Complex Spine Symposium - Cervical Spine

MRI of the cervical spine

Christian W. A. Pfirrmann MD, MBA
University Hospital Balgrist
University of Zurich Switzerland

People
BONUS 10-PAGE Olympics Preview!
FEBRUARY 10, 2014
She's How Old?
Christie AT 60!
ALL HER STAY-YOUNG SECRETS
After three kids, four husbands and a tough decade, Christie Brinkley looks this good.
THE SUPERMODEL IN 1979!

Joe Klein: Finally, the Real Hillary
The Clintons: How Winning Trumps All
Why Obama Is Tougher Than He Looks
Interviews: Hillary and Barack Trade Jabs
TIME
The Fighter
How she came back— and why it could be too late
Hillary Clinton in Beaumont, Texas, on March 3

11y

University of Zurich[UZH]

The Balgrist

18y

24y

33y

52y

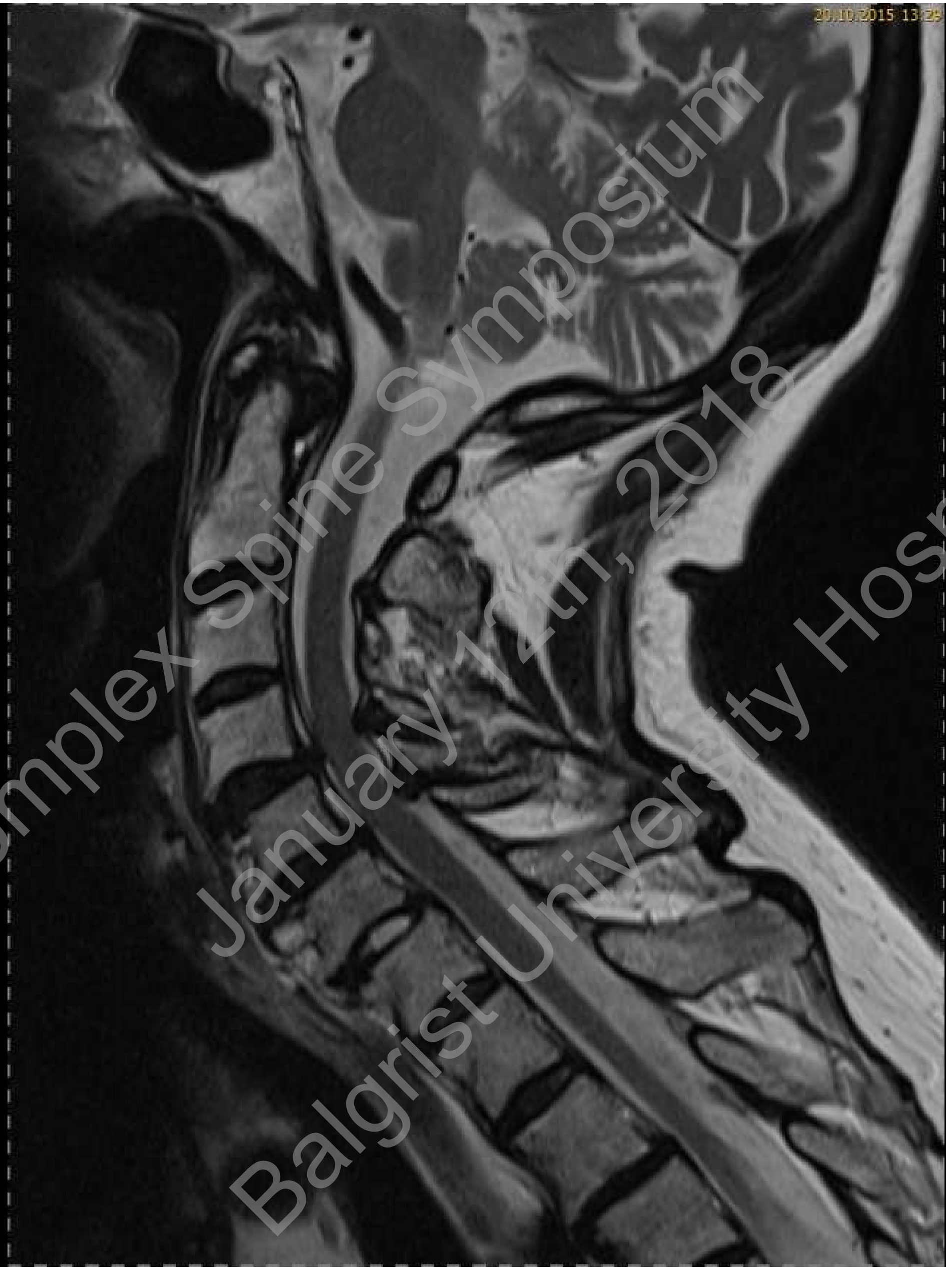
68y

University of Zurich[UZH]

The Balgrist

75y

93y



60y

60y

University of Zurich[UZH]

The Balgrist

Normal aging process

What is the Definition of “Normal Aging” ?

Proposed Imaging Definition: Changes in an healthy & asymptomatic person

- Studies in asymptomatic subject
- Imaging spectrum of aging

What is the Evolution of “Normal Aging” ?

- How fast is normal ..

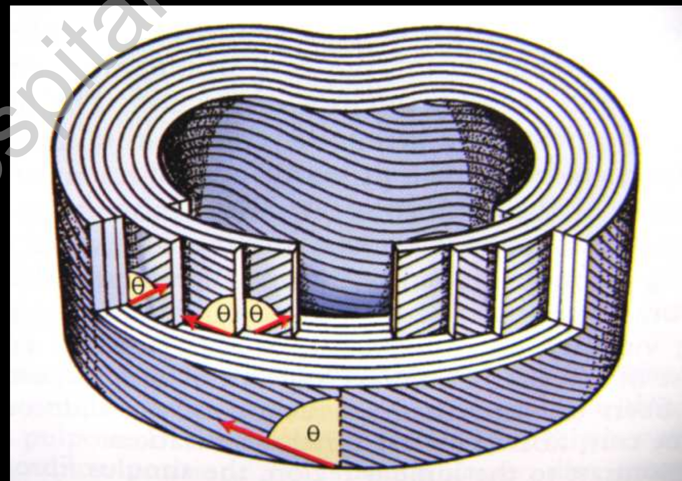
Which Findings become symptomatic ?

What are Factors Influencing “Normal Aging” ?

- Genetic Factors
- Occupational Factors
- Exogenic/Environmental Factors

Disc Aging : Normal Structure & Function

- Disc is avascular.
- Height increases from peripheral edges to the center, biconvex shape
- Becomes larger by about 11% per segment from cephalad to caudal
- Annulus fibrosus: type I collagen
- Nucleus pulposus: type II collagen, proteoglycan, and hyaluronan long chains.
- Highly hydrophilic, hydrate the nucleus by an osmotic pressure effect.



Disk Aging: Histology of Cervical Disk

ELSEVIER
The Spine Journal ■■ (2017) ■■–■■
THE SPINE JOURNAL

Basic Science

Validation of the intervertebral disc histological degeneration score in cervical intervertebral discs and their end plates

Krzysztof A. Tomaszewski, MD, PhD[a,*], Brandon Michael Henry, MD[a], Tomasz Gładysz, DDS, PhD[a,b], Roman Głowacki, MD, PhD[c], Jerzy A. Walocha, MD, PhD[a], Romana Tomaszewska, MD, PhD[d]

[a]Department of Anatomy, Jagiellonian University Medical College, 12 Kopernika St, 31-034 Krakow, Poland
[b]Department of Oral Surgery, Institute of Dentistry, Jagiellonian University Medical College, 12 Kopernika St, 31-034 Krakow, Poland
[c]Department of Otorhinolaryngology, Rydygier Specialistic Hospital, os. Złotej Jesieni 1, 30-001 Krakow, Poland
[d]Department of Pathology, Jagiellonian University Medical College, 12 Kopernika St, 31-034 Krakow, Poland

Received 10 September 2016; revised 8 December 2016; accepted 12 January 2017

Abstract

BACKGROUND CONTEXT: Vertebral joints consist of intervertebral discs (IVDs) and cartilaginous end plates (EP) that lie superiorly and inferiorly to the IVDs and separate them from the adjacent vertebral bodies. With aging, both IVDs and EPs undergo degeneration. The Histologic Degeneration Score (HDS) is a grading system that microscopically evaluates the degree of degeneration in lumbar discs and predicts it with high accuracy basing on several histological markers of IVD and EP. There is currently a lack of validated histologic grading schemes for cervical spine degeneration.

PURPOSE: The aim of our study was to describe the changes in cervical IVDs and EPs with degeneration and to test the validity of the HDS in the cervical spine.

STUDY DESIGN: A histological study on degenerative changes in cervical IVDs and EPs was conducted.

METHODS: Thirty human cadavers were dissected to obtain 60 cervical IVDs from the lower half of C4 to the level of the upper half of C6. The IVDs were carefully excised along with EPs and then sectioned to obtain midsagittal samples for macroscopic examination according to a five-grade classification system. The samples were further dissected, fixed, and stained for histological examination according to HDS.

RESULTS: Thirty C4–C5 IVDs and thirty C5–C6 IVDs were macroscopically examined for degeneration. The averaged Thompson's grade was found to be 2.9±1.3. The mean HDS for IVDs was 13.1±5.8 and for EP was 10.2±5.2. The interrater reliability estimates indicated excellent reliability (κ values>0.81, percentage agreement 86.1%-96.1%). Spearman's rank correlation coefficients for IVD and EP scores showed good consistency in predicting macroscopic degeneration. No significant differences were found between the values for cervical IVDs and EPs in the present study and those for lumbar discs derived in previous studies.

FDA device/drug status: Not applicable.

Author disclosures: ***KAT:*** Grant: National Science Center – Poland (D, Paid to the institution); Foundation for Polish Science (FNP) and the Polish Ministry of Science and Higher Education Grant for Young Scientists (C), pertaining to submitted manuscript. ***BMH:*** Nothing to disclose. ***TG:*** Nothing to disclose. ***RG:*** Nothing to disclose. ***JAW:*** Nothing to disclose. ***RT:*** Nothing to disclose.

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

Funding statement: Krzysztof A. Tomaszewski was supported by the Foundation for Polish Science (FNP). This study was funded by the National Science Center—Poland under grant number DEC-2012/07/N/NZ5/00078.

No conflict of interest was present.

* Corresponding author. Department of Anatomy, Jagiellonian University Medical College, 12 Kopernika St, 31-034 Krakow, Poland. Tel.: +48 12 422 95 11.
E-mail address: krtomaszewski@gmail.com (K.A. Tomaszewski)

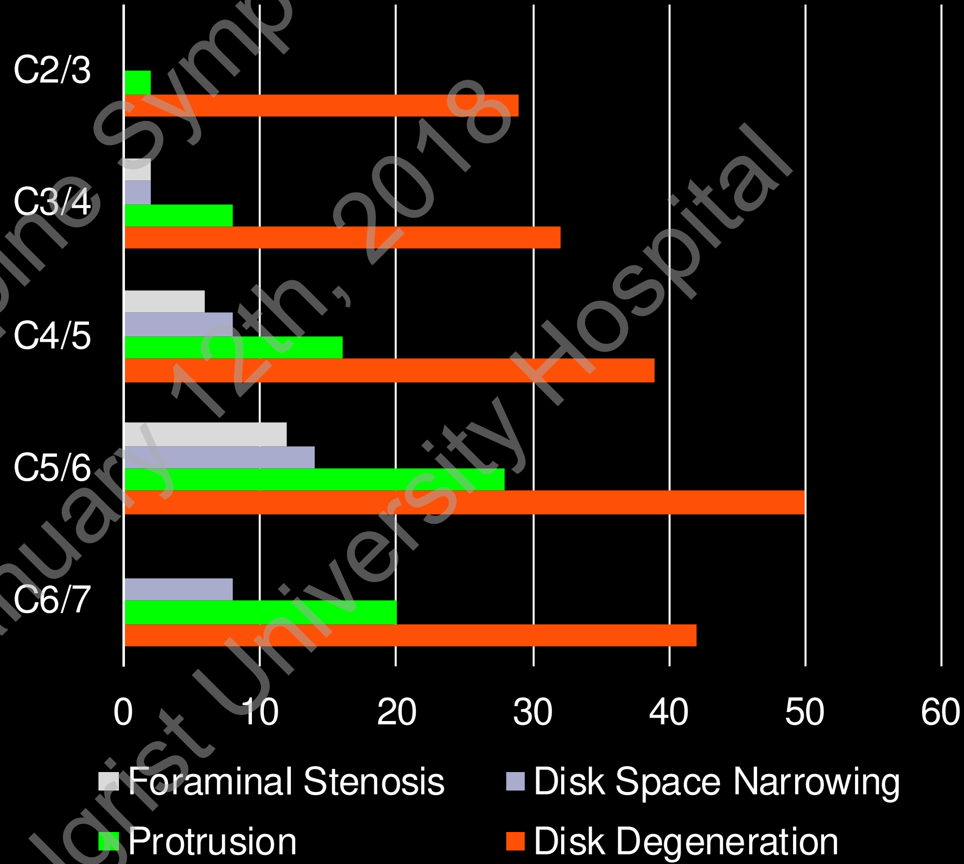
http://dx.doi.org/10.1016/j.spinee.2017.01.006

