neurological Institute (VKHS), Phoenix, Arizona; Division of Neurosurgery, Northwestern University Medical School (LJC), Chicago, Illinois; and Division of Neurosurgery, University of Alabama at Birmingham (MNH), Birmingham, Alabama

Injuries to the cervical spine among athletes present inherent difficulties, especially in advising for return to contact sports. Experience with the acute care of 63 patients who sustained cervical spine injuries while participating in organized sporting events is analyzed. Forty-five patients had permanent injury to the vertebral column and/or spinal cord, while 18 suffered only transient spinal cord symptoms. Football mishaps accounted for the highest number of injuries, followed by wrestling and gymnastics. Twelve patients had complete spinal cord injury, 14 patients had incomplete spinal cord injury, and 19 patients had injury to the vertebral column alone. The majority of the spinal cord lesions occurred at the C4 and C5 levels, while bony injuries of C4 through C6 predominated. Twenty-five patients required surgical stabilization, and 20 were treated with orthosis only. There was no instance of associated systemic injuries, and hospital complications were few. The mean time of hospitalization was 19.1 days for injured patients and 3.0 days for patients with transient symptoms. A classification was developed to assist in the management of these patients: *Type 1* athletic injuries to the cervical spine are those that cause neurological injury; patients with Type 1 injuries are not allowed to participate in contact, competitive sporting events. *Type 2* injuries consist of transient neurological deficits without radiological evidence of abnormalities; these injuries usually do not prohibit further participation in contact sports unless they become repetitive. *Type 3* injuries are those that cause radiological abnormality alone; these represent a heterogeneous group. The athlete with fractures involving a significant structural portion of the vertebral column, ligament instability, spinal cord contusion, or congenital


Type I
Episode
Repeater
Return
Non-Return
Type II
Non-Return
Type III
Fracture
Other Structural
Stable Radiographically
Unstable
Physiological Stability
Stress Stability
Non-Return
Return
Non-Return
Ligamentous Instability
Canal Stenosis
Cord Contusion
Ligamentous Compromise
Herniated Disc
Congenital Fusion
Spear Tackler's Spine
Non-Return
Individualized Return

Spinal Cord Contusion



Spinal Stenosis

Spinal Instability

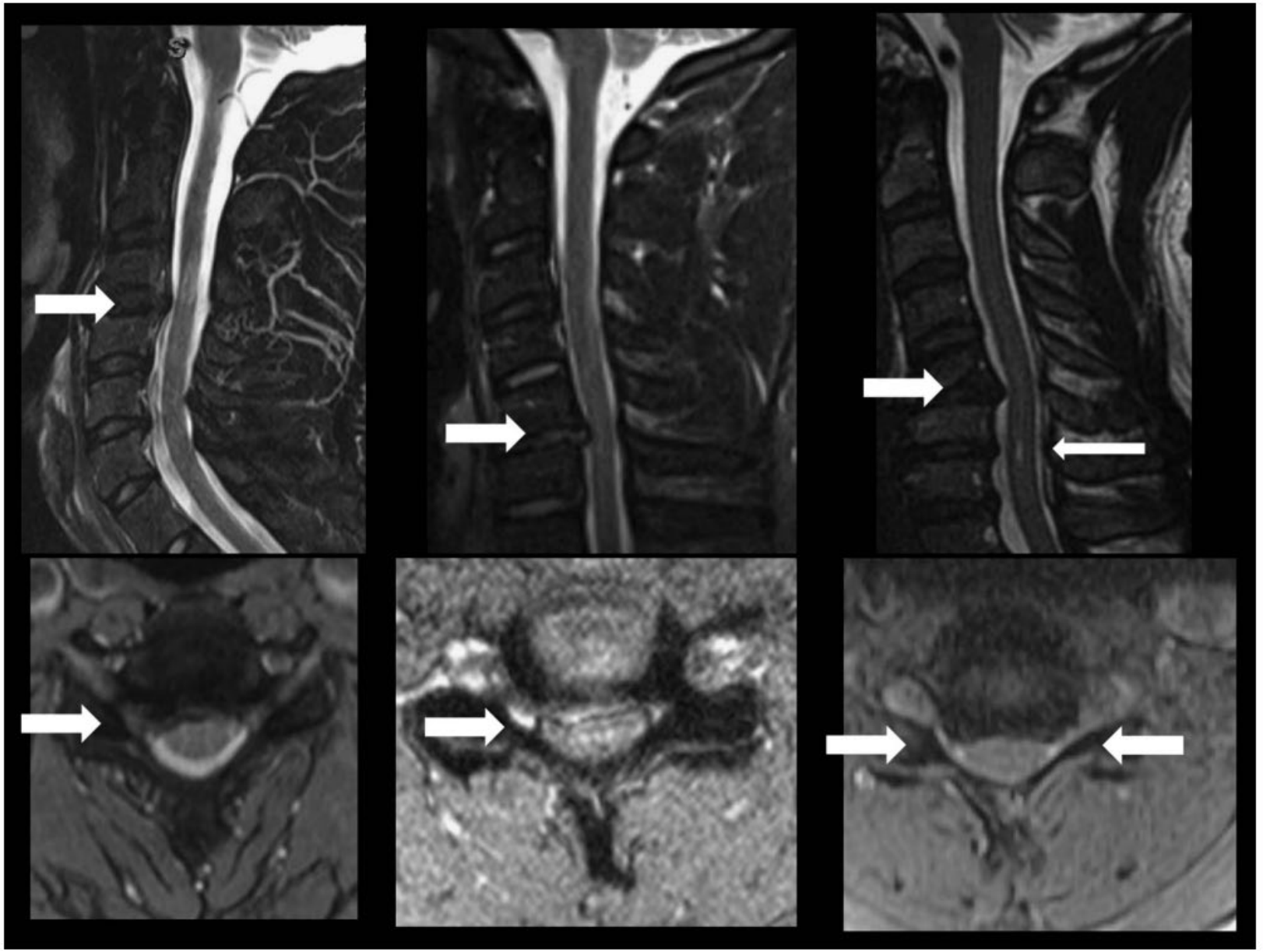
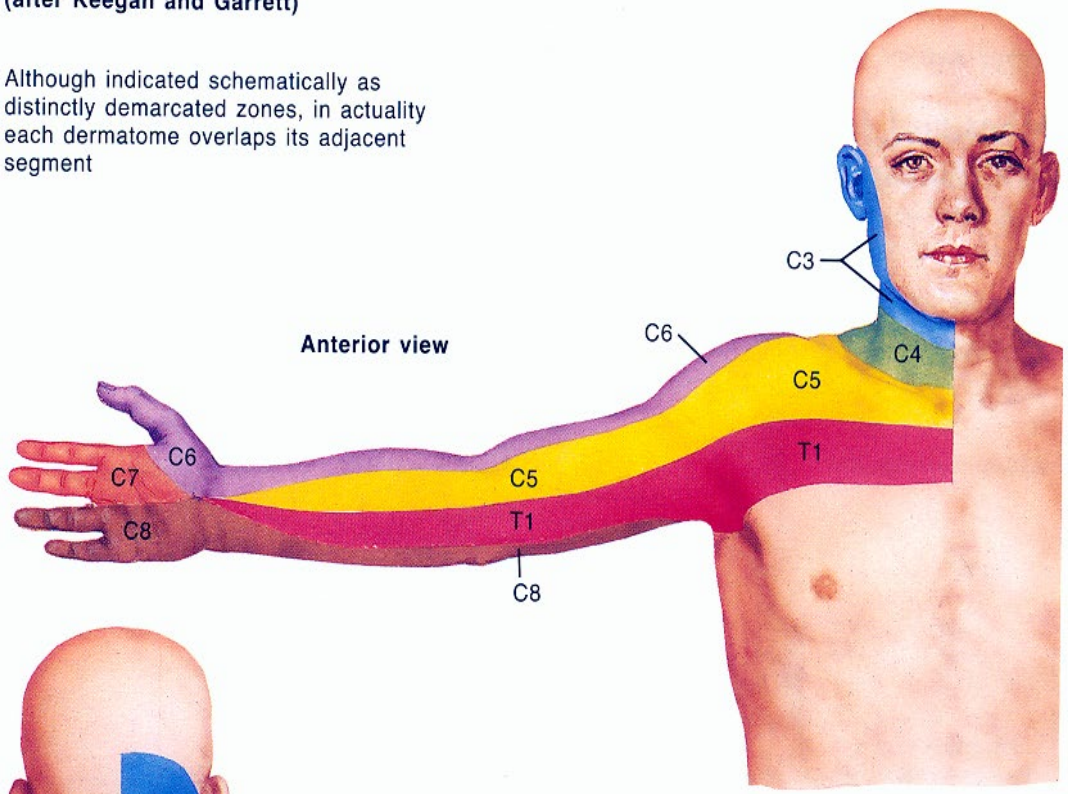
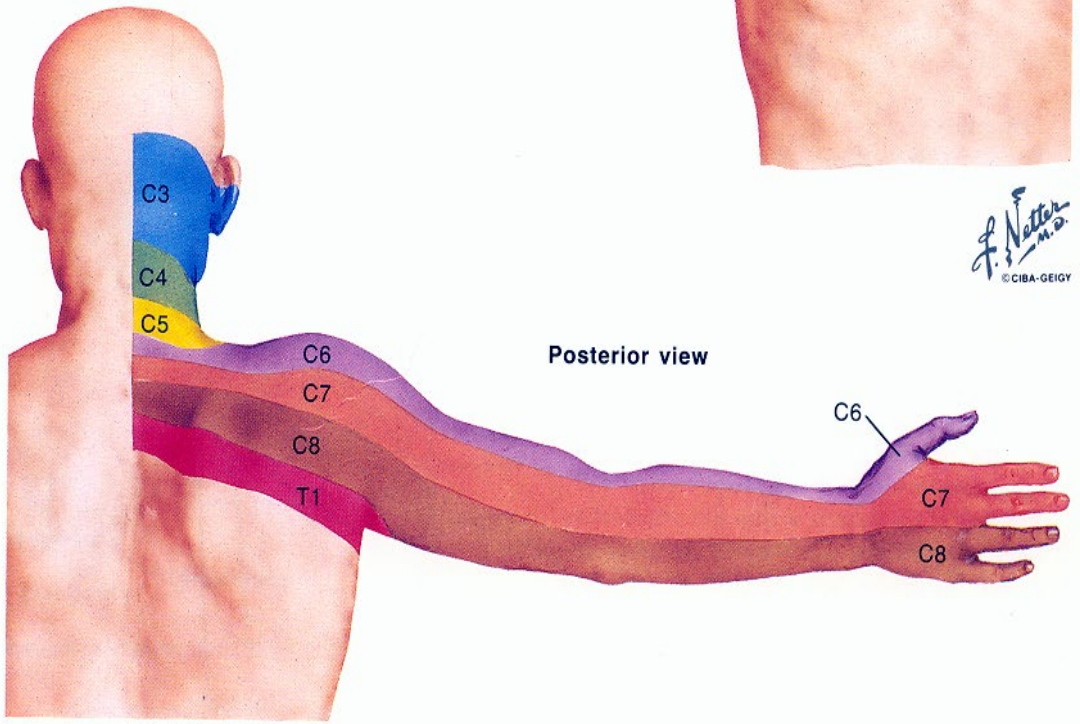


