Reviews on Injury Parameters and Injury Criteria for Minor Neck Injuries during Rear-end Impacts

Koshiro Ono
Japan Automobile Research Institute

8th and 9th of September, 2014

Technical University Berlin (TUB)

Objective

- *To review the published papers including the data and the current available knowledge for a reduction of minor neck injury on rear-end impacts.*

- *To share the biomechanical knowledge and the valuable information based on current existing available data for rear-end impacts, and to reflect proper neck injury evaluation parameters and injury criteria into the regulation documents of the informal GTR7.*

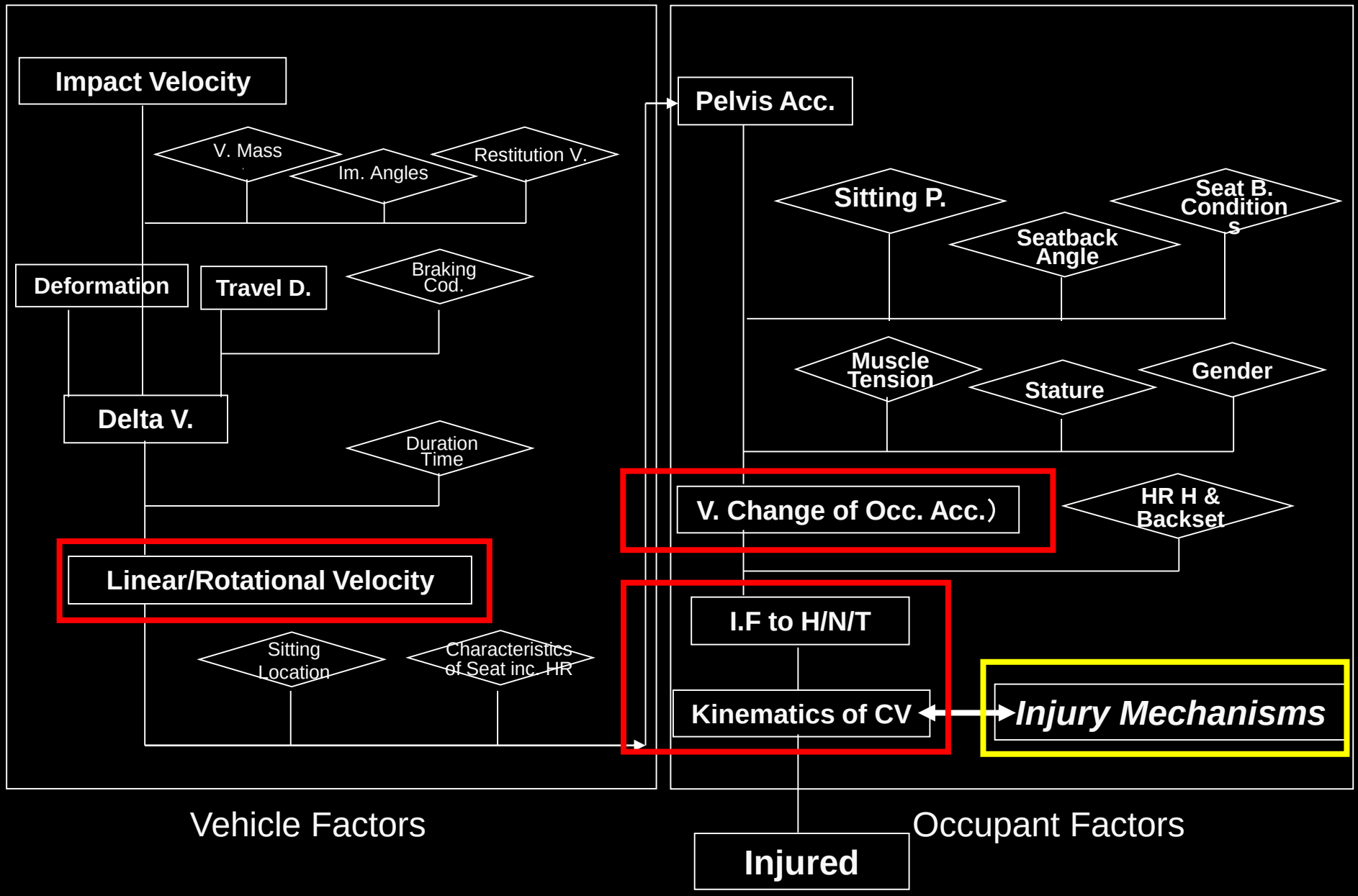
Contents

1. Overview of Reduction Methods on Minor Neck Injuries during Rear-end Impacts
2. Injury Evaluation Parameters & Injury Criteria based on HVT & ARS
3. Step1: Human Volunteer Tests
4. Step2: Accident Data
5. Step3:Accident Reconstruction based on FE model
6. Draft Proposal on Evaluation of Injury Parameters and Injury Risk Curve based on the Collaboration between NHTSA and Japan
7. Influence of Muscle Conditions to Cervical Vertebral Motions
8. Conclusions