Criterion	Boos et al.	The present study	z-Value	p-Value
Intervertebral disc				
Cell	0.592	0.61	0.18	.86
Granular changes	0.407	0.43	0.18	.86
Mucous degeneration	0.637	0.68	0.49	.62
Edge neovascularity	0.257	0.30	0.30	.76
Rim lesions	0.199	0.21	0.07	.94
Concentric tears	0.598	0.58	0.18	.86
Radial tears	0.588	0.60	0.12	.90
Notochordal cells	–0.258	–0.39	0.95	.34
Cell death	0.450	0.49	0.33	.74
Scar formation	0.231	0.21	0.14	.89
Tissue defects	0.145	0.10	0.29	.77
End plate				
Cells	0.390	0.42	0.23	.82
Cartilage disorganization	0.460	0.51	0.42	.67
Cartilage cracks	0.487	0.52	0.28	.78
Microfractures	0.371	0.35	0.15	.88
Neovascularity	0.427	0.47	0.35	.73
New bone formation	0.540	0.51	0.27	.79
Bony sclerosis	0.509	0.53	0.18	.86
Physiologic vessels	–0.549	–0.59	0.39	.70
Obliterated vessels	0.015	0.09	0.48	.63
Scar formation	0.079	0.11	0.20	.84
Tissue defects	0.149	0.19	0.27	.79

Tomaszewski KA Spine J. 2017

Normal Aging: Asymptomatic Findings


Abnormal Magnetic-Resonance Scans of the Cervical Spine in Asymptomatic Subjects

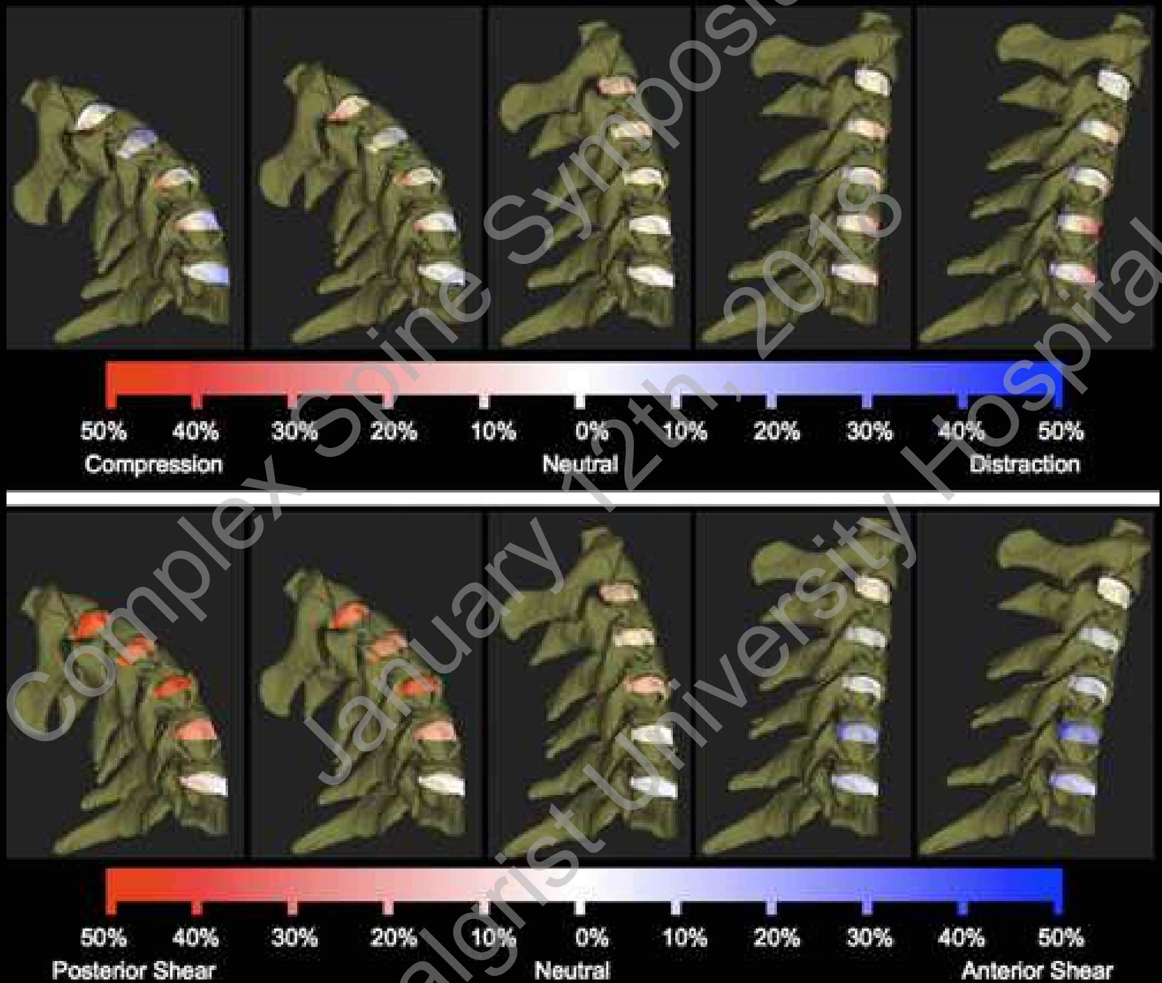


Boden SD J BJS Am. 1990 Sep;72(8):1178-84.

University of Zurich[UZH]

The Balgrist

C5/C6? - Cervical disc deformation



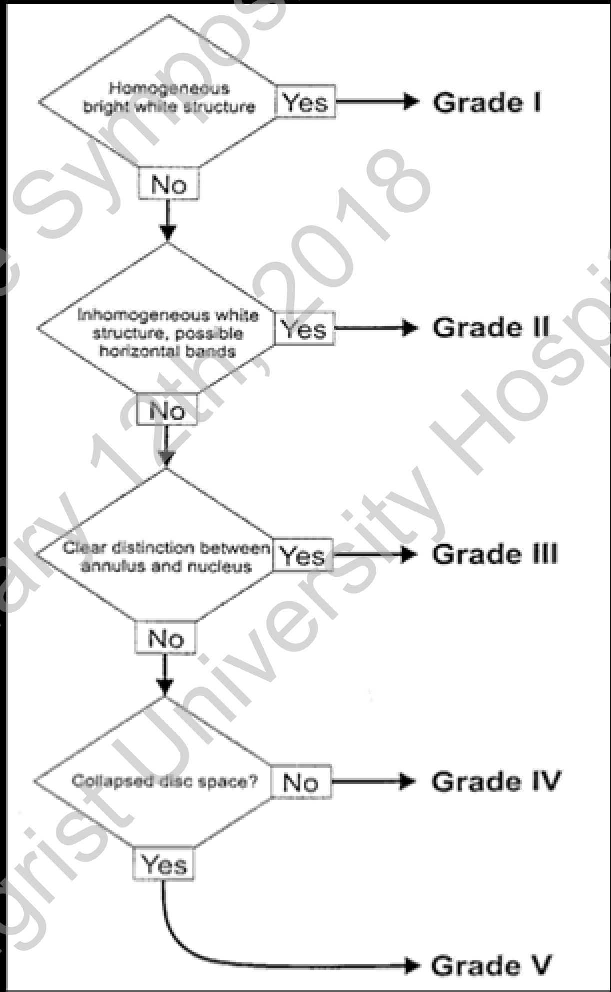
Anderst, W. J. Orthop. Res., 31: 1881–1889

University of Zurich[UZH]

The Balgrist

Disk Aging: MR Imaging

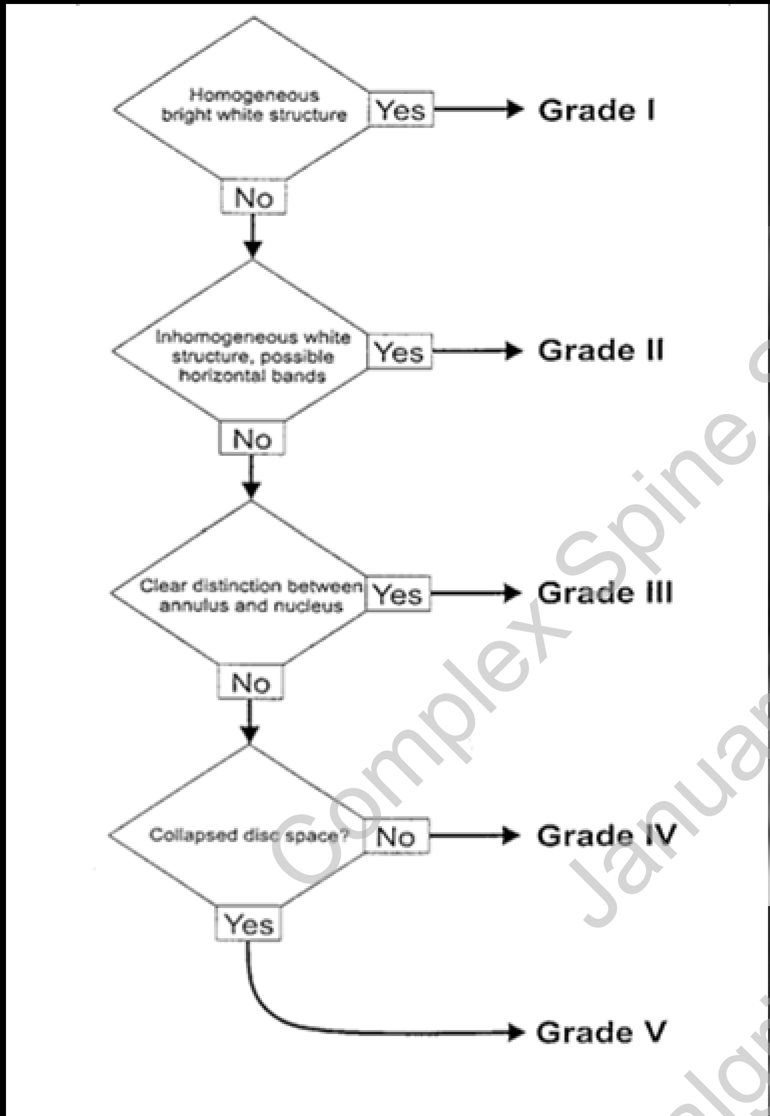
Magnetic Resonance Classification of Lumbar Intervertebral Disc Degeneration



Pfirrmann et al, Spine, 26, 1873-8, 2001

University of Zurich[UZH]

The Balgrist



Kettler A, European Spine Journal. 2006
Pfirrmann C, Spine 2001

Healthy volunteers: 10y MRI Follow-up

SPINE Volume 34, Number 7, pp 706–712
©2009, Lippincott Williams & Wilkins

Aging of the Cervical Spine in Healthy Volunteers

A 10-Year Longitudinal Magnetic Resonance Imaging Study

Eijiro Okada, MD,* Morio Matsumoto, MD,† Daisuke Ichihara, MD,* Kazuhiro Chiba, MD,* Yoshiaki Toyama, MD,* Hirokazu Fujiwara, MD,‡ Suketaka Momoshima, MD,‡ Yuji Nishiwaki, MD,§ Takeshi Hashimoto, MD,¶ Jun Ogawa, MD,‖ Masahiko Watanabe, MD,** and Takeshi Takahata, MD††

Study Design. Prospective longitudinal study, mean follow-up period; 11.7 ± 0.8 years was conducted from 1995 to 2007.

Objective. To clarify normal aging process of cervical spine and correlation between progression of disc degeneration and development of clinical symptoms.

Summary of Background Data. Aging of the cervical spine can inevitably occur in anyone. Long-term longitudinal studies following the same individuals are necessary to elucidate the accurate aging processes of the cervical spine.

Methods. Two hundred twenty-three subjects of 497 original cohorts (123 men, 100 women, mean age: 39.0 ± 15.0, follow-up rate: 44.9%). Subjects, who underwent MRI 10 years ago, underwent another MRI, neurologic examination, and questionnaire survey regarding symptoms related to cervical spine and life style. Following 5 MR findings representing intervertebral disc degeneration were evaluated: (1) decrease in signal intensity of disc, (2) anterior compression of dura and spinal cord, (3) posterior disc protrusion (PDP), (4) disc space narrowing (DSN), and (5) foraminal stenosis (FS).

Results. Progression of degenerative findings was observed in 189 subjects (81.1%). Progression of decrease in signal intensity of disc was observed in 59.6%, anterior compression of dura and spinal cord in 61.4%, PDP in 70.0%, DSN in 26.9%, and FS in 9.0%. Logistic regression analysis revealed that incidence of progression of PDP, DSN, FS was higher in elderly subjects. There were no correlations between any degenerative MR findings and sex, smoking, alcohol, sport, or body mass index. Neck pain, shoulder stiffness, and numbness in upper extremities were recognized in 9.9%, 30.0%, and 4.0% of subjects, and 1 or more clinical symptoms have developed in 34.1% during 10 years.

Conclusion. Progression of degeneration of cervical spine on MRI was frequently observed during 10-year period, with development of symptoms in 34% of subjects. No factor related to progression of degeneration of cervical spine was identified except for age.