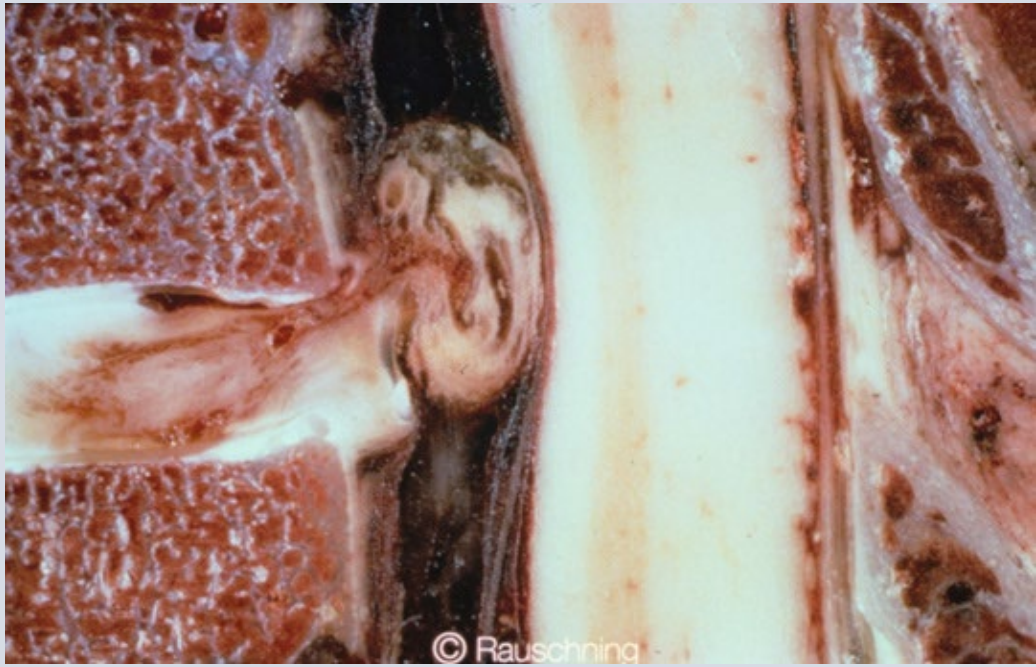
FIGURE 1. Left, *patient 6, preoperative magnetic resonance imaging (MRI) with sagittal and axial images showing moderate stenosis and a large herniated disc at the C3-4 level to the right entering the neural foramen.* **Middle**, *patient 4, preoperative MRI with sagittal and axial images showing stenosis, spondylosis, and a broad-based herniated disc at the C5-6 level to the right.* **Right**, *patient 9, preoperative MRI with sagittal and axial images showing stenosis and a diffuse herniated disc at the C5-6 level bilaterally along with a small central canal syrinx from C4 to C7.*

Dermal Segmentation of Upper Limb
(after Keegan and Garrett)

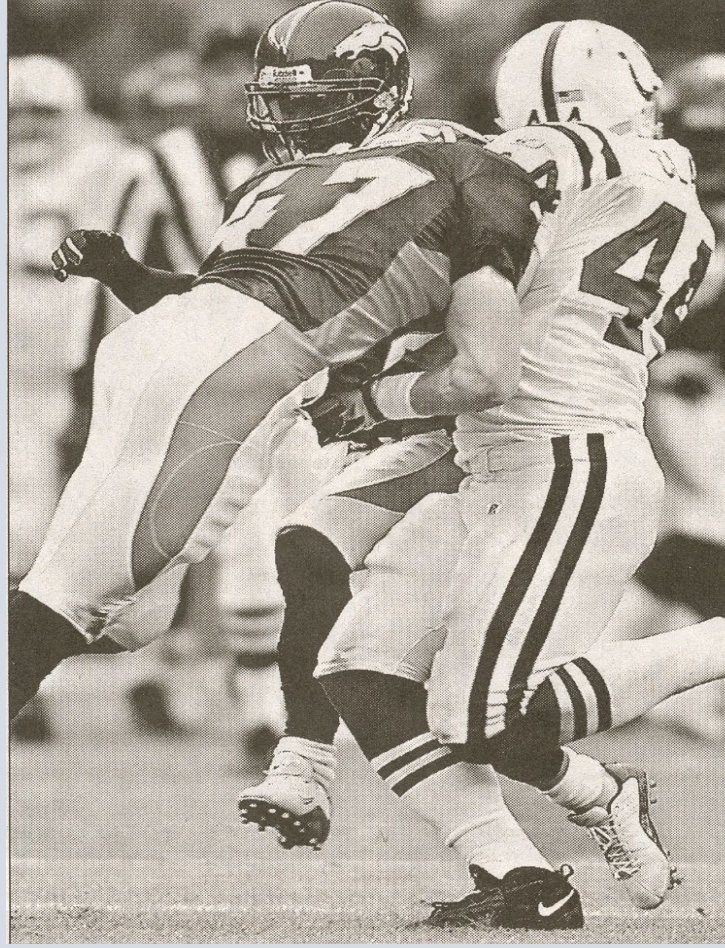
Although indicated schematically as distinctly demarcated zones, in actuality each dermatome overlaps its adjacent segment







Transient Spinal Cord Injury



- Usually seen football, hockey, soccer, wrestling
- Duration seconds-minutes, up to 48 hrs.
- Quadriplegia, weakness or numbess in all or 2 or more extremities
- Stenosis in 19 (54%)
- No radiographic abnormality in 46%

Transient Spinal Cord Injury-Mechanisms

Neurapraxia

Spinal Cord “Concussion”

Vascular: Central Cord Syndrome variant

“Burning Hands” Syndrome

J Neurosurg Spine 2:11–16, 2005

Experience with cervical stenosis and temporary paralysis in athletes

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Object. Transient spinal cord injury (TSCI) in athletes presents one of the most challenging clinical scenarios. Management difficulties in and subsequent return-to-play decisions are especially important in those with cervical canal stenosis.

Methods. Ten athletes (nine male and one female patients) were evaluated for TSCI. The diagnostic survey included physical and neurological examinations, plain radiographs with flexion–extension dynamic studies, computerized tomography, and magnetic resonance (MR) imaging. Clinical courses were followed and, in those who returned to contact sports activities, subsequent experience was noted.

Symptoms consisted of paralysis, weakness, or numbness in all four extremities, their duration ranging from 15 minutes to 48 hours. Radiography revealed no evidence of fracture/dislocation or ligamentous instability. Spinal stenosis of 8 to 13 mm in length at three or more levels was evident in all cases. Four patients returned to competition without recurrent TSCI (mean follow-up duration 40 months); six individuals retired.

The occurrence of TSCI is not uncommon in athletes involved in contact sports. The diagnostic workup focuses on excluding fracture/dislocation, cord contusion, ligamentous infolding or instability, herniated nucleus pulposus, syrinx, or other surgically correctable lesions. There appear to be two groups of athletes who sustain TSCI: those who experience TSCI yet in whom radiographic studies are normal, and those with cervical stenosis, the most difficult management group.

Conclusions. It does not appear that a single episode of TSCI in an athlete with spinal stenosis will substantially increase the risk of subsequent catastrophic spinal cord injury in those in whom MR imaging demonstrates preservation of cerebrospinal fluid signal.