1. Overview of Reduction Methods on Minor Neck Injuries during Rear-end Impacts

A) Influence factors for the occurrence of neck injuries during rear-end impacts
B) Needing proper minor neck injury parameters in rear-end impacts
C) Current knowledge for clarifications of neck injury mechanisms in rear impacts
    - Example: Clinical Findings
D) Flowchart for clarifications of neck injury criteria/threshods in rear impacts

A) Influence Factors for the Occurrence of Neck Injuries during Rear-end Impacts

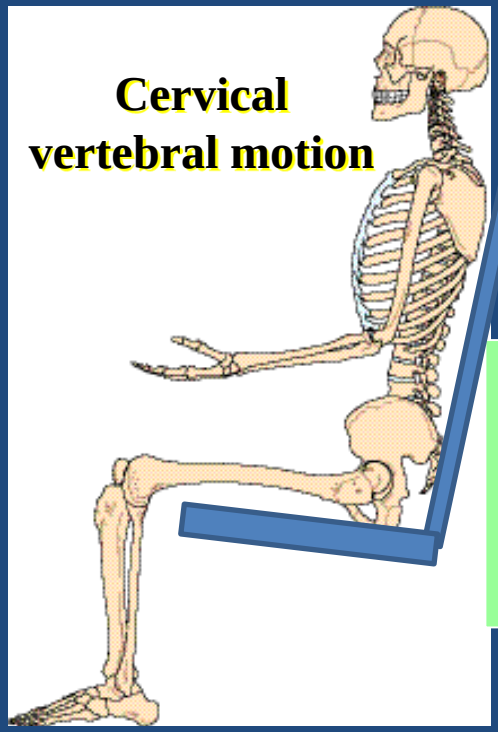


Minor neck injury

Not only neck region

Focus on whole spine motion

Current evaluation method
Not enough
focuses only on upper neck
1) Angle
2) Moment, axial force



S-Shape Motion
(Vertical, Horizontal Motion)

Neck angle

Additional parameters

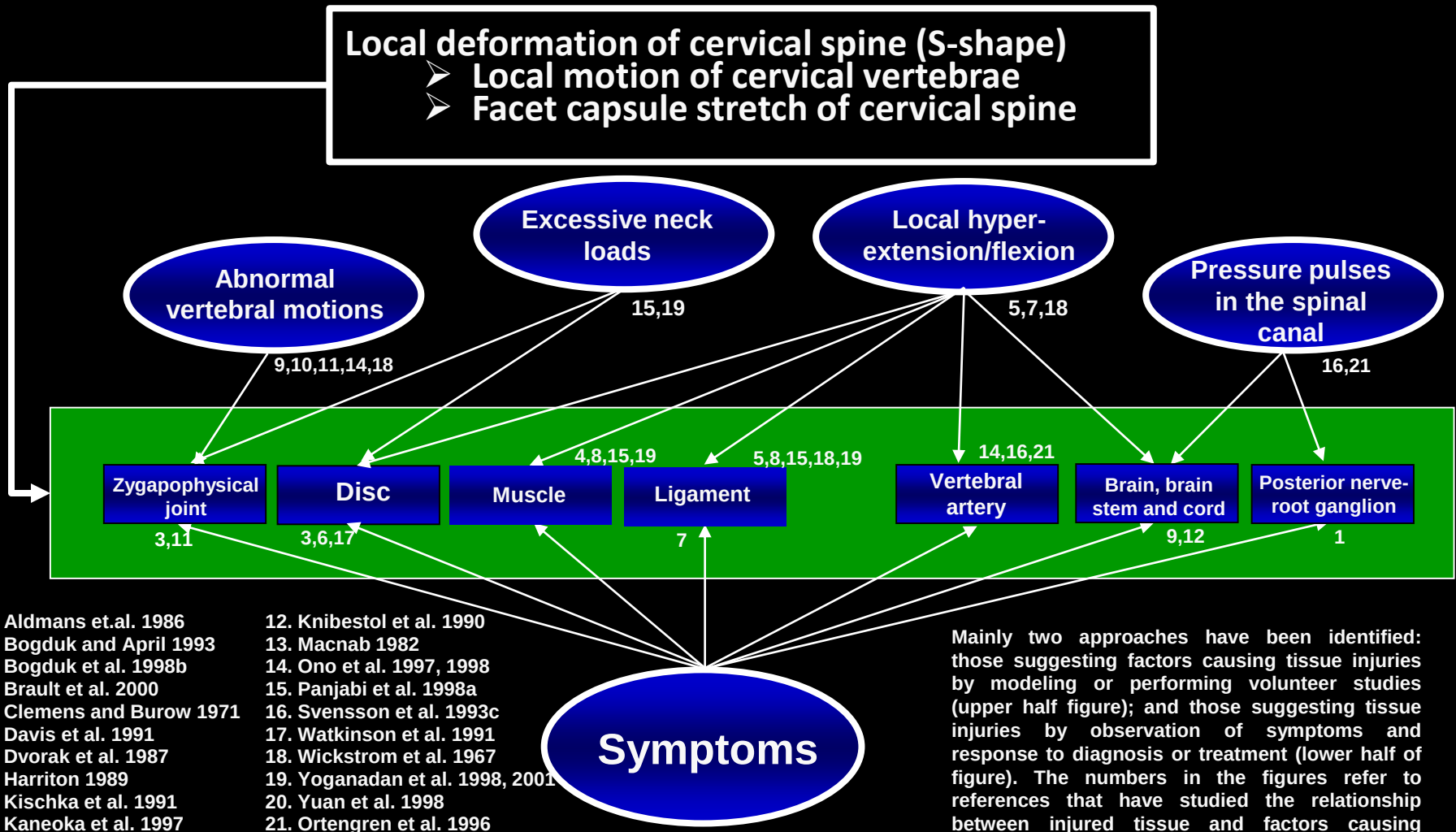
Lower neck
1) Axial, shear forces
2) Neck angle wrt T1