Key words: aging, cervical spine, longitudinal study, magnetic resonance imaging (MRI), asymptomatic subjects. **Spine 2009;34:706–712**

Prevalence of back and neck problems is high among general populations,[1] and it has been estimated that neck pain is recognized in 9,000,000 and both neck and low back pain in 19,000,000 people in the United States.[2] The total cost for the treatment of neck pain in Netherlands in 1996 was estimated to be US $686 million.[3]

- Progression was frequent
- Factor correlated with progression: Age
- Factor not correlated with progression: Gender, BMI, Sports, Alcohol, Smoking
- 1/3 of subjects developed symptom

Okada E, Spine (Phila Pa 1976). 2009

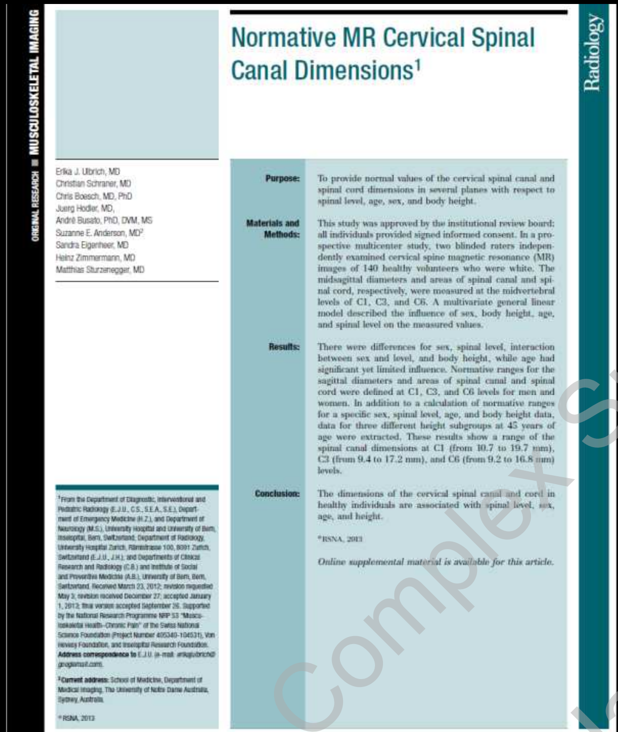
Progression Linked with Symptoms

	Neck Pain 22/223 (9.9%)	
	Prevalence	*P*
Decrease in signal intensity		
+	9/113 (8.0%)	0.098*
−	13/90 (14.4%)	
Anterior compression of dura and spinal cord		
−	17/137 (12.4%)	0.015*
+	5/86 (5.8%)	
Posterior disc protrusion		
+	15/156 (9.6%)	0.081*
−	7/67 (10.4%)	
Disc space narrowing		
+	6/60 (10.0%)	0.905
−	16/163 (9.8%)	
Foraminal stenosis		
+	5/20 (25.0%)	0.041*
−	17/203 (8.4%)	

Progression of compression of the dura/spinal cord, disc protrusion, and foraminal stenosis significantly more frequent in subjects with neck pain.

Okada E, Spine (Phila Pa 1976). 2009

Cervical Spinal Canal and Aging



ORIGINAL RESEARCH ■ MUSCULOSKELETAL IMAGING

Radiology

Normative MR Cervical Spinal Canal Dimensions[1]

Erika J. Ulbrich, MD
Christian Schraner, MD
Chris Boesch, MD, PhD
Juerg Hodler, MD,
André Busato, PhD, DVM, MS
Suzanne E. Anderson, MD[2]
Sandra Eigenheer, MD
Heinz Zimmermann, MD
Matthias Sturzenegger, MD

Purpose: To provide normal values of the cervical spinal canal and spinal cord dimensions in several planes with respect to spinal level, age, sex, and body height.

Materials and Methods: This study was approved by the institutional review board; all individuals provided signed informed consent. In a prospective multicenter study, two blinded raters independently examined cervical spine magnetic resonance (MR) images of 140 healthy volunteers who were white. The midsagittal diameters and areas of spinal canal and spinal cord, respectively, were measured at the midvertebral levels of C1, C3, and C6. A multivariate general linear model described the influence of sex, body height, age, and spinal level on the measured values.

Results: There were differences for sex, spinal level, interaction between sex and level, and body height, while age had significant yet limited influence. Normative ranges for the sagittal diameters and areas of spinal canal and spinal cord were defined at C1, C3, and C6 levels for men and women. In addition to a calculation of normative ranges for a specific sex, spinal level, age, and body height data, data for three different height subgroups at 45 years of age were extracted. These results show a range of the spinal canal dimensions at C1 (from 10.7 to 19.7 mm), C3 (from 9.4 to 17.2 mm), and C6 (from 9.2 to 16.8 mm) levels.

Conclusion: The dimensions of the cervical spinal canal and cord in healthy individuals are associated with spinal level, sex, age, and height.

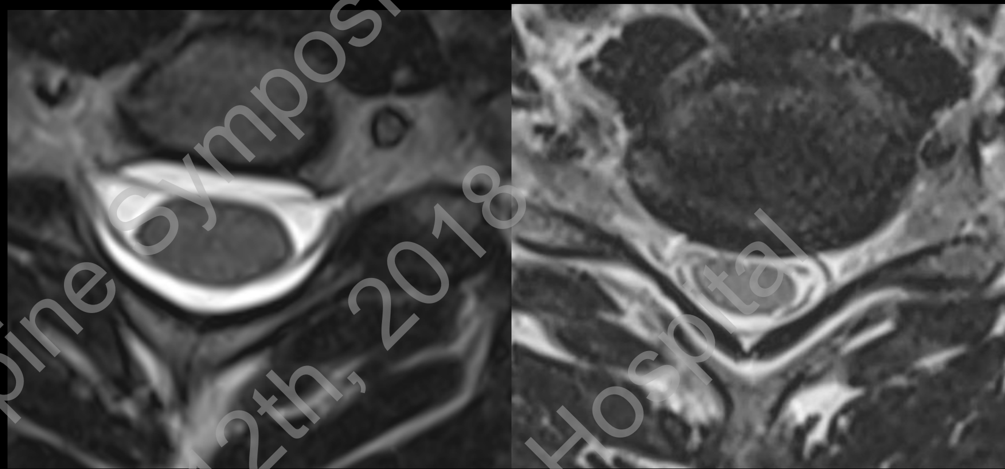
Online supplemental material is available for this article.

[1] From the Department of Diagnostic, Interventional and Pediatric Radiology (E.J.U., C.S., S.E.A., S.E.), Department of Emergency Medicine (H.Z.), and Department of Neurology (M.S.), University Hospital and University of Bern, Inselspital, Bern, Switzerland; Department of Radiology, University Hospital Zurich, Rämistrasse 100, 8091 Zurich, Switzerland (E.J.U., J.H.); and Departments of Clinical Research and Radiology (C.B.) and Institute of Social and Preventive Medicine (A.B.), University of Bern, Bern, Switzerland.

Received March 23, 2012; revision requested May 3; revision received December 27; accepted January 1, 2013; final version accepted September 26. Supported by the National Research Programme NRP 53 "Musculoskeletal Health–Chronic Pain" of the Swiss National Science Foundation (Project Number 405340-104531), Von Hevesy Foundation, and Inselspital Research Foundation.

Address correspondence to E.J.U.

[2] **Current address:** School of Medicine, Department of Medical Imaging, The University of Notre Dame Australia, Sydney, Australia.



Cervical spinal canal dimensions in
healthy volunteers
C1 10.7 - 19.7 mm
C3 9.4 - 17.2 mm
C6 9.2 - 16.8 mm

Ulbrich EJ, Radiology. 2014 172-82.

Cervical Spinal Canal and Aging

Eur Spine J (2012) 21:1499–1507
DOI 10.1007/s00586-012-2176-4

ORIGINAL ARTICLE

Normal morphology, age-related changes and abnormal findings of the cervical spine. Part II: magnetic resonance imaging of over 1,200 asymptomatic subjects

Fumihiko Kato · Yasutsugu Yukawa · Kota Suda · Masatsune Yamagata · Takayoshi Ueta

Received: 17 October 2011 / Revised: 11 January 2012 / Accepted: 23 January 2012 / Published online: 3 February 2012

Abstract
Purpose The aim of this study is to establish standard MRI values for the cervical spinal canal, dural tube, and spinal cord, to evaluate age-related changes in healthy subjects, and to assess the prevalence of abnormal findings in asymptomatic subjects.
Methods The sagittal diameter of the spinal canal and the sagittal diameter and cross-sectional area of the dural tube and spinal cord were measured on MRIs of 1,211 healthy volunteers. These included at least 100 men and 100 women in each decade of life between the third (20s) and eighth (70s). Abnormal findings such as spinal cord compression and signal changes in the spinal cord were recorded.
Results The sagittal diameter of the spinal canal was 11.2 ± 1.4 mm [mean ± standard deviation (SD)]/11.1 ± 1.4 mm (male/female) at the mid-C5 vertebral level, and 9.5 ± 1.8/9.6 ± 1.6 mm at the C5/6 disc level. The cross-sectional area of the spinal cord was 78.1 ± 9.4/74.4 ± 9.4 mm^2 at the mid-C5 level and 70.6 ± 11.7/68.9 ± 11.3 mm^2 at the C5/6 disc level. Both the sagittal diameter and the axial area of the dural tube and spinal cord tended to decrease with increasing age. This tendency was more marked at the level of the intervertebral discs than at the level of the vertebral bodies, especially at the C5/6 intervertebral disc level. The spinal cord occupation rate in the dural tube at the C5 vertebral body level averaged 58.3 ± 7.0%. Spinal cord compression was observed in 64 cases (5.3%) and a T2 high-signal change was observed in 28 cases (2.3%).
Conclusions Using MRI data of 1,211 asymptomatic subjects, the standard values for the cervical spinal canal, dural tube, and spinal cord for healthy members of each sex and each decade of life and the age-related changes in these parameters were established. The relatively high prevalence of abnormal MRI findings of the cervical spine in asymptomatic individuals emphasizes the dangers of predicating operative decisions on diagnostic tests without precisely correlating these findings with clinical signs and symptoms.

Keywords Cervical spine · MRI · Standard values · Anatomy · Aging change

F. Kato · Y. Yukawa (✉)
Department of Orthopedic Surgery, Chubu Rosai Hospital, 1-10-6 Komei, Minato-ku, Nagoya, Aichi 455-8530, Japan
e-mail: yukawa.ort@chubuh.rofuku.go.jp

K. Suda
Department of Orthopedic Surgery, Hokkaido Chuo Rosai Hospital Sekison Center, Bibai, Hokkaido, Japan

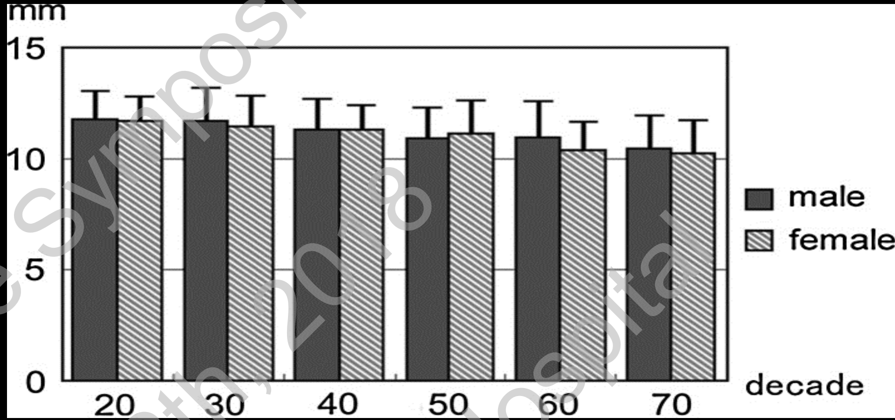
M. Yamagata
Department of Orthopedic Surgery, Chiba Rosai Hospital, Ichihara, Chiba, Japan

T. Ueta
Department of Orthopedic Surgery, Spinal Injuries Center, Iizuka, Fukuoka, Japan

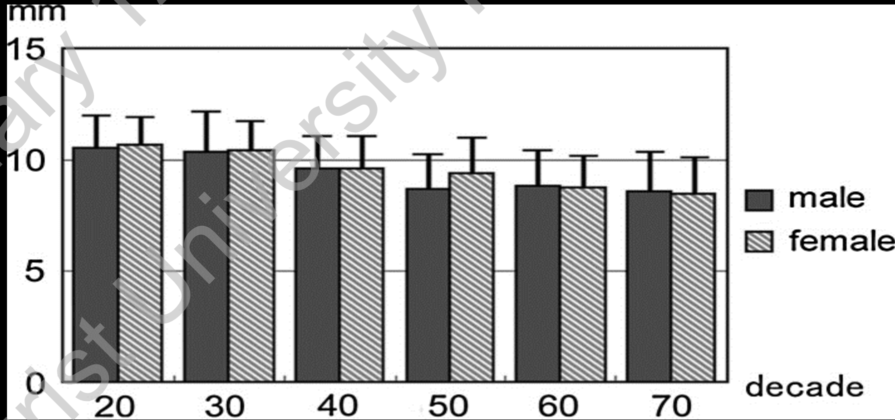
Introduction

The number of patients with cervical spondylotic myelopathy (CSM) is increasing in the aging population. Although CSM is the most common disease of the spinal cord that occurs during and after middle age, its pathophysiology remains unclear. In the pathophysiology of CSM, there are static factors such as preexisting developmental canal stenosis, bulging of the posterior margin of the intervertebral disc, and hypertrophy of the ligamentum