KEY WORDS • spinal stenosis • cervical spine • transient spinal cord injury • athlete

Transient Spinal Cord Symptoms

Sport	N	Quadriplegia/-paresis	Sensory		Hemiparesis
			4 extremities	Arms	
Football	24	13	7	3	1
Wrestling	7	4	2	1	-
Gymnastics	1	-	-	1	-
Baseball	2	1	1		-
Skiing	1	-	-	1	-
Total	**35**	**18**	**10**	**6**	**1**

Current Evaluation

- Plain radiographs w/ F/E
- Computerized tomography
- Magnetic resonance
- “Functional” MRI
- Non-focal stenosis w/o compromise w/ dynamic studies

TABLE 1

*Characteristics obtained in five football players who suffered neurapraxia**

Age (yrs), Sex	Position	Symptoms	Level	Treatment	Results
29, M	defensive end	quadriparesthesia (Grade III)	C4–5	ACDF w/o plate	played 3 yrs; asymptomatic
29, M	fullback	quadriparesthesia (Grade III)	C6–7	ACDF & plate	played 3 yrs; asymptomatic
26, M	defensive back	quadriparesthesia (Grade I)	C4–5	ACDF & plate	played 27 games; new HNP C5–6; ACDF
20, M	linebacker	BUE paresthesia (Grade III)	C4–5	ACDF & plate	played 7 games; new C3–4 HNP; no surgery
32, M	offensive lineman	BUE paresthesia (Grade I)	C3–4	ACDF & plate	played 2 yrs; asymptomatic

* BUE = bilateral upper-extremity; HNP = herniated nucleus pulposis.

Conclusions

- Two types of TSCI w/o correctable problem: cord “concussion” (normal studies) & stenosis
- No definitive association for subsequent permanent injury :1/117 (0.9%)FB quad injuries w/ prior Sx-sensory
- Narrow spinal canal leads to deformation
- Structural failure with catastrophic injury; not with stenosis.
- Only 4 reported cases of quad injury a/w preceeding spinal cord symptoms
- **Return to play tolerated especially single episode**

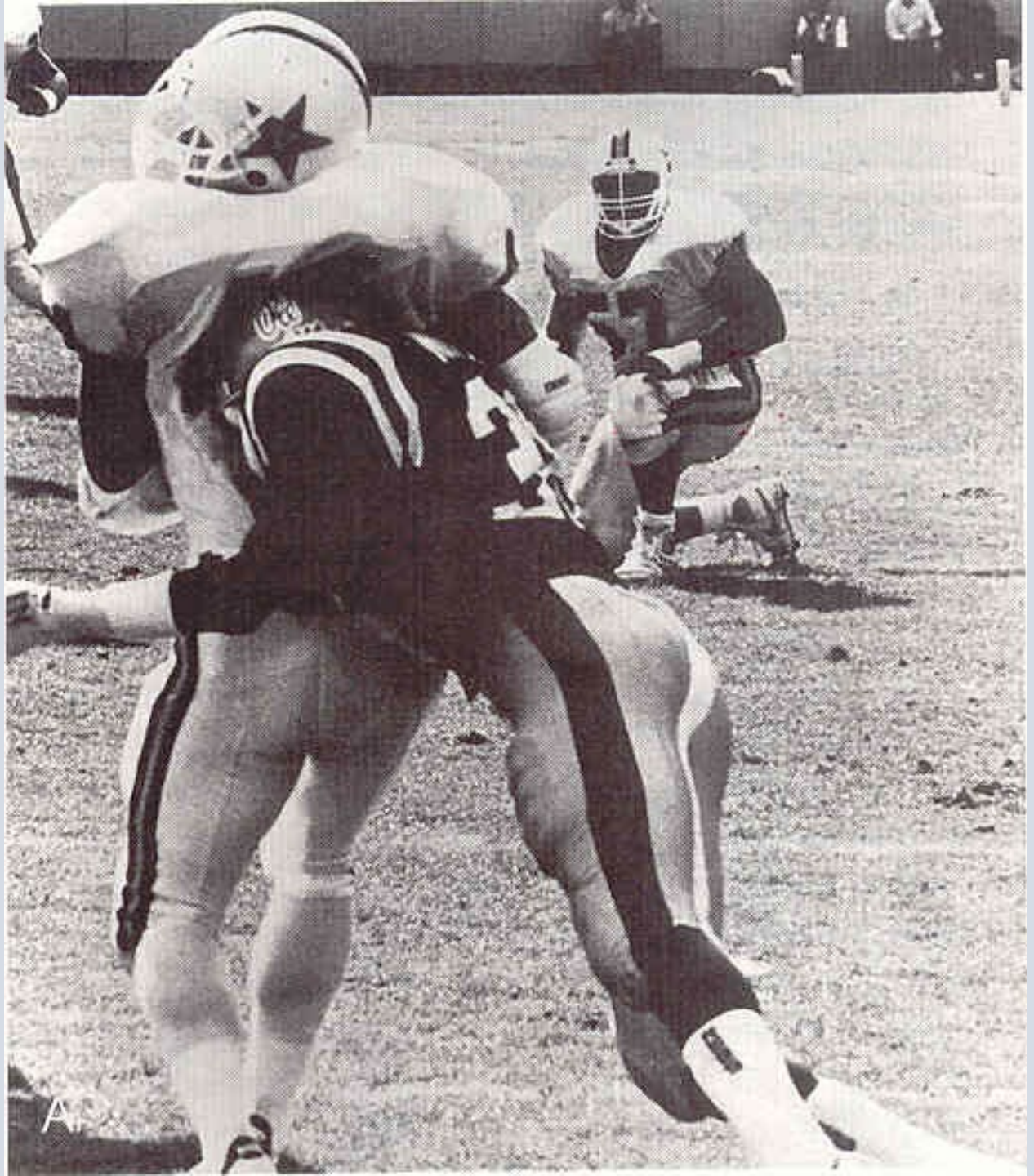
Spear Tackler's Spine

1-Reversal of lordosis

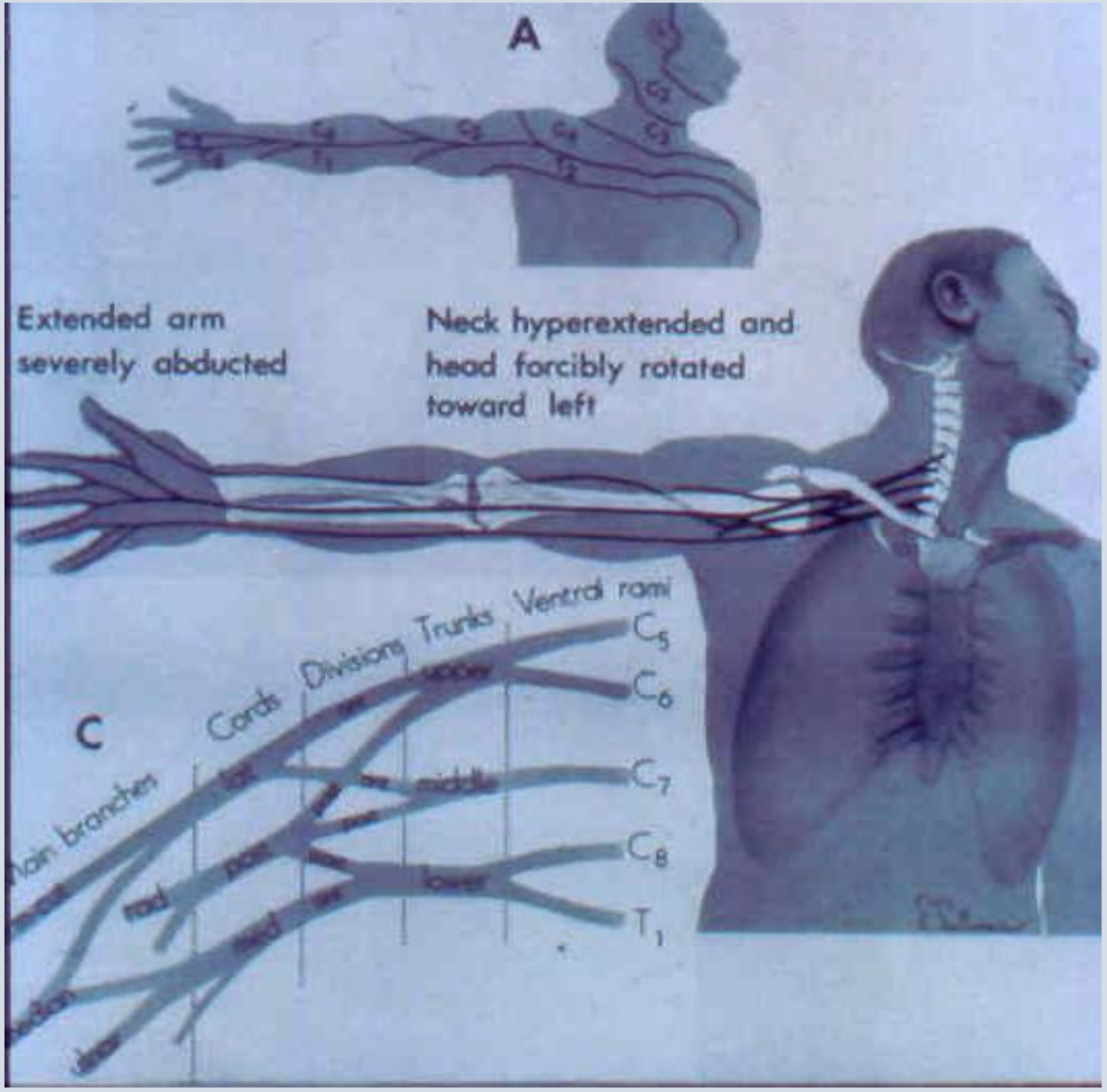
2-Evidence previous, minor cervical fractures