Spine straightening
Ramping-up

Needs to consider proper neck injury parameters

B) Needing proper minor neck injury parameters in rear-end impacts

C) Current Knowledge for Clarifications of Neck Injury Mechanisms in Rear Impacts



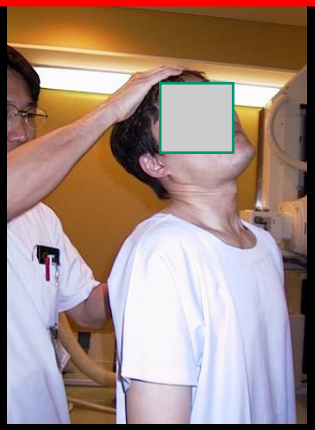
1. Aldmans et.al. 1986
2. Bogduk and April 1993
3. Bogduk et al. 1998b
4. Brault et al. 2000
5. Clemens and Burow 1971
6. Davis et al. 1991
7. Dvorak et al. 1987
8. Harriton 1989
9. Kischka et al. 1991
10. Kaneoka et al. 1997
11. Kaneoka et al. 1999
12. Knibestol et al. 1990
13. Macnab 1982
14. Ono et al. 1997, 1998
15. Panjabi et al. 1998a
16. Svensson et al. 1993c
17. Watkinson et al. 1991
18. Wickstrom et al. 1967
19. Yoganadan et al. 1998, 2001
20. Yuan et al. 1998
21. Ortengren et al. 1996

Mainly two approaches have been identified: those suggesting factors causing tissue injuries by modeling or performing volunteer studies (upper half figure); and those suggesting tissue injuries by observation of symptoms and response to diagnosis or treatment (lower half of figure). The numbers in the figures refer to references that have studied the relationship between injured tissue and factors causing injury/symptoms and response to diagnosis or treatment

Suggested factors causing tissues injuries such as abnormal vertebral motions, excessive neck loads, local hyper-extension/flexion, and pressure pulses in the spinal canal are predicted by the expression of the local deformation of cervical spine (s-shape). According to this result, the proper evaluation for the reduction of the risk of neck injury is proposed.