Springer



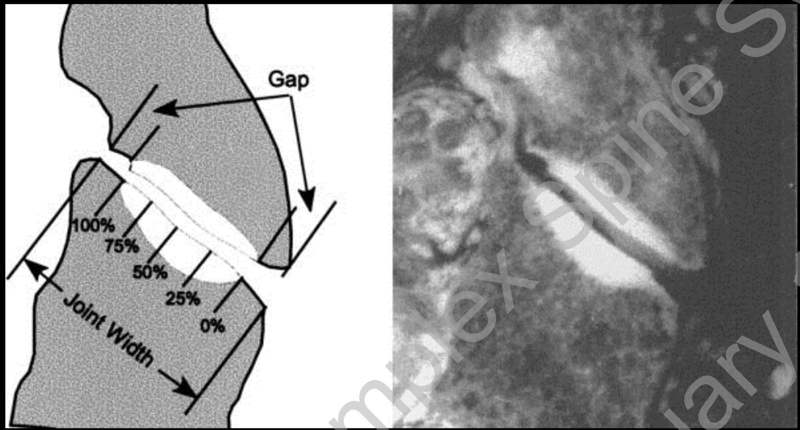
Dural tube diameter at the C5 in each sex and decade

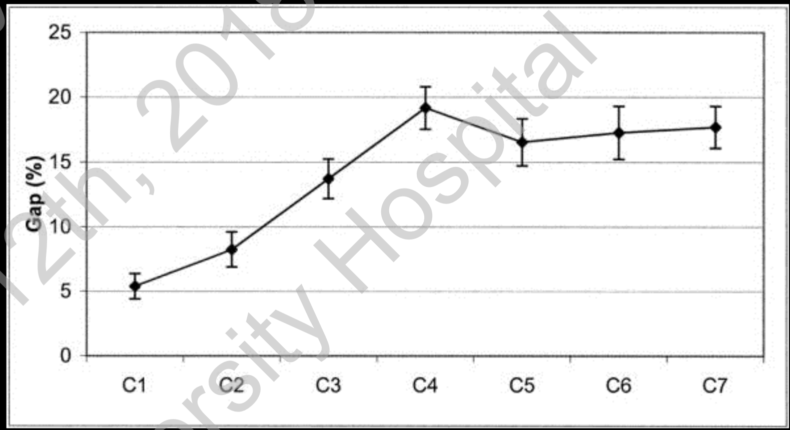


Dural tube diameter at the C5/6 in each sex and decade

Kato F, Eur Spine J. 2012 :1499-507.

Aging of Cervical Facet Joints





Yoganandan, N, Spine. 28(20):2317-2323, 2003.

Aging of Cervical Facet Joints

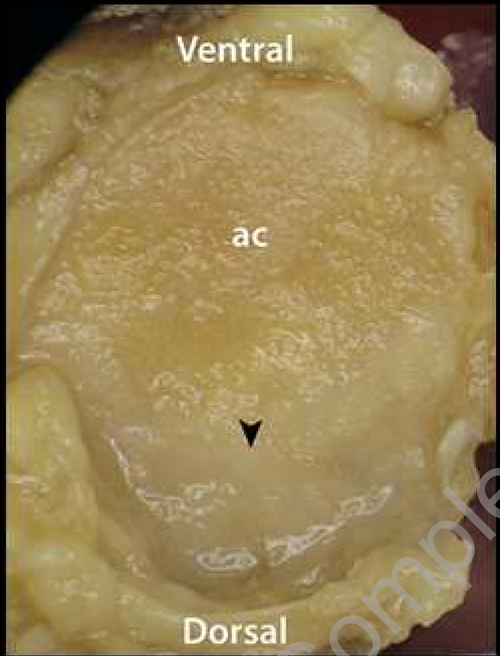


Image from Farrell SF

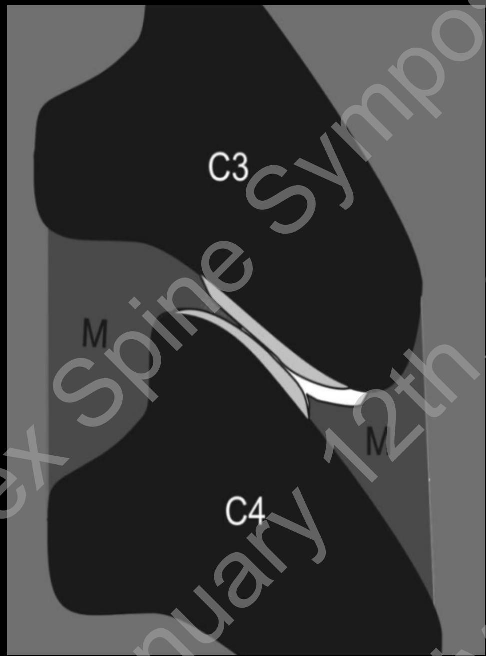


Image from Friedrich KM

The articular cartilage covers the central region of the articular processes

The remainder of the articular processes are covered by the meniscoids (M), which are attached to the bone and the fibrous joint capsule

Farrell SF Surgical and Radiologic Anatomy 2014
Friedrich KM Spine 2008

Aging of Facet Joints

817

Age-Related Changes in the Cervical Facet Joints: Studies with Cryomicrotomy, MR, and CT

Geoffrey Fletcher[1]
Victor M. Haughton[1]
Khang-Cheng Ho[2]
Shiwei Yu[1]

The cervical facet joints of 20 cadavers were studied systematically with MR, CT, cryomicrotomy, and histologic sections to determine the anatomic changes that occur with age. Uniform layers of cartilage and subarticular cortical bone characterize the cervical facet joints in cadavers under 20 years of age. Most adult cervical facet joints have only a discolored or microscopically thin layer of cartilage and have irregularly thickened subarticular cortical bone. The appearance of the cervical facet joints changes significantly with aging.

AJNR 11:27–30, January/February 1990; AJR 154:817–820, April 1990

Anatomic criteria to distinguish normal from abnormal cervical facet joints have not been defined. We noted that many adult cervical facet joints lacked the uniform layer of cartilage and the meniscus that has been described in the normal cervical facet joints [1–3]. We therefore studied the age-related changes of the cervical facet joints with MR, CT, and cryomicrotomy.

Materials and Methods

Twenty cadavers (12 male, eight female) with no recorded spinal symptoms or disease were selected from the cadavers donated to the Medical College of Wisconsin. The cervical spines in these cadavers were imaged with a 1.5-T cryogenic imager (Signa, General Electric, Milwaukee) and a 3-in. "butterfly" surface coil (Medical Advances, Milwaukee) placed behind the neck. Contiguous 3-mm-thick images in the sagittal plane were obtained with a 256 × 256 matrix and two excitations. Long and short TR images (600–1000/20, 2000/20, 2000/80) were acquired. Image acquisition time was between 30 and 43 min. CT was performed with a GE CT 9800 scanner in the same plane as the MR images. A 1.5- or 3-mm-thick slice was used with a 512 × 512 matrix, 120 kV, 200 mA, 4 sec scan time, 1.5–2.0 magnification factor, and bone windows. After CT and MR imaging the cadavers were frozen and a block of tissue that included the entire cervical spine was removed with a bandsaw. The block was placed on the stage of a planing cryomicrotome (LKB, Gaithersburg, MD). Anatomic sections were obtained in the same plane as the MR and CT images. As 1-mm-thick sections were removed, the surface of the specimen was photographed. The photographs and MR and CT images were compared. In three specimens the cryomicrotome sectioning was terminated when the midpoint of the facet joints was reached. The remaining tissue was placed in formalin and then decalcified, embedded, sectioned, stained with hematoxylin and eosin, and examined with light microscopy. In four cases, the cervical facet joints on one side were unavailable for this study. The case material was divided into two groups: under 20 years old (two cadavers ages 10 and 19) and over 35 years old (18 cadavers ages 37–86).

Results

The facet joints in the cadavers under 20 years of age conformed to the conventional anatomic depiction [3] (Fig. 1A). In these facet joints, a layer of glistening homogeneous ivory-white cartilage, measuring 1–1.3 mm in thickness,

Received December 7, 1987; revision requested February 10, 1988; revision received May 19, 1989; accepted May 19, 1989.

This work was supported by NIH grant 1 RO1 AR33667-01A2.

[1] Department of Radiology, The Medical College of Wisconsin, Froedtert Memorial Lutheran Hospital, 9200 W. Wisconsin Ave., Milwaukee, WI 53226. Address reprint requests to V. M. Haughton.

[2] Department of Pathology, The Medical College of Wisconsin, Froedtert Memorial Lutheran Hospital, Milwaukee, WI 53226.

0361–803X/90/1544–0817

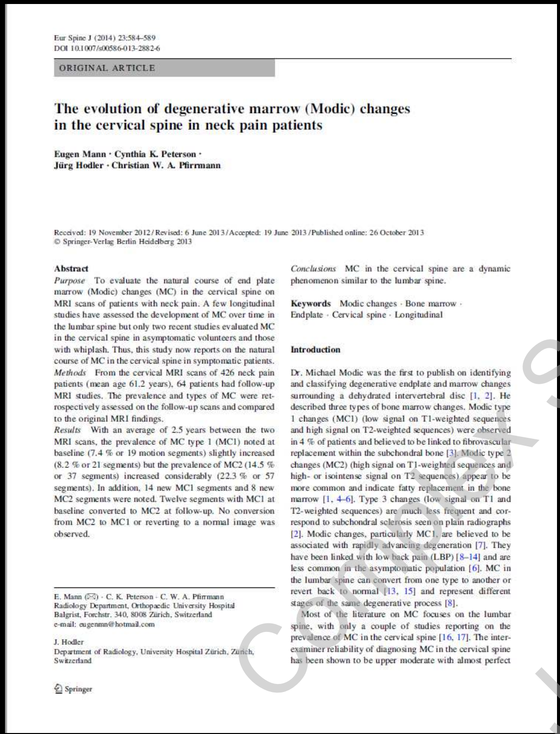
- Only in the first two decades normal cervical facet joints - normal articular cartilage and meniscus
- After 37 years of age and older less cartilage, less regular cortical margins, and no grossly evident meniscus in the cervical facet joints.

Flecher G, AJR. 1990;154: 817-820

University of Zurich[UZH]

The Balgrist

Modic changes in the cervical spine:



Eur Spine J (2014) 23:584–589
DOI 10.1007/s00586-013-2882-6

ORIGINAL ARTICLE

The evolution of degenerative marrow (Modic) changes in the cervical spine in neck pain patients

Eugen Mann · Cynthia K. Peterson · Jürg Hodler · Christian W. A. Pfirrmann

Received: 19 November 2012 / Revised: 6 June 2013 / Accepted: 19 June 2013 / Published online: 26 October 2013

Abstract
Purpose To evaluate the natural course of end plate marrow (Modic) changes (MC) in the cervical spine on MRI scans of patients with neck pain. A few longitudinal studies have assessed the development of MC over time in the lumbar spine but only two recent studies evaluated MC in the cervical spine in asymptomatic volunteers and those with whiplash. Thus, this study now reports on the natural course of MC in the cervical spine in symptomatic patients.
Methods From the cervical MRI scans of 426 neck pain patients (mean age 61.2 years), 64 patients had follow-up MRI studies. The prevalence and types of MC were retrospectively assessed on the follow-up scans and compared to the original MRI findings.
Results With an average of 2.5 years between the two MRI scans, the prevalence of MC type 1 (MC1) noted at baseline (7.4 % or 19 motion segments) slightly increased (8.2 % or 21 segments) but the prevalence of MC2 (14.5 % or 37 segments) increased considerably (22.3 % or 57 segments). In addition, 14 new MC1 segments and 8 new MC2 segments were noted. Twelve segments with MC1 at baseline converted to MC2 at follow-up. No conversion from MC2 to MC1 or reverting to a normal image was observed.
Conclusions MC in the cervical spine are a dynamic phenomenon similar to the lumbar spine.

Keywords Modic changes · Bone marrow · Endplate · Cervical spine · Longitudinal

E. Mann (✉) · C. K. Peterson · C. W. A. Pfirrmann
Radiology Department, Orthopaedic University Hospital Balgrist, Forchstr. 340, 8008 Zürich, Switzerland
e-mail: eugenmn@hotmail.com

J. Hodler
Department of Radiology, University Hospital Zürich, Zürich, Switzerland

Introduction

Dr. Michael Modic was the first to publish on identifying and classifying degenerative endplate and marrow changes surrounding a dehydrated intervertebral disc [1, 2]. He described three types of bone marrow changes. Modic type 1 changes (MC1) (low signal on T1-weighted sequences and high signal on T2-weighted sequences) were observed in 4 % of patients and believed to be linked to fibrovascular replacement within the subchondral bone [3]. Modic type 2 changes (MC2) (high signal on T1-weighted sequences and high- or isointense signal on T2 sequences) appear to be more common and indicate fatty replacement in the bone marrow [1, 4–6]. Type 3 changes (low signal on T1 and T2-weighted sequences) are much less frequent and correspond to subchondral sclerosis seen on plain radiographs [2]. Modic changes, particularly MC1, are believed to be associated with rapidly advancing degeneration [7]. They have been linked with low back pain (LBP) [8–14] and are less common in the asymptomatic population [6]. MC in the lumbar spine can convert from one type to another or revert back to normal [13, 15] and represent different stages of the same degenerative process [8].