3-Relative cervical stenosis

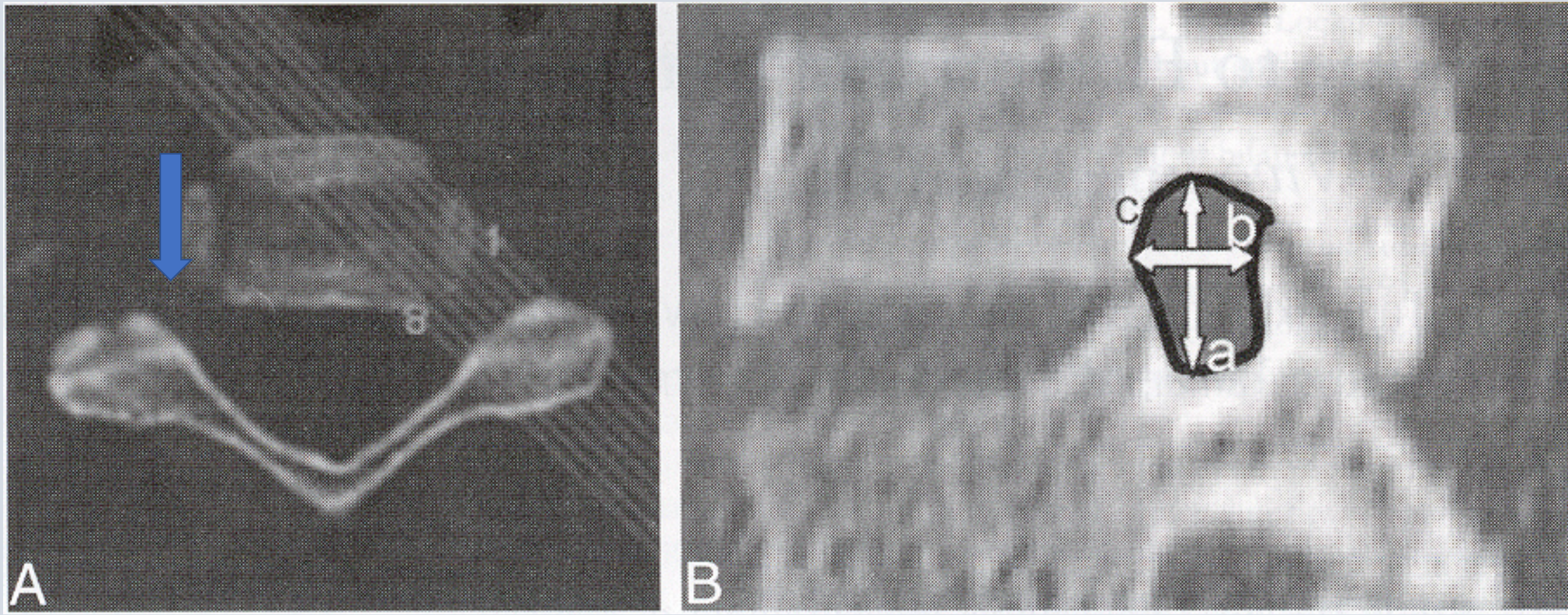
4-Habitual use of spearing techniques



Burners-stingers-brachial plexus or nerve root



Foraminal narrowing-common cause of radiculopathy



SPINE Volume 29, Number 24, pp 2821–2825

Morphologic Changes in the Cervical Neural Foramen due to Flexion and Extension

In Vivo Imaging Study

Tomoaki Kitagawa, MD, Atsushi Fujiwara, MD, Naoki Kobayashi, MD, Kazuhiko Saiki, MD, Kazuya Tamai, MD, and Koichi Saotome, MD

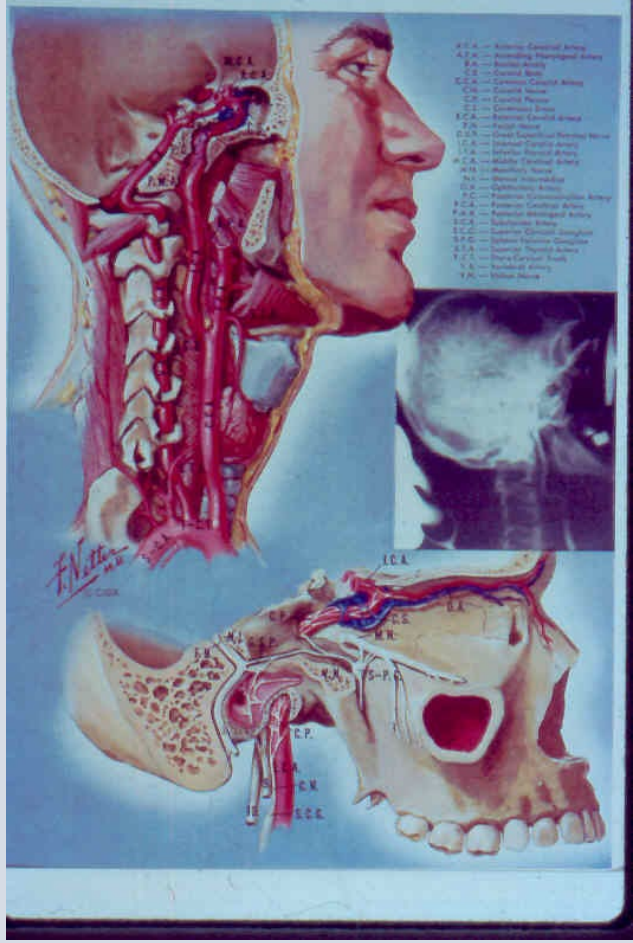
Study Design. Dimensional measurement of cervical neural foramen at various positions, using reformatted computed tomography.

Objectives. To examine the morphologic changes in the neural foramen during flexion and extension of the cervical spine *in vivo*.

Summary of Background Data. Previous cadaveric studies have shown the effect of cervical spinal motion on

symptoms in patients with cervical radiculopathy, and flexion often relieves them. Although cervical motion may affect the amount of intervertebral disc bulging into the neural foramen, changes in bony structural dimensions of the foramen during the motion could also cause impingement of the nerve root within the cervical foramen.[5–7] Previous *in vitro* studies have shown the effect of

Spinal Injury?
Other Diagnoses to Consider

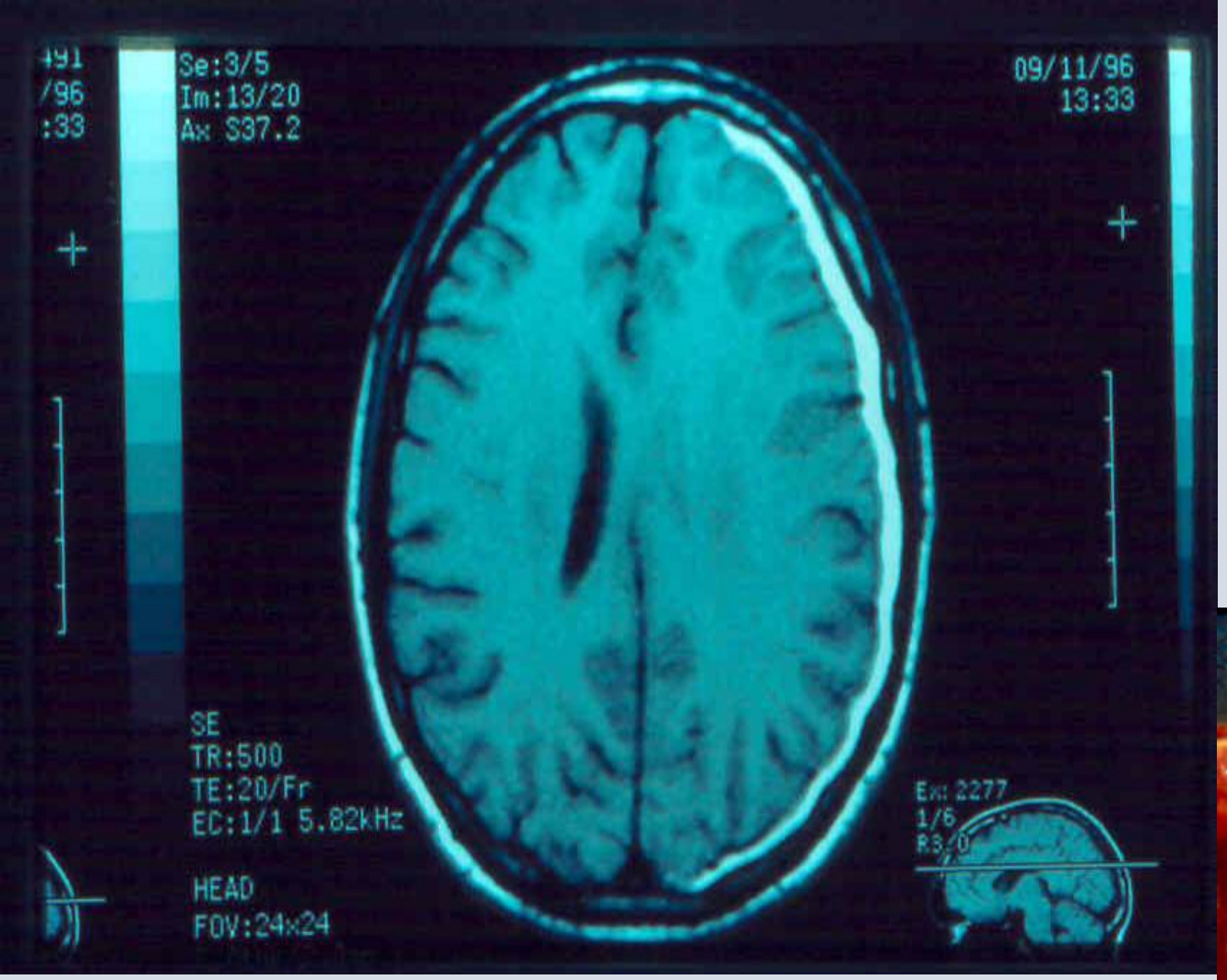


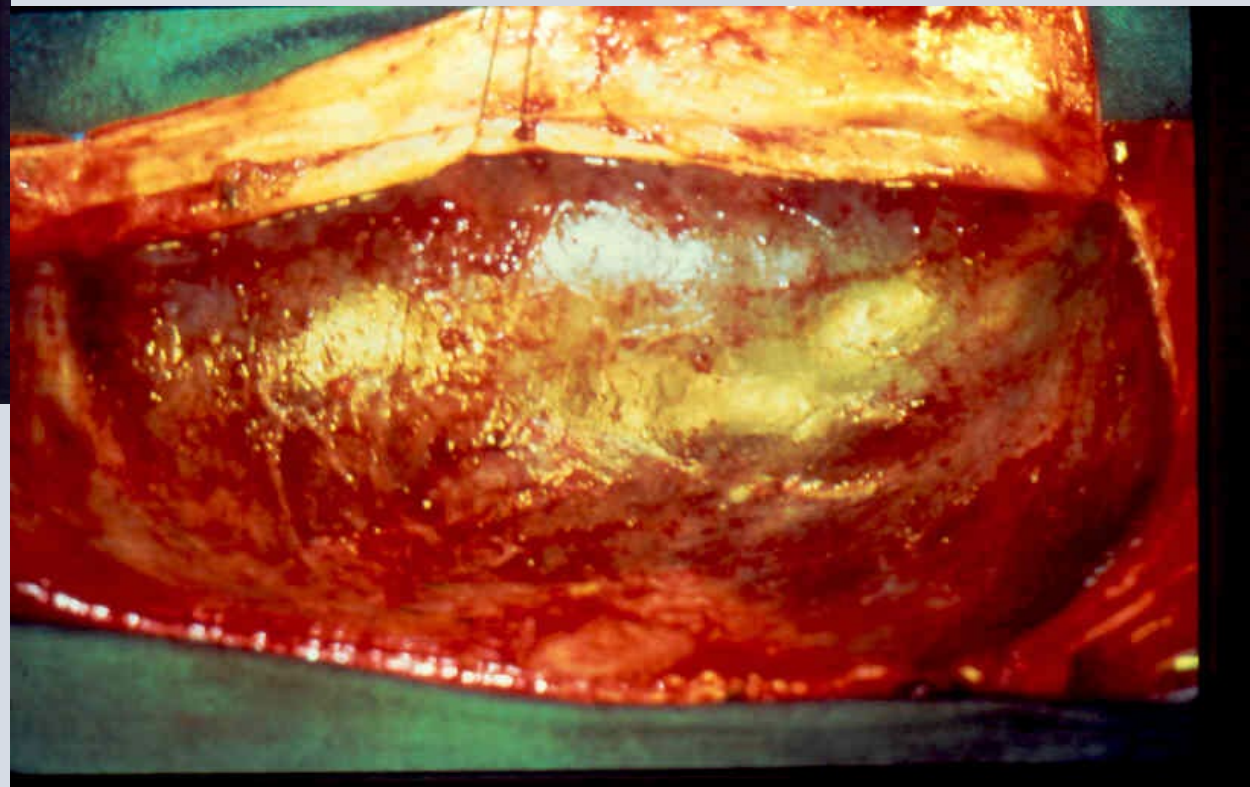
Vascular injury---Vertebral artery, Internal carotid artery