Most of the literature on MC focuses on the lumbar spine, with only a couple of studies reporting on the prevalence of MC in the cervical spine [16, 17]. The inter-examiner reliability of diagnosing MC in the cervical spine has been shown to be upper moderate with almost perfect

Type 1

Type 2

Type 3

Mann E, Eur Spine J 2014

Modic changes in the cervical spine:

■ SPINE

Modic changes in the cervical spine

PROSPECTIVE 10-YEAR FOLLOW-UP STUDY IN ASYMPTOMATIC SUBJECTS

M. Matsumoto,
E. Okada,
D. Ichihara,
K. Chiba,
Y. Toyama,
H. Fujiwara,
S. Momoshima,
Y. Nishiwaki,
T. Takahata

From Department of Orthopaedic Surgery, Keio University, Tokyo, Japan

M. Matsumoto, MD, Orthopaedic Surgeon, Associate Professor
E. Okada, MD, Orthopaedic Surgeon, Attending surgeon
D. Ichihara, MD, Orthopaedic Surgeon, Attending Surgeon
K. Chiba, MD, Orthopaedic Surgeon, Associate Professor
Y. Toyama, MD, Orthopaedic Surgeon, Professor
Keio University, Department of Orthopaedic Surgery, Shinanomachi 35, Shinjuku-ku, Tokyo 160-8582, Japan.

H. Fujiwara, MD, Neuroradiologist, Assistant Professor
S. Momoshima, MD, Neuroradiologist, Assistant Professor
Keio University, Department of Diagnostic Radiology, Shinanomachi 35, Shinjuku-ku, Tokyo 160-8582, Japan.

Y. Nishiwaki, MD, Professor
Toho University, Department of Environmental and Occupational Health, Ohmori Nishi 6-11-1, Ota-ku, Tokyo 143-8541, Japan.

T. Takahata, MD, Orthopaedic Surgeon, Dean
Isehara Kyodo Hospital, Sakuradai 2-17-1, Isehara City, Kanagawa 259-1132, Japan.

Correspondence should be sent to Dr M. Matsumoto; e-mail: morio@a5.keio.jp

doi:10.1302/0301-620X.94B5.28519 $2.00

J Bone Joint Surg Br 2012;94-B:678-83.
Received 18 October 2011; Accepted after revision 23 January 2012

We conducted a prospective follow-up MRI study of originally asymptomatic healthy subjects to clarify the development of Modic changes in the cervical spine over a ten-year period and to identify related factors. Previously, 497 asymptomatic healthy volunteers with no history of cervical trauma or surgery underwent MRI. Of these, 223 underwent a second MRI at a mean follow-up of 11.6 years (10 to 12.7). These 223 subjects comprised 133 men and 100 women with a mean age at second MRI of 50.5 years (23 to 83). Modic changes were classified as not present and types 1 to 3. Changes in Modic types over time and relationships between Modic changes and progression of degeneration of the disc or clinical symptoms were evaluated. A total of 31 subjects (13.9%) showed Modic changes at follow-up: type 1 in nine, type 2 in 18, type 3 in two, and types 1 and 2 in two. Modic changes at follow-up were significantly associated with numbness or pain in the arm, but not with neck pain or shoulder stiffness. Age (≥ 40 years), gender (male), and pre-existing disc degeneration were significantly associated with newly developed Modic changes.

In the cervical spine over a ten-year period, type 2 Modic changes developed most frequently. Newly developed Modic changes were significantly associated with age, gender, and pre-existing disc degeneration.

Degenerative changes of the vertebral bodies adjacent to intervertebral discs seen on MRI are known as Modic changes.[1,2] These changes have been extensively studied in the lumbar spine, with a prevalence ranging from 8% to 81%, reflecting differences in the backgrounds of the populations examined.[3-6] Modic changes are classified into three types according to their signal patterns on T_1 and T_2 sagittal MR images: type 1, T_1 low signal intensity and T_2 high; type 2, both T_1 and T_2 high; and type 3, both T_1 and T_2 low.[1,2] Histological and radiological studies have demonstrated that Modic type 1 changes reflect inflammatory changes in the vertebral endplates; type 2 reflect fatty marrow; and type 3 reflect sclerotic changes of the endplates. Modic changes, especially type 1, have been reported to be associated with low back pain[2,4,7-9]; however, they have also been observed in asymptomatic individuals.[10] It has been shown that there is a significant correlation between Modic changes and pain provocation at discography, suggesting that they can be a predictive sign of low back pain.[11,12]

In several longitudinal studies Modic changes have been shown to vary with the passage of time.[13,14] Hutton, Bayer and Powell[14] found that, of 36 endplates with Modic type 1 changes in the first MRI study, 18 remained the same, 13 progressed to type 2, three progressed to type 3, and two became normal, at a mean follow-up of 1.9 years. There have been few studies of these changes in the cervical spine. We previously reported a prospective ten-year follow-up MRI study of the cervical intervertebral discs in 223 healthy subjects, in which we found a progression in disc degeneration in 85% of the participants.[15] The objectives of this current study were to elucidate the natural history of Modic changes by examining the variations between the two MRI studies conducted ten years apart, and to see if there are any correlations between these changes with disc degeneration and clinical symptoms.

Materials and Methods

Approval was obtained from the institutional review boards of all the participating institutions. The previous study was conducted between 1993 and 1996 and investigated age-related changes in the cervical spine; 497 asymptomatic healthy volunteers with no history of cervical trauma or surgery underwent MRI.[16] Volunteers for the follow-up MRI study were recruited by mail and telephone and 223 agreed to participate in the follow-up study. There were 133 men and 100 women

Modic changes in asymptomatic subjects and 10-year follow-up study

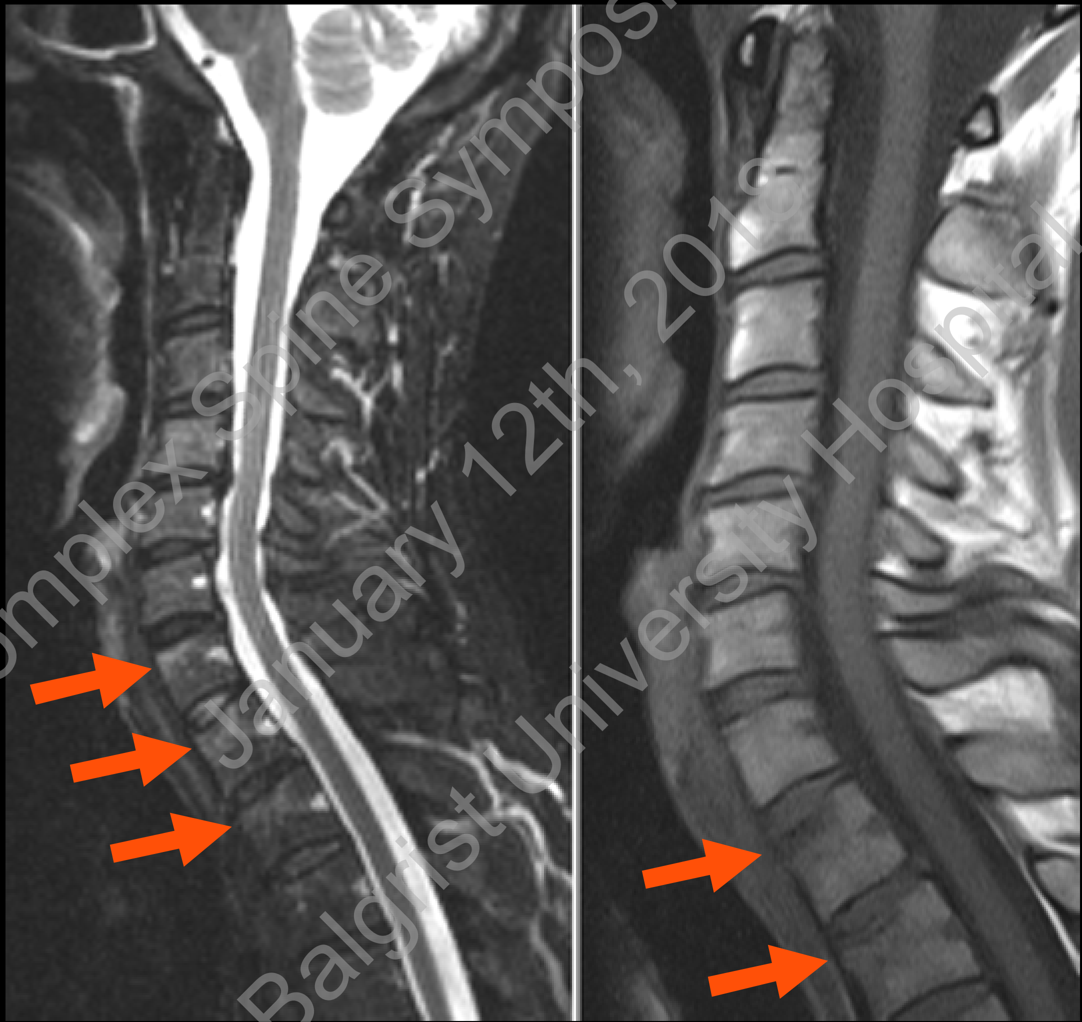
	Initial	10 years
	4.5%	13.9%
Type 1	7	9
Type 2	3	18
Type 3	2	2

Modic changes associated
with arm pain
not with neck pain

Postive association with
Age (≥ 40 years),
gender (male)
pre-existing disc degeneration

Matsumoto M, JBJS 2012 94

Modic changes in the cervical spine:



University of Zurich[UZH]

The Balgrist

1: Radiology. 1988 Jun;167(3):757-60.

Transient osteoporosis: transient bone marrow edema?

Wilson AJ, Murphy WA, Hardy DC, Totty WG.

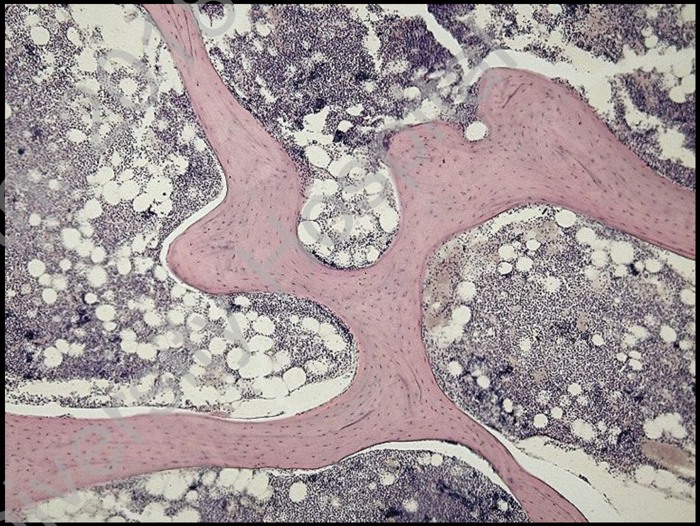
Mallinckrodt Institute of Radiology, Washington University School of Medicine, St Louis, MO 63110.

Ten patients with debilitating hip or knee pain were examined with magnetic resonance (MR) imaging. All had conventional radiographs that were either normal or showed nonspecific osteopenia. Nine patients had bone scintigrams that showed focal increased radionuclide uptake in the region of the painful joint. In each case, MR images of the affected joint showed regional decreased signal intensity of the bone marrow on T1-weighted images and increased signal intensity on T2-weighted images. Biopsy results of four patients excluded ischemic necrosis and metastases. The symptoms resolved spontaneously in all cases. The ten patients were followed up for 12-36 months, and there were no recurrences. The authors believe that the findings on MR images represent a transient increase in bone marrow water content. The focal findings on scintigrams confirmed the periarticular distribution of the process and provided evidence of accompanying hyperemia and increased bone mineral metabolism. For lack of a better term and to emphasize the generic character of the condition, the authors termed this condition "the transient marrow edema syndrome."