Intracranial injury---contusion, subdural or epidural hemorrhage

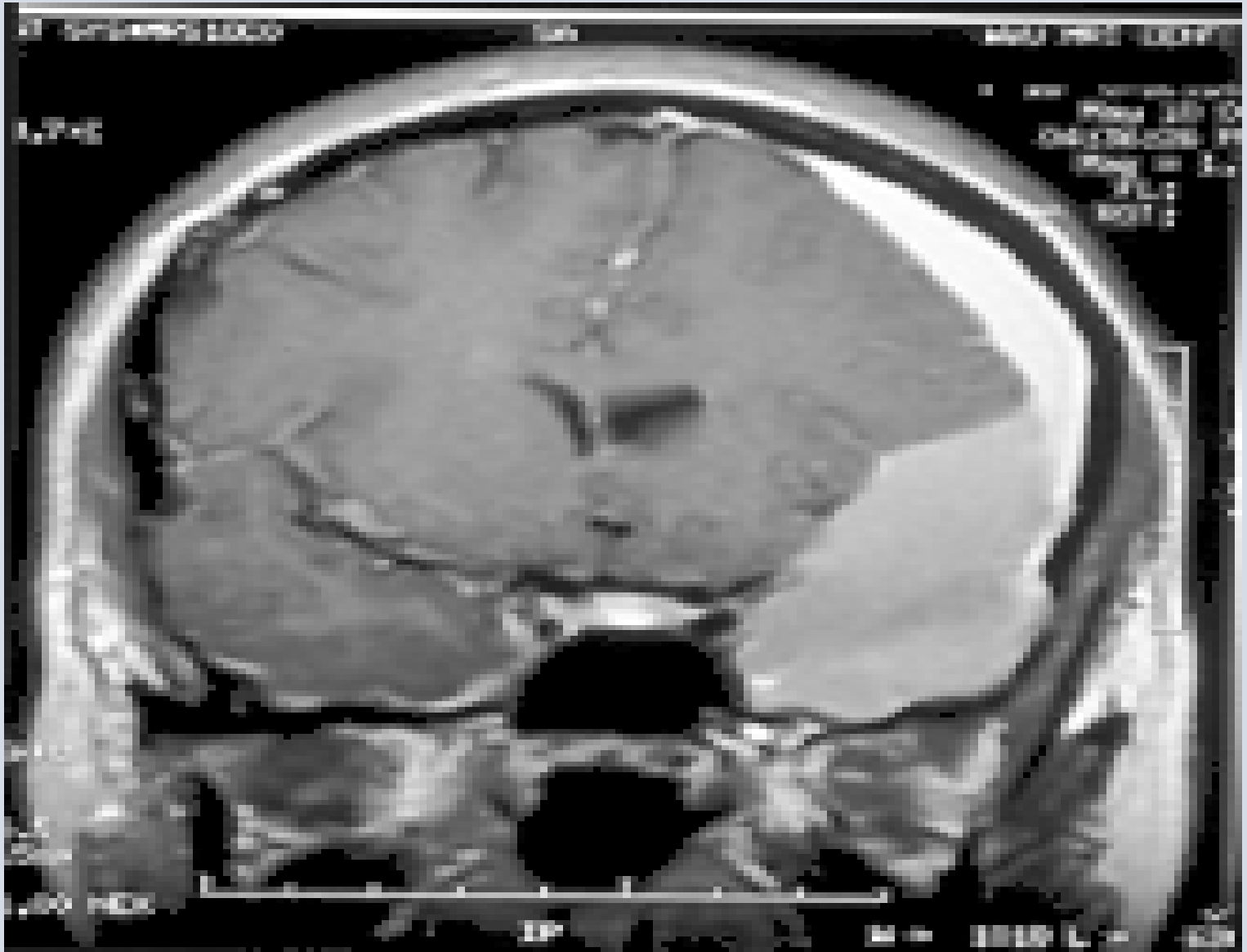
Brachial plexus injury

Subdural hematoma





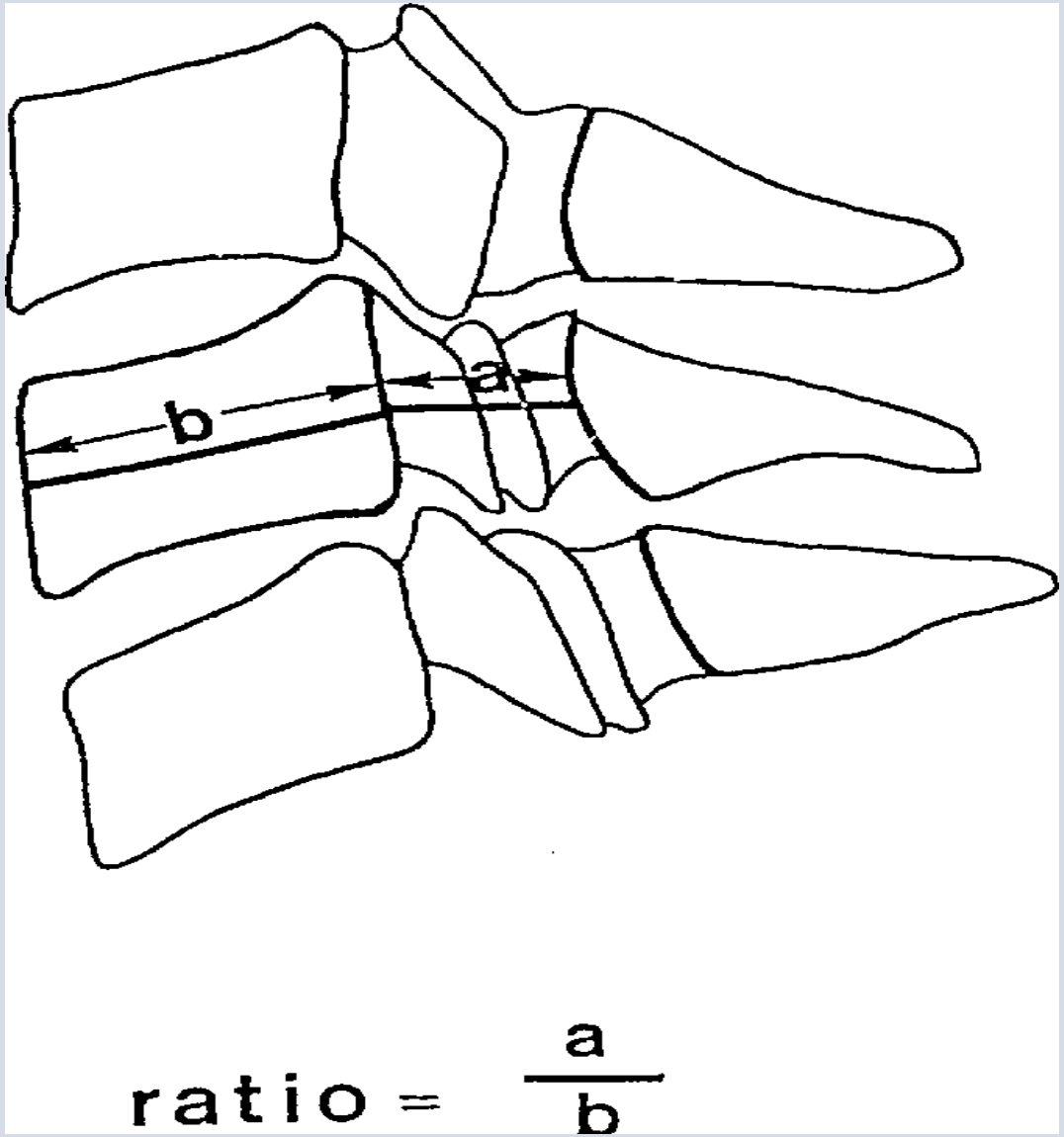
Ruptured congenital arachnoid cyst

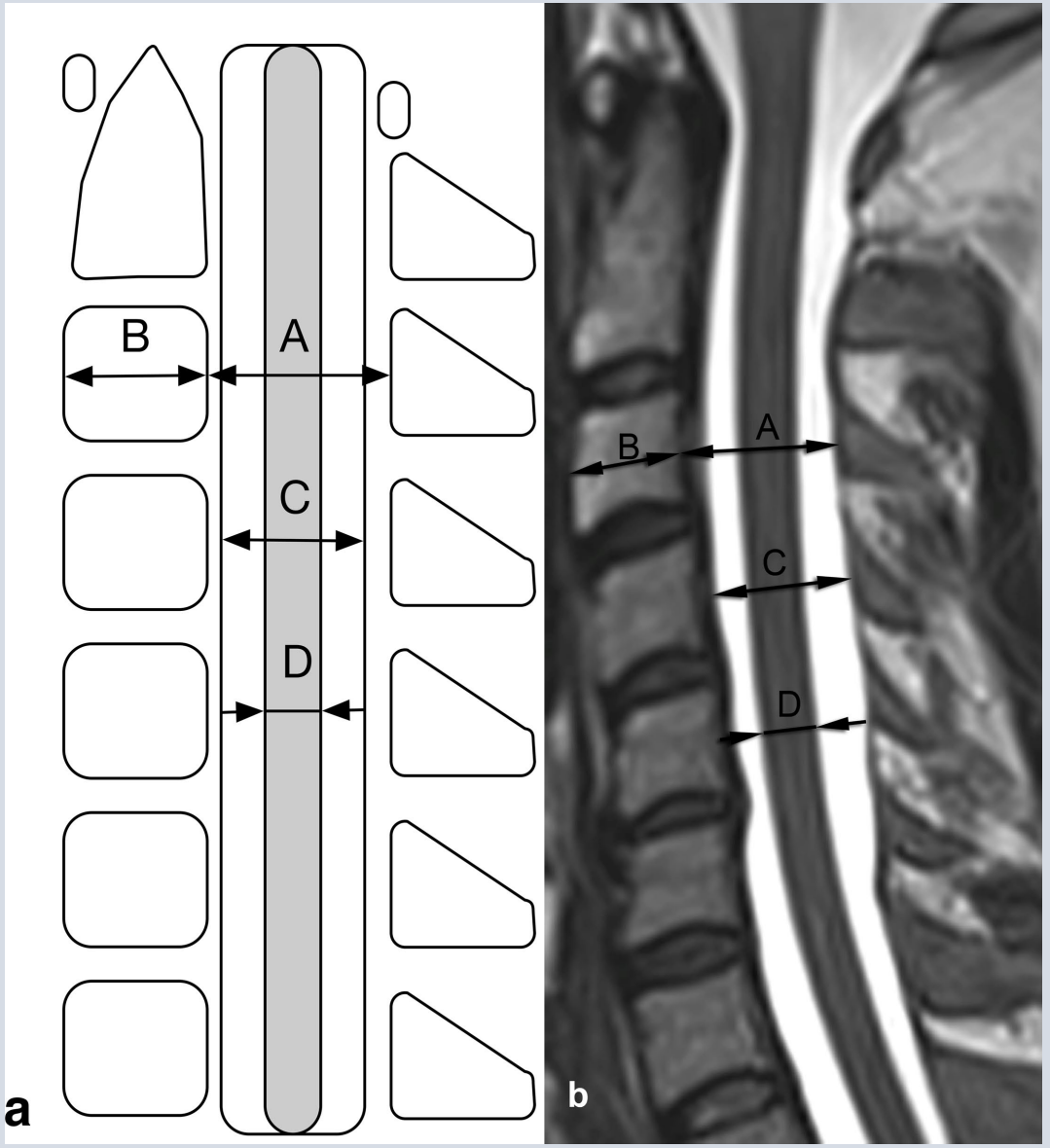


Spine Evaluation

- Plain radiographs w/ F/E
- Computerized tomography
- Magnetic resonance
- “Functional” MRI
- Non-focal stenosis w/o compromise w/ dynamic studies

Torg Ratio-->Functional MRI





Management Athletic SCI

Initial on-field care

Triage and decision making

Emergency care

Steroid protocol

If indicated, surgical decompression/stabilization

Rehabilitation

Helmet and shoulder pads removal

Treatment

Rest

Medications-NSAIDs, myorelaxants,analgesics, Omega-3 FA’s (pharmaceutical grade)