PMID: 3363136 [PubMed - indexed for MEDLINE]

Histology of Bone Marrow Edema

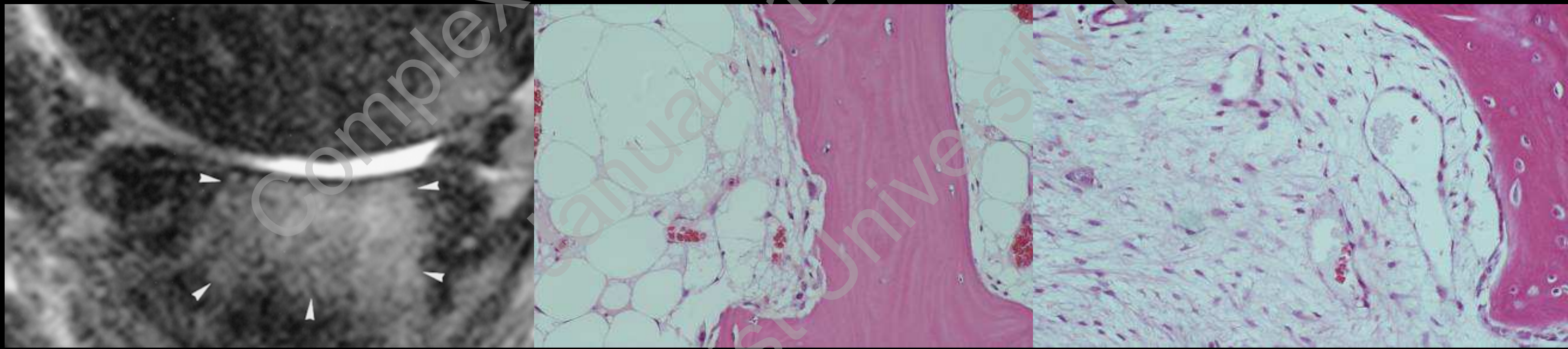
N = 5 Knees with Bone Bruise
Microfractures of trabecular bone
Edema
Bleeding into fatty bone marrow
Fragments of hyaline cartilage
Fragments of trabecular bone



Rangger C et al. Acta orthop 1998; 69:291-294

Bone Marrow Edema

Histology	"Edema" (n = 11)	Control (n = 15)	Paired t-test
Edema	4%	2%	0.069
Necrosis	11%	2%	0.021
Fibrosis	4%	1%	0.014
Trabecular alterations	8%	3%	0.011



University of Zurich

Zanetti M et al Radiology 2000; 215:835-

The Balgrist

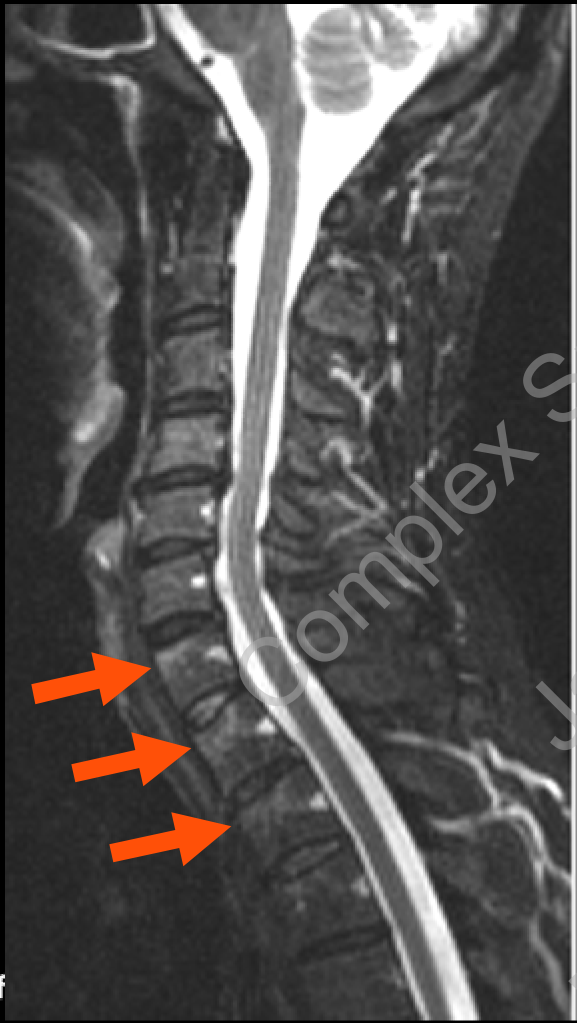
Bone Marrow Edema Pattern

Bone Marrow Edema Pattern
= High signal on fluid sensitive MR sequences
(STIR, T2 fat sat, PD fat st)

Non specific finding!

Trauma (Fracture, Bone bruise)
Inflammatory lesions
Infection
Tumors
Degenerative reactive changes

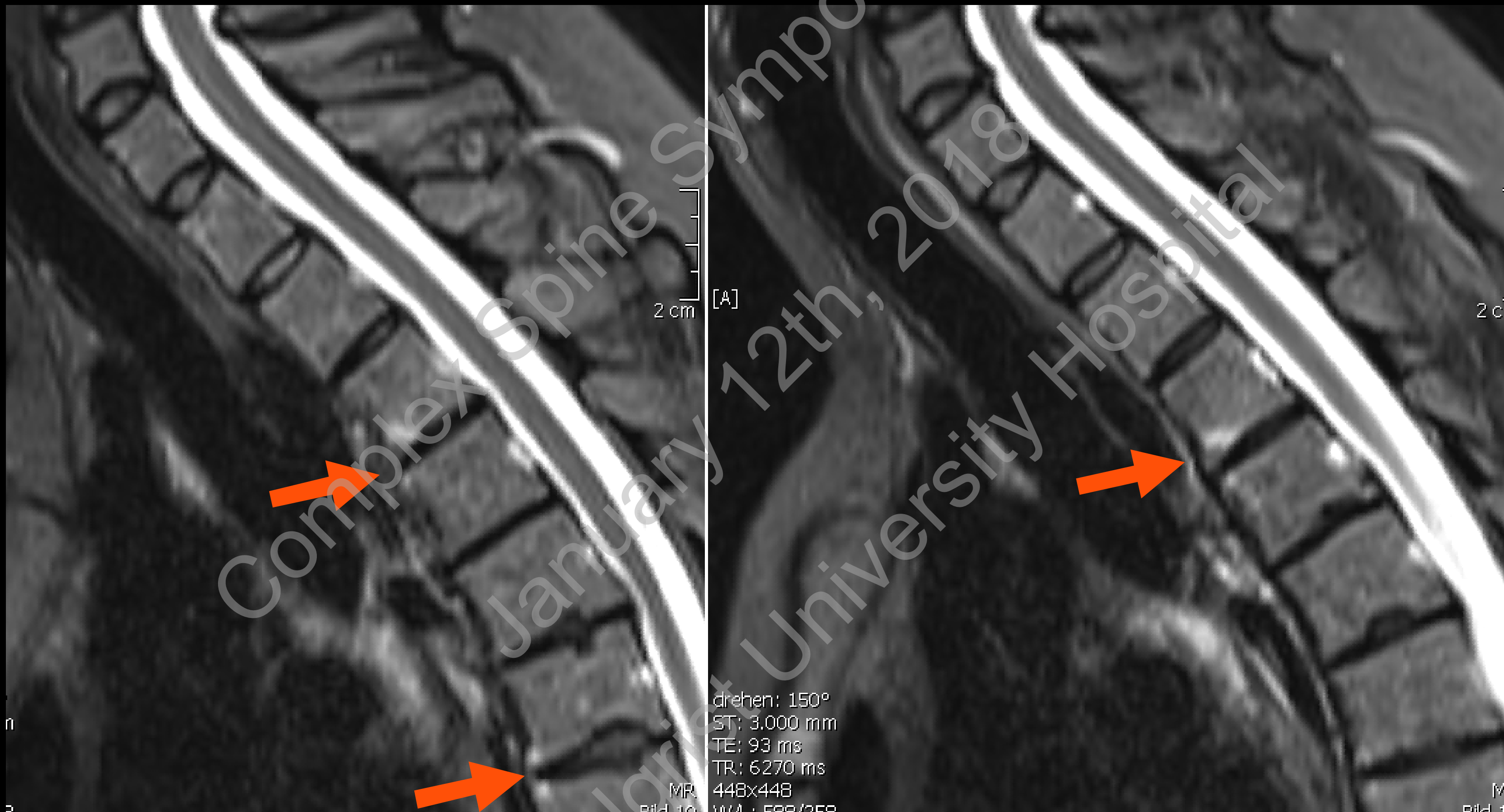
Fractures



University of Zurich[UZH]

The Balgrist

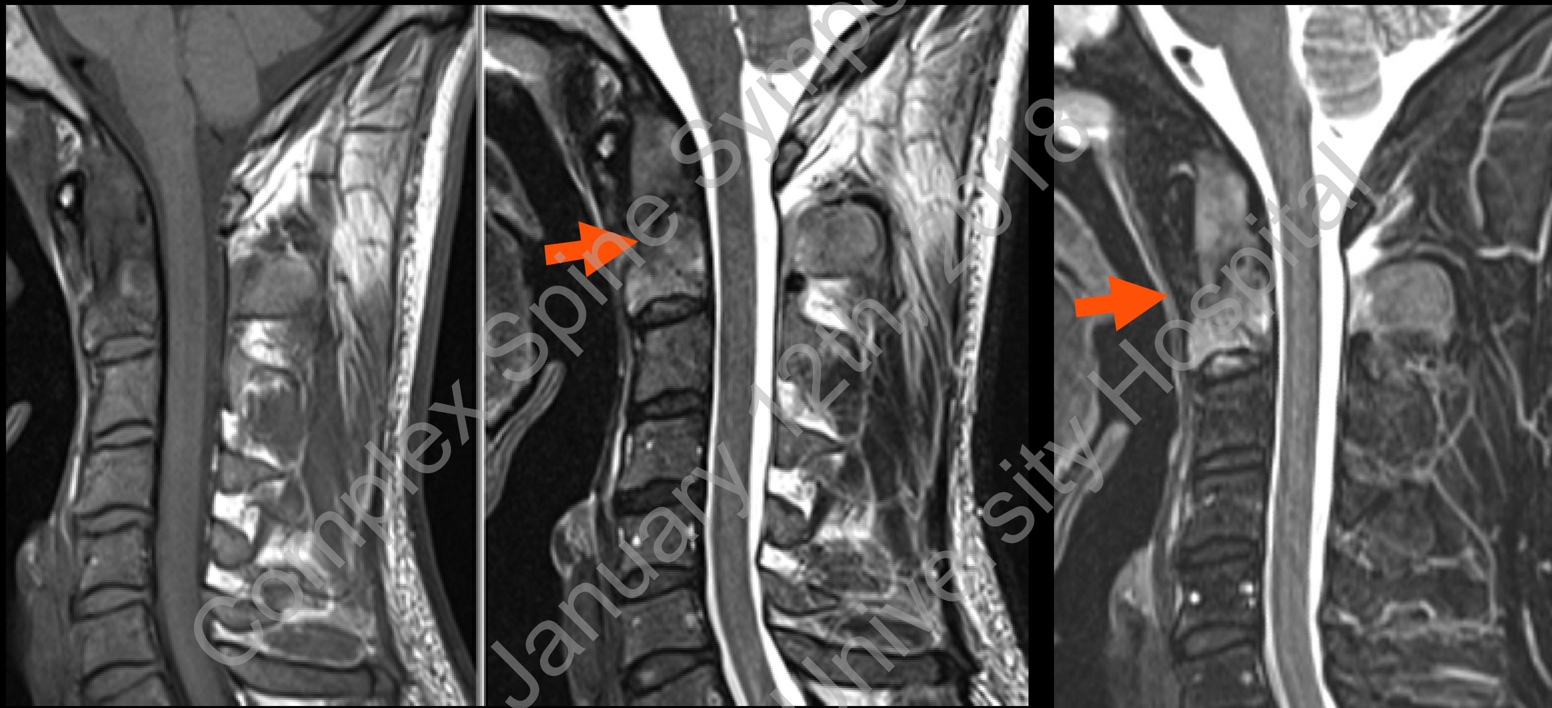
Inflammatory Lesions Ankylosing Spondalitis



Severe neck pain I - 15y Fall from Horse

Severe neck pain I - 15y Fall from Horse

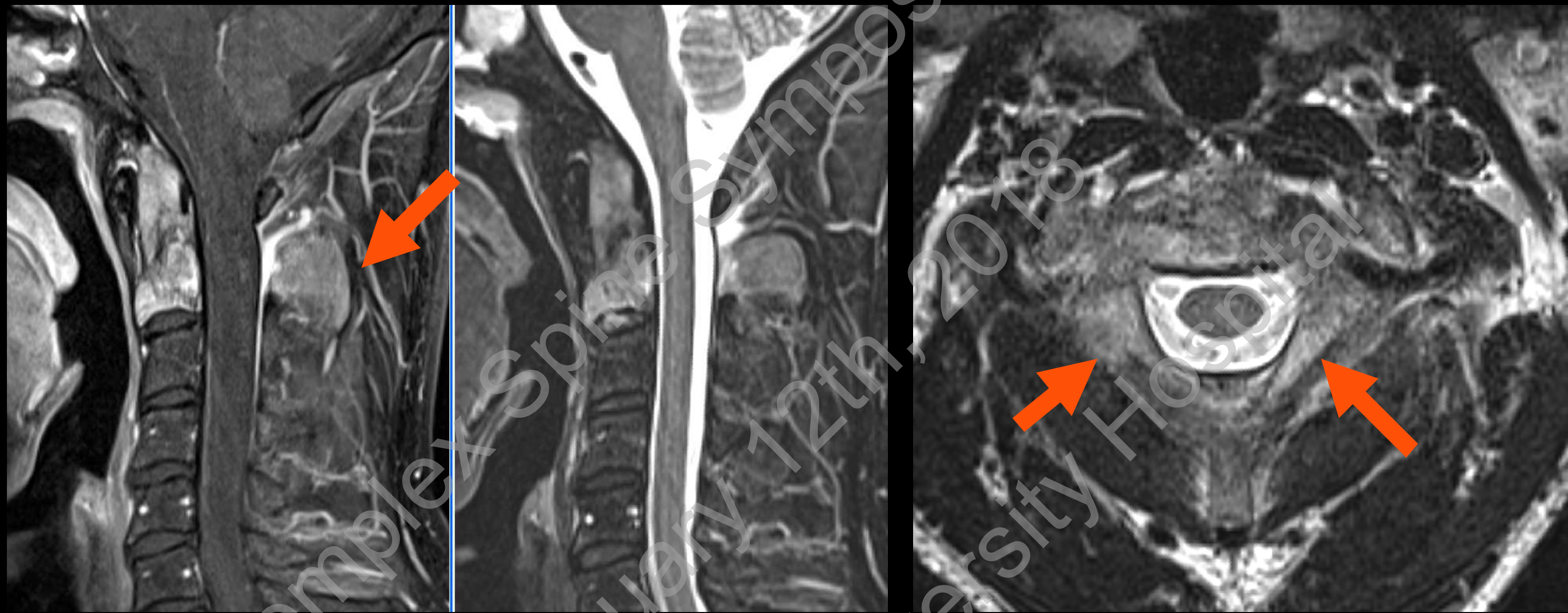
Severe neck pain II - 34y m, Trauma C-Spine



Bone marrow edema

Fracture of dens?