Physical therapy-multimodality

Pain management modalities

Chiropractic

Rehabilitation

Return to Play

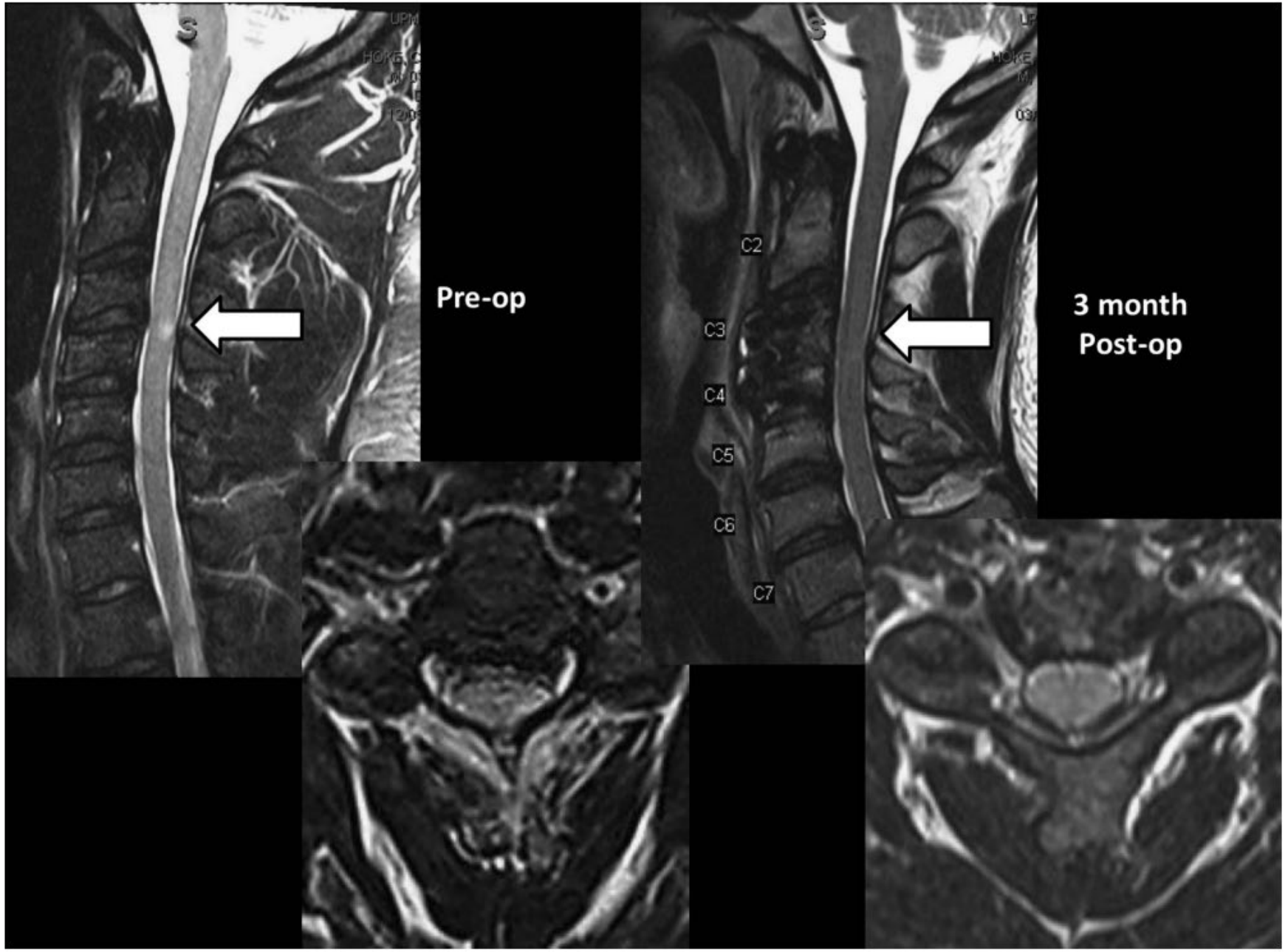


FIGURE 3. *Patient 7 showing both sagittal and axial magnetic resonance images preoperatively and 3 months postoperative. The arrows point to the hyperintensity cord changes at the C3-4 level preopoperatively and resolution of these changes at 3 months postoperatively.*

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John Norwig, ATC¶
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Outcomes After Anterior Cervical Discectomy and Fusion in Professional Athletes

BACKGROUND: Significant controversy exists regarding when an athlete may return to contact sports after anterior cervical discectomy and fusion (ACDF). Return-to-play (RTP) recommendations are complicated due to a mix of medical factors, social pressures, and limited outcome data.

OBJECTIVE: The aim of this study was to characterize our diagnostic and surgical criteria, intervention, postoperative imaging results, and rehabilitation and report RTP decisions and outcomes for professional athletes with cervical spine injuries.

METHODS: Fifteen professional athletes who had undergone a 1-level ACDF by a single neurosurgeon were identified after a retrospective chart and radiographic review from 2003 to 2012. Patient records and imaging studies were recorded.

RESULTS: Seven of the 15 athletes presented with neurapraxia, 8 with cervical radiculopathy, and 2 with hyperintensity of the spinal cord. Cervical stenosis with effacement of the cerebrospinal fluid signal was noted in 14 subjects. The operative level included C3-4 (4 patients), C4-5 (1 patient), C5-6 (8 patients), and C6-7 (2 patients). All athletes were cleared for RTP after a neurological examination with normal findings, and radiographic criteria for early fusion were confirmed. Thirteen of the 15 players returned to their sport between 2 and 12 months postoperatively (mean, 6 months), with 8 still participating. The RTP duration of the 5 who retired after full participation ranged from 1 to 3 years. All athletes remain asymptomatic for radicular or myelopathic symptoms or signs.

CONCLUSION: After a single-level ACDF, an athlete may return to contact sports if there are normal findings on a neurological examination, full range of neck movement, and solid arthrodesis. There may be an increased risk of the development of adjacent segment disease above or below the level of fusion. Cord hyperintensity may not necessarily preclude RTP.

KEY WORDS: Anterior cervical discectomy and fusion, Cervical fusion, Neurapraxia, Professional athletes, Spinal injury

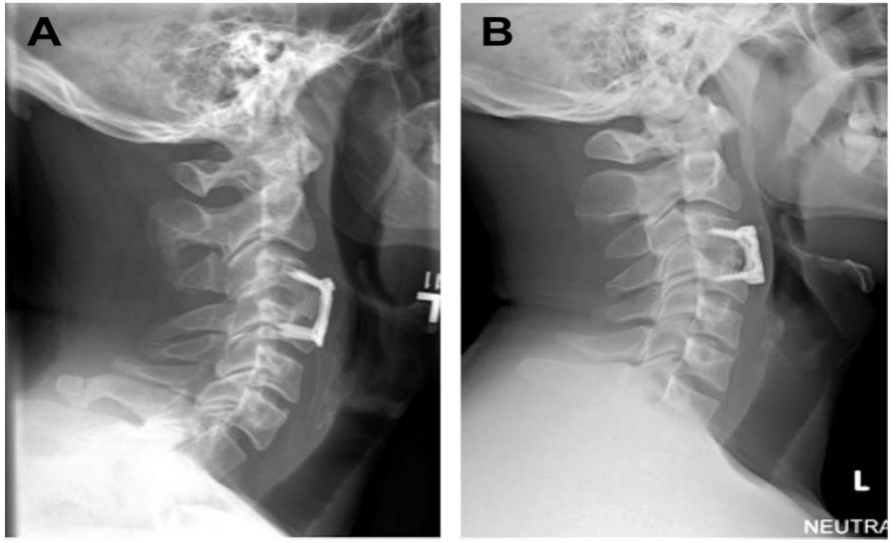

FIGURE 1. *Lateral C-spine radiographs of 2 patients (**A** and **B**) demonstrating solid arthrodesis at the operative level 6 months after surgery.*

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Cervical neurapraxia in elite athletes: evaluation and surgical treatment

Report of five cases

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Object. Neurapraxia, transient posttraumatic paralysis of the motor and/or sensory tracts in the spinal cord, may be a career-ending event in an athlete. Management, rehabilitation, and return-to-play decisions remain controversial.

Methods. Five elite football players were evaluated after experiencing episodes of neurapraxia. All patients experienced bilateral paresthesias—three in all four extremities and two in the upper extremities—lasting a few minutes to more than 24 hours. Transient motor deficits occurred in two individuals but caused no permanent sequelae. Neuroimaging confirmed the presence of herniated discs, focal cord compression, and no parenchymal changes in all cases.

All patients underwent anterior cervical microdiscectomy and fusion, and cervical plates were placed in four. After aggressive rehabilitation and confirmation of fusion ranging from 9 weeks to 8 months postoperatively, the players were allowed to return to active play. Two of the players developed recurrent career-ending disc herniations, one above and the other below the fusion level. One player required repeated spinal cord decompression.

Conclusions. Neurologically intact athletes with focal cord compression due to a single-level herniated disc may safely return to football after undergoing decompressive surgery and confirmation of fusion. It appears, however, that there may be an increased chance of repeated herniation above or below a fused level.

Key Words • neurapraxia • spinal concussion • spinal stenosis • transient spinal cord injury • quadriplegia

Significance of T2 Hyperintensity on Magnetic Resonance Imaging After Cervical Cord Injury and Return to Play in Professional Athletes

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BACKGROUND: Cervical cord magnetic resonance imaging (MRI) T2 hyperintensity is used as evidence of cord trauma in the evaluation and management of athletes in contact sports. The long-term pathophysiologic and prognostic value of this finding is poorly understood, especially in return to play (RTP).

OBJECTIVE: To examine the significance of T2 hyperintensity in the cervical spinal cord of professional athletes.

METHODS: Retrospective review of MRI T2 hyperintensity findings between 2007 and 2014 in 5 professional athletes. Pertinent examination and demographics, including mechanism of injury, surgical intervention, radiographs, MRI studies, long-term outcomes, and RTP recommendations were collected.

RESULTS: Four National Football League players and 1 professional wrestler had prior traumatic neurapraxia that at the time of initial consultation had resolved. MRIs showed congenitally small cervical canal (1) and multilevel spondylosis/stenosis/disc herniation (4) along with focal cord T2 hyperintensity (5). The signal abnormalities were at C3/C4 (3), C4 mid-vertebral body (1), and C5/C6 (1). Four athletes had single-level anterior cervical discectomy and fusion, and 1 was nonoperative. Serial MRI imaging at 3 months after surgery showed hyperintensity partially resolved (4) and unchanged (1), and at 9-months 3 of the 5 completely resolved. Based on the author's RTP criteria, 4 of 5 were released to return to their sport. Clearance for RTP preceded complete resolution of MRI T2 hyperintensity in 3 of 4 athletes. The 2 athletes that have returned to profession sport have not had any additional episodes of neurapraxia or any cervical spine-related complications.

CONCLUSION: MRI T2 hyperintensity in contact sport athletes who are symptom-free with normal examination and no evidence of spinal instability may not be a contraindication to RTP. Additional observations are needed to confirm this observation.