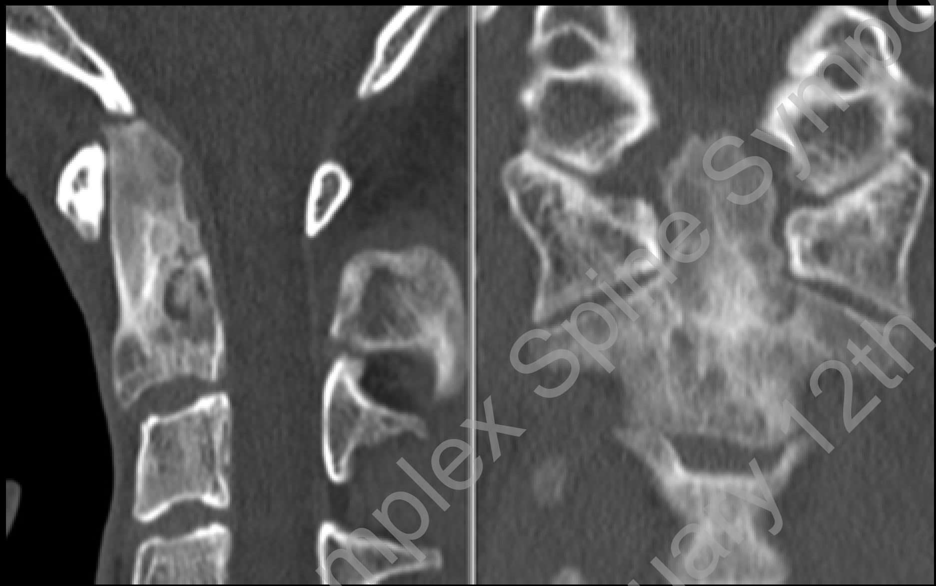
Severe neck pain II - 34y m, Trauma C-Spine



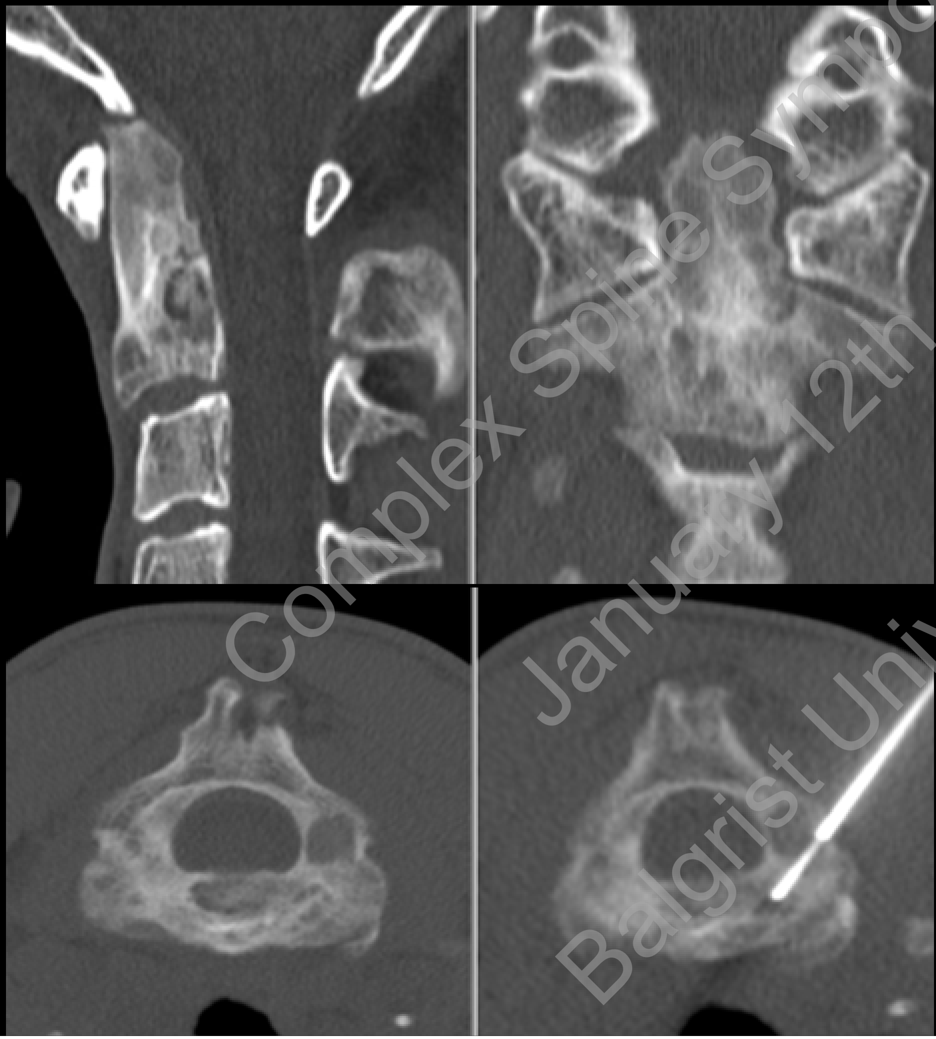
Bone marrow edema

Reason for posterior arc edema?

Severe neck pain II - 34y m, Trauma C-Spine



Severe neck pain II - 34y m, Trauma C-Spine



Dx: Paget's disease

University of Zurich[UZH]

The Balgrist

Severe Neck Pain III – 41 f Acute onset No trauma

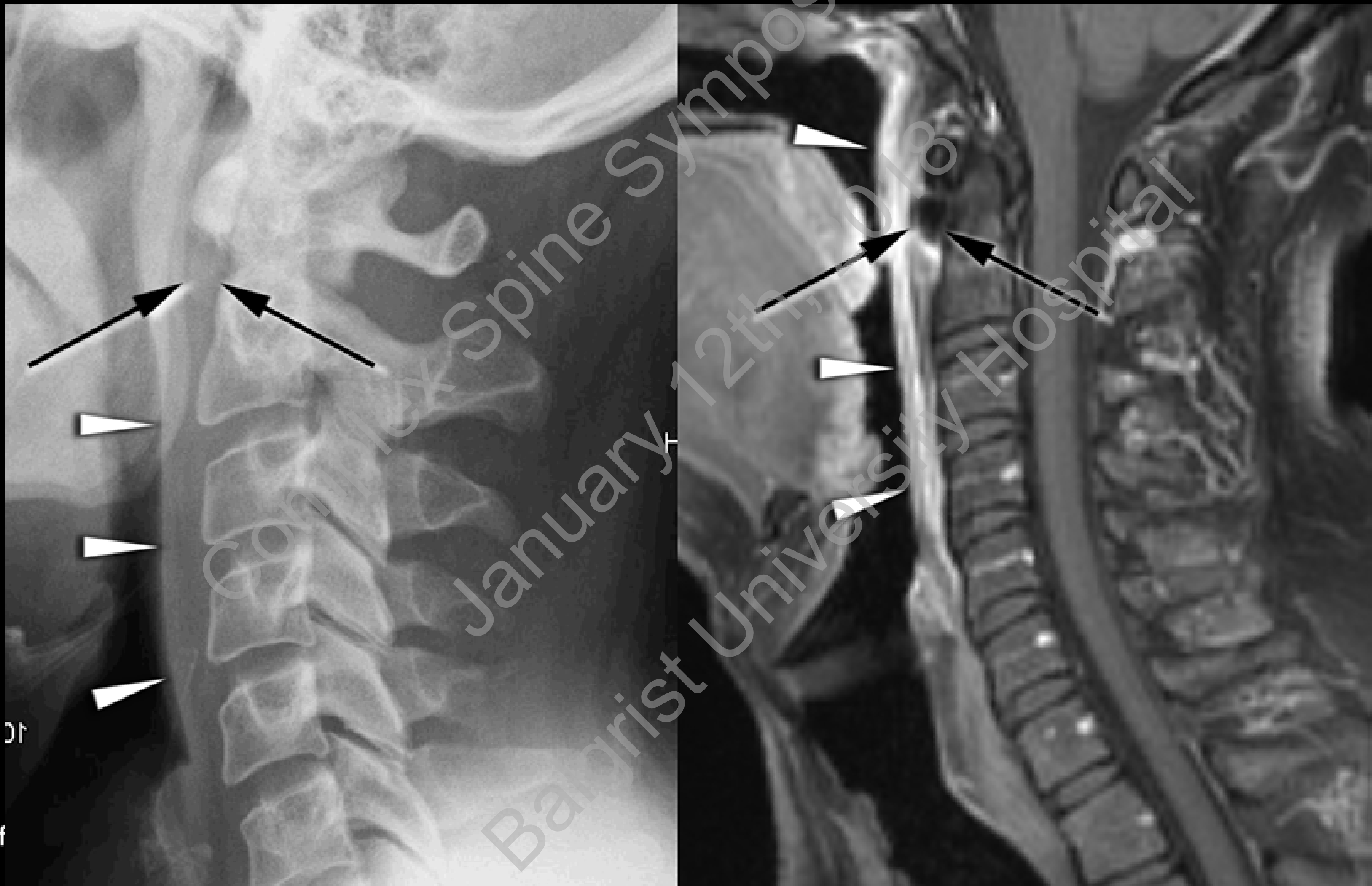
University of Zurich[UZH]

Balgrist

MR: T1 & T2

MR: STIR and T1 fat sat after i.v. Gad

Radiograph and T1 fat sat after i.v. Gad

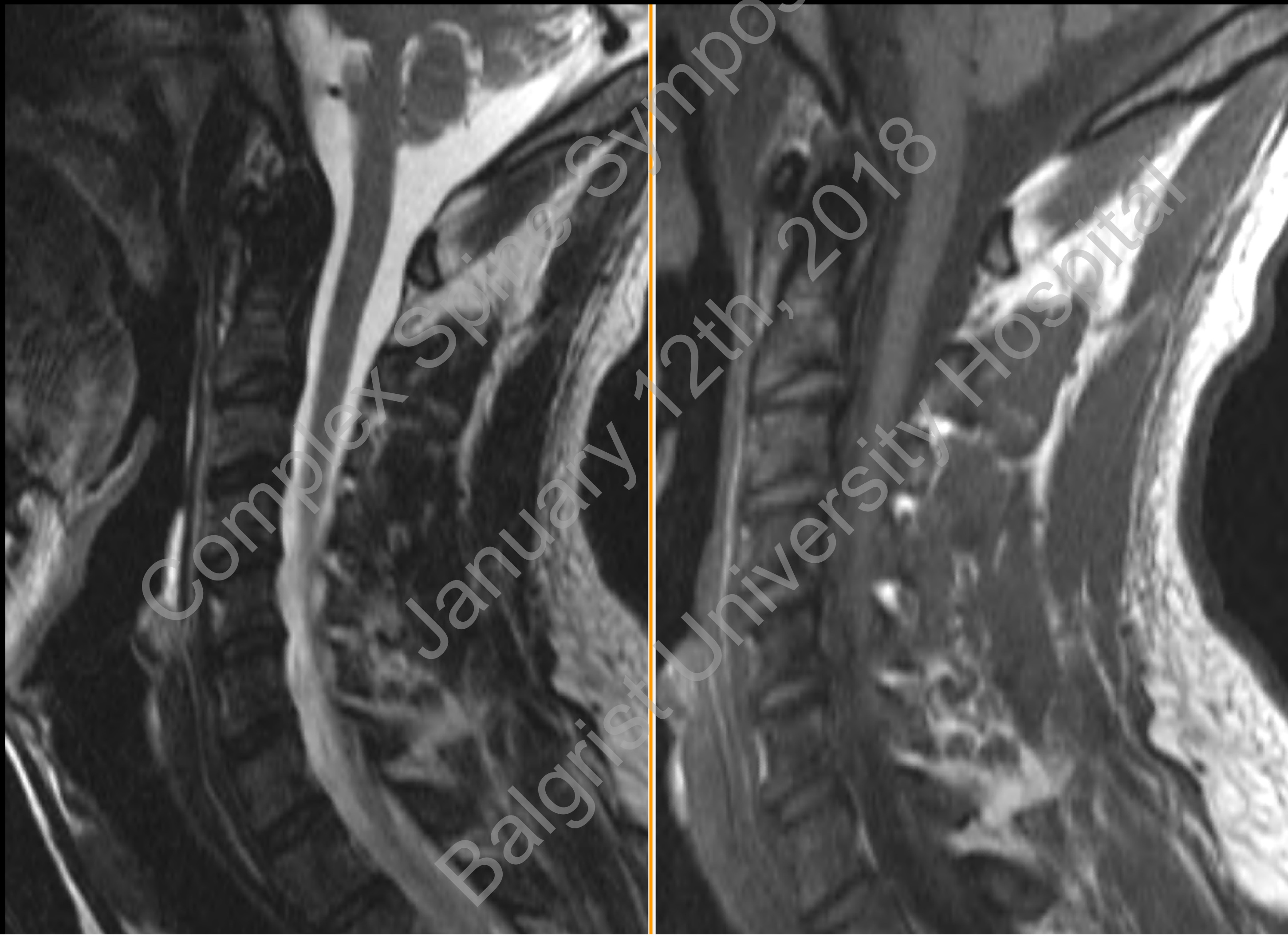


D: Calcific Retropharyngeal Tendinitis

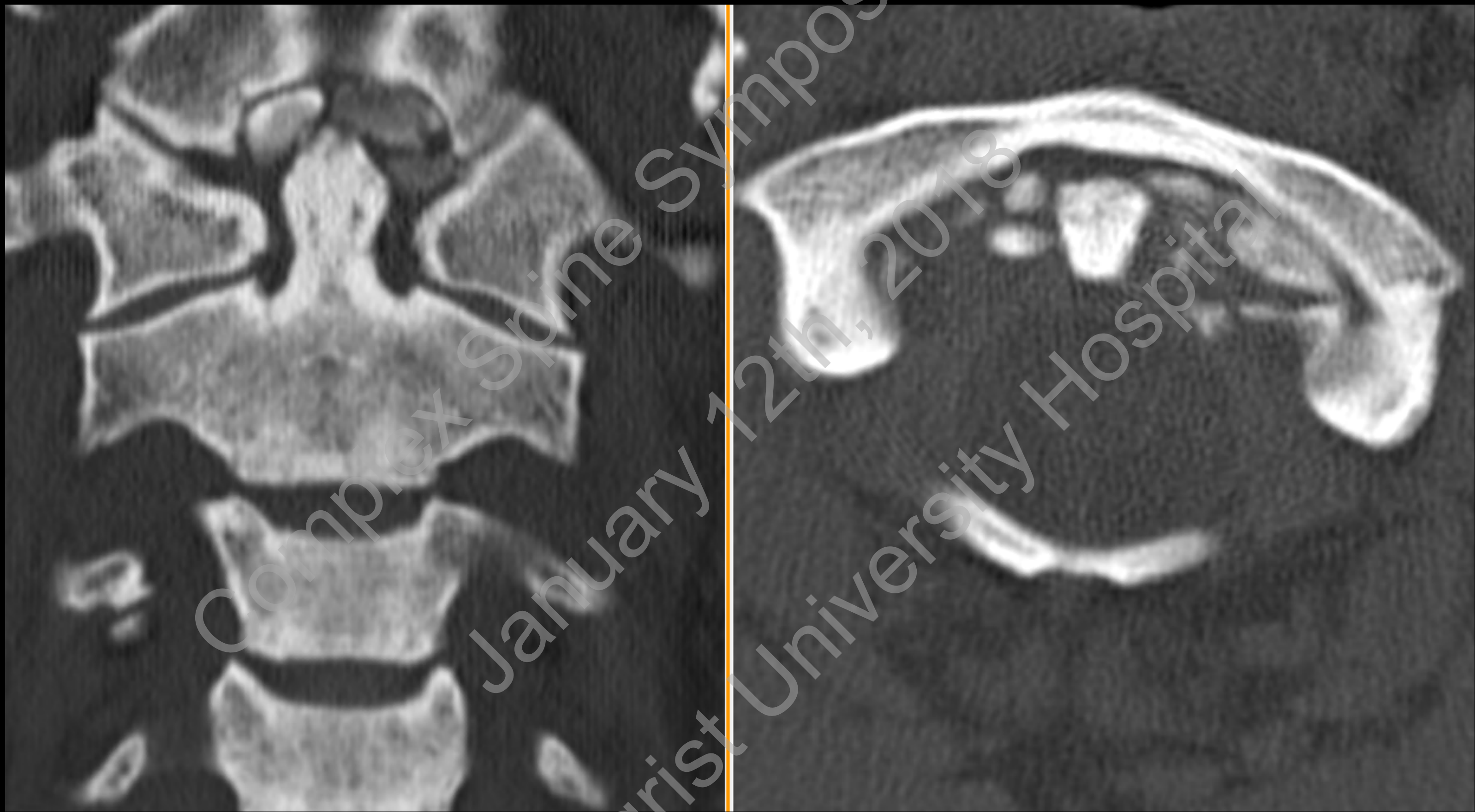
- Acute calcific retropharyngeal tendinitis
- (Syn: Acute calcific prevertebral tendinitis)
- Foreign-body inflammatory response crystals of hydroxyapatite
- Insertion of longus colli (Anterior arch of C1)
- Symptoms: Severe neck pain, pain on swallowing, reduced range of motion of the neck.
- Clinical presentation similar to calcific tendinitis elsewhere.
- Self-limiting, (NSAID), symptoms disappear within 1 week.
- Calcification slowly resolves after a period of 2–3 months.

Ring D, Vaccaro AR, Scuderi G, Pathria MN, Garfin SR. Acute calcific retropharyngeal tendinitis. JBJS Am 1994;76:1636–42

Severe Neck Pain IV – 51y m Acute onset No trauma



Crowned Dens



Crowned Dens: CPPD of the craniocervical joints and ligaments

Severe Neck Pain V 84 y, F, Chronic Pain

University of Zurich[UZH]

The Balgrist

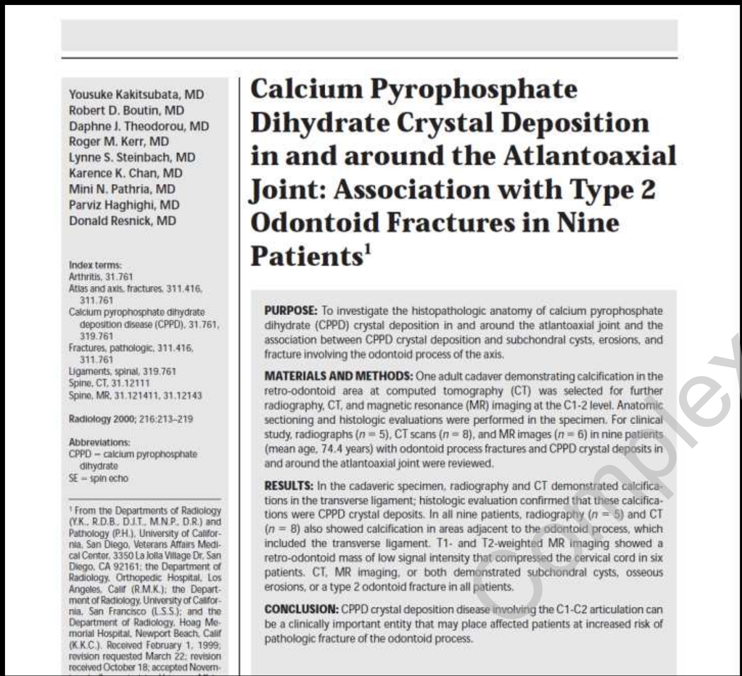
Severe Neck Pain V 84 y, F, Chronic Pain

University of Zurich[UZH]

The Balgrist

Severe Neck Pain V 84 y, F, Chronic Pain

Severe Neck Pain V 84 y, F, Chronic Pain



Yousuke Kakitsubata, MD
Robert D. Boutin, MD
Daphne J. Theodorou, MD
Roger M. Kerr, MD
Lynne S. Steinbach, MD
Karence K. Chan, MD
Mini N. Pathria, MD
Parviz Haghighi, MD
Donald Resnick, MD

Index terms:
Arthritis, 31.761
Atlas and axis, fractures, 311.416, 311.761
Calcium pyrophosphate dihydrate deposition disease (CPPD), 31.761, 319.761
Fractures, pathologic, 311.416, 311.761
Ligaments, spinal, 319.761
Spine, CT, 31.12111
Spine, MR, 31.121411, 31.12143

Radiology 2000; 216:213–219

Abbreviations:
CPPD = calcium pyrophosphate dihydrate
SE = spin echo

[1] From the Departments of Radiology (Y.K., R.D.B., D.J.T., M.N.P., D.R.) and Pathology (P.H.), University of California, San Diego, Veterans Affairs Medical Center, 3350 La Jolla Village Dr, San Diego, CA 92161; the Department of Radiology, Orthopedic Hospital, Los Angeles, Calif (R.M.K.); the Department of Radiology, University of California, San Francisco (L.S.S.); and the Department of Radiology, Hoag Memorial Hospital, Newport Beach, Calif (K.K.C.). Received February 1, 1999; revision requested March 22; revision received October 18; accepted Novem-

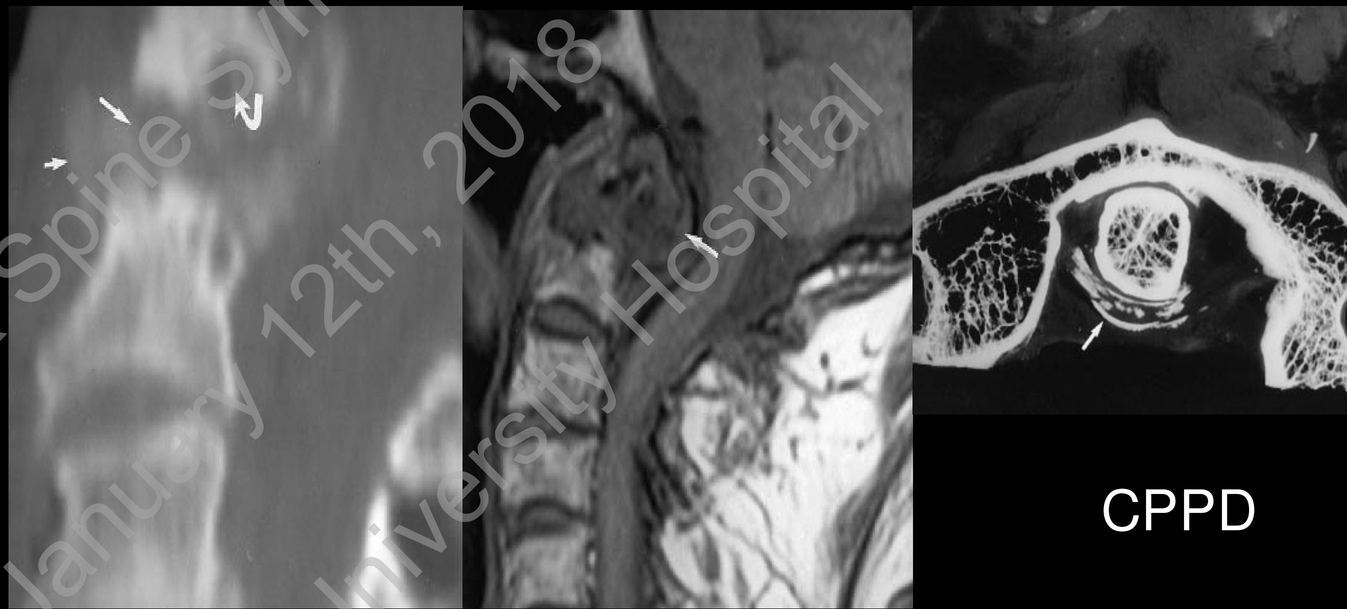
Calcium Pyrophosphate Dihydrate Crystal Deposition in and around the Atlantoaxial Joint: Association with Type 2 Odontoid Fractures in Nine Patients[1]

PURPOSE: To investigate the histopathologic anatomy of calcium pyrophosphate dihydrate (CPPD) crystal deposition in and around the atlantoaxial joint and the association between CPPD crystal deposition and subchondral cysts, erosions, and fracture involving the odontoid process of the axis.

MATERIALS AND METHODS: One adult cadaver demonstrating calcification in the retro-odontoid area at computed tomography (CT) was selected for further radiography, CT, and magnetic resonance (MR) imaging at the C1-2 level. Anatomic sectioning and histologic evaluations were performed in the specimen. For clinical study, radiographs ($n = 5$), CT scans ($n = 8$), and MR images ($n = 6$) in nine patients (mean age, 74.4 years) with odontoid process fractures and CPPD crystal deposits in and around the atlantoaxial joint were reviewed.

RESULTS: In the cadaveric specimen, radiography and CT demonstrated calcifications in the transverse ligament; histologic evaluation confirmed that these calcifications were CPPD crystal deposits. In all nine patients, radiography ($n = 5$) and CT ($n = 8$) also showed calcification in areas adjacent to the odontoid process, which included the transverse ligament. T1- and T2-weighted MR imaging showed a retro-odontoid mass of low signal intensity that compressed the cervical cord in six patients. CT, MR imaging, or both demonstrated subchondral cysts, osseous erosions, or a type 2 odontoid fracture in all patients.

CONCLUSION: CPPD crystal deposition disease involving the C1-C2 articulation can be a clinically important entity that may place affected patients at increased risk of pathologic fracture of the odontoid process.



CPPD

Summary

- Imaging definition of “Normal Aging”: Changes evident in asymptomatic and healthy subjects
- Relevance of Findings - Spectrum of imaging findings of normal aging of the cervical spine is broad
- Changes at C5/C6 level most prevalent
- Bone marrow edema is sensitive but not specific
- Differential Diagnosis - Don’t forget inflammatory lesion