KEY WORDS: Cervical cord hyperintensity, Cervical cord injury in athletes, MRI T2 hyperintensity, Neurapraxia, Return to play after cord injury

TABLE. Demographic Data, Mechanism of Injury, Clinical Features, Radiographic Findings, Management, and Outcome in 5 Professional Athletes With Spinal Cord Injury and T2 Hyperintensity on MRI[a]

Case	Age	Sport/ Position	Mechanism	Signs	Initial S&S	Imaging	Management	Neurological Outcome
1	31	Wrestling	Body slam with hyperflexion	L'hermitte's sign	Left UE paresthesias	C5/C6 HNP	C5/C6 ACDF	Complete resolution
				Bilateral triceps weakness	Bilateral triceps weakness	Focal T2 HI		**Cleared for RTP**
					Grade II			**RTP in 6 months**
2	35	Football/ DL	Axial loading with hyperflexion while tackling	L'hermitte's sign	Bilateral UE paresthesias	C3/C4 HNP	C3/C4 ACDF	Complete resolution
				Right deltoid and biceps weakness	Grade I	Focal T2 HI		**Cleared for RTP**
				Hyper-reflexia				**Retired**
3	35	Football/ DE	Axial loading with hyperflexion while tackling	L'hermitte's sign	Bilateral UE paresthesias	C3/C4 HNP	C3/C4 ACDF	Complete resolution
					Grade I	Broad T2 HI		**Cleared for RTP**
								Retired
4	26	Football/ TE	Hyperextension during open field hit after a catch	L'hermitte's sign	Quadri-paresthesia	C3/C4 HNP Focal T2 HI	C3/C4 ACDF	Complete resolution
					Quadriplegia			**Awaiting final RTP clearance**[b]
					Grade III			
5	28	Football/ LB	Axial loading with flexion and extension while tackling	None	Bilateral UE paresthesias	Focal T2 HI	Observation	Complete resolution
					Quadriparesis			**Cleared for RTP**
					Grade I			**RTP in 10 months**

[a]DE, defensive end; DL, defensive lineman; HI, hyperintensity; HNP, herniated nucleus pulposis; LB, line backer; S&S, signs and symptoms; TE, tight end; UE, upper extremity.
[b]Return to play (RTP) clearance was complicated due to fibro-osseous union after anterior cervical discectomy and fusion (ACDF).

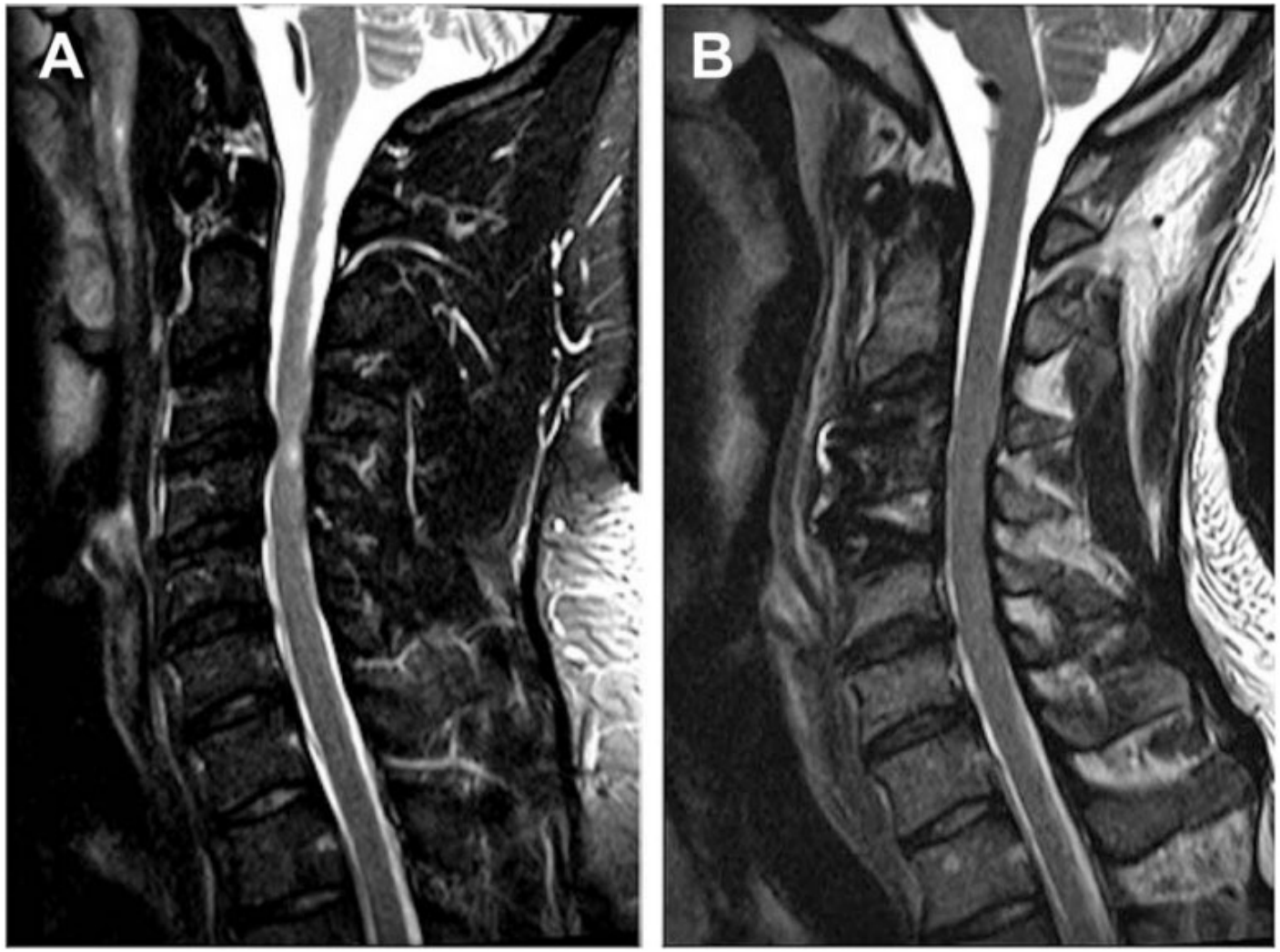
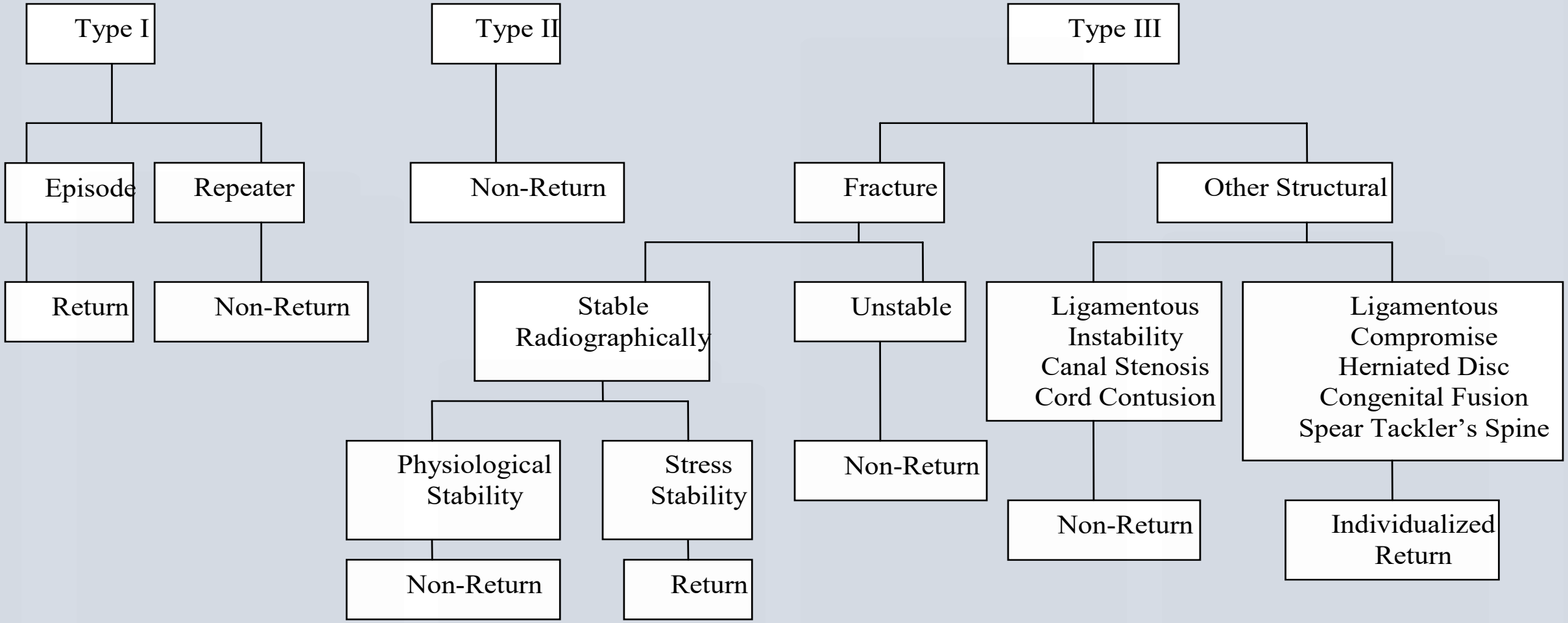


FIGURE 3. *T2-weighted sagittal MRI (**A**) demonstrating preoperative hyperintensity at C3/C4 and (**B**) resolution of hyperintensity 6 months after surgery.*

Probable Contraindications to Contact Sports

- Congenital: Odontoid-os, hypoplasia, A-O fusion, Klippel-Feil, multi-level cervical fusion
- Acquired: prior spinal cord injury, spinal cord lesion (tumor, syrinx, vascular), Spear Tackler's Spine
- Post-traumatic: significant fracture, instability, symptomatic HNP, post-surgical fusion > 2 levels
- Repetitive transient cord symptoms
- Management and RTP must be individualized


Type I
Episode
Repeater
Return
Non-Return
Type II
Non-Return
Type III
Fracture
Other Structural
Stable Radiographically
Unstable
Physiological Stability
Stress Stability
Non-Return
Return
Non-Return
Ligamentous Instability
Canal Stenosis
Cord Contusion
Ligamentous Compromise
Herniated Disc
Congenital Fusion
Spear Tackler's Spine
Non-Return
Individualized Return