Example : Clinical Findings on Zygopophysial Joint

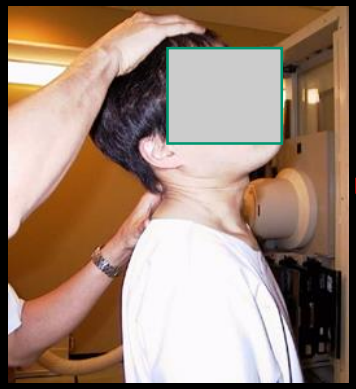
Tenderness around the right facet joint



Passive neck extension with right rotation induced pain

Facet Block (Rt. C5/6)

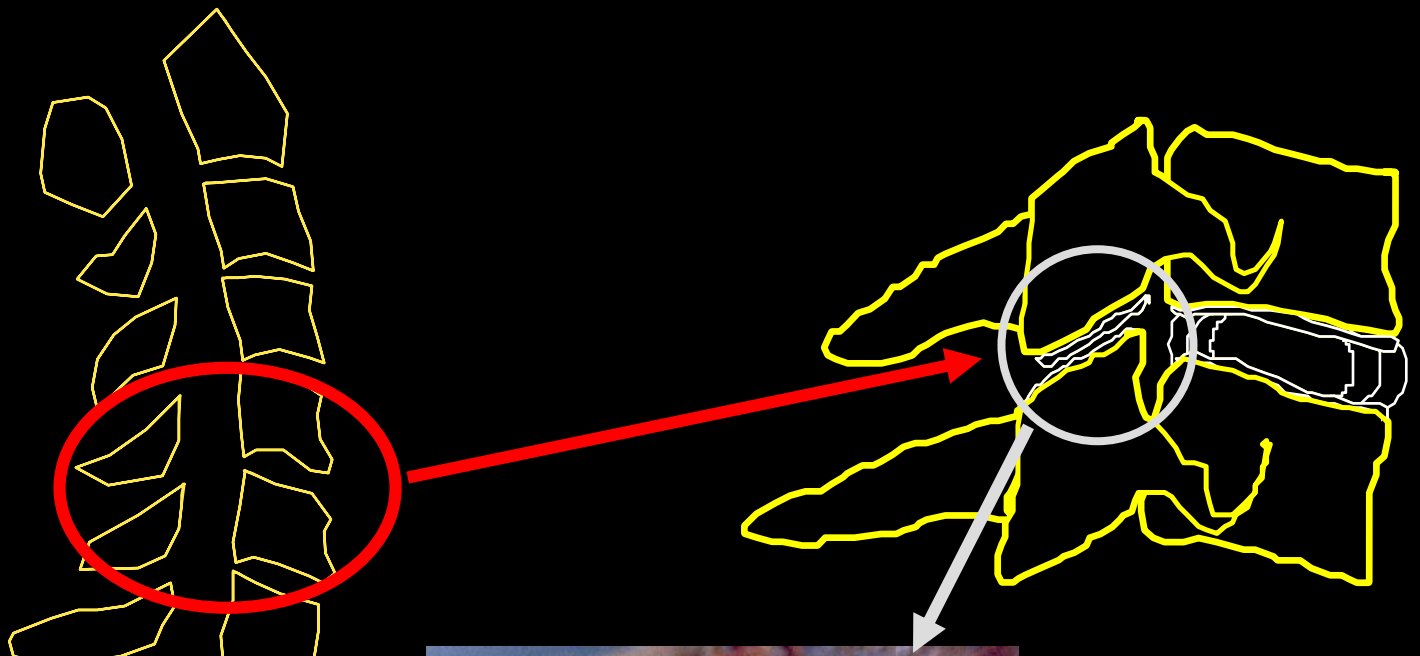
Before

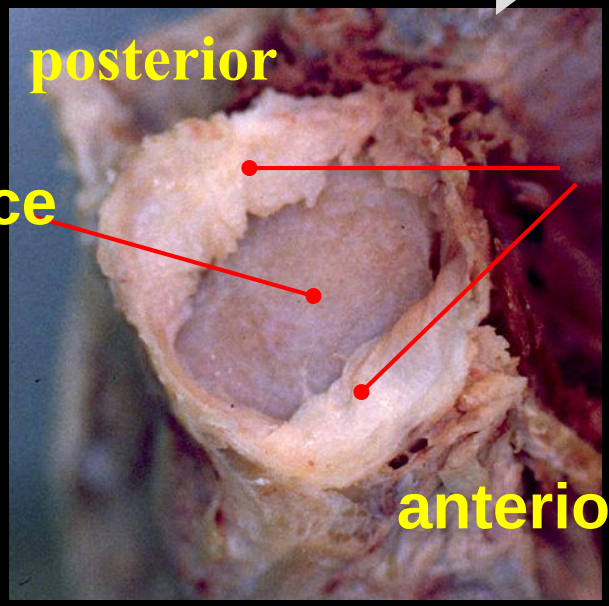


After

Full range of motion without pain

Example : Cervical Zygapophysial Joint (Facet Joint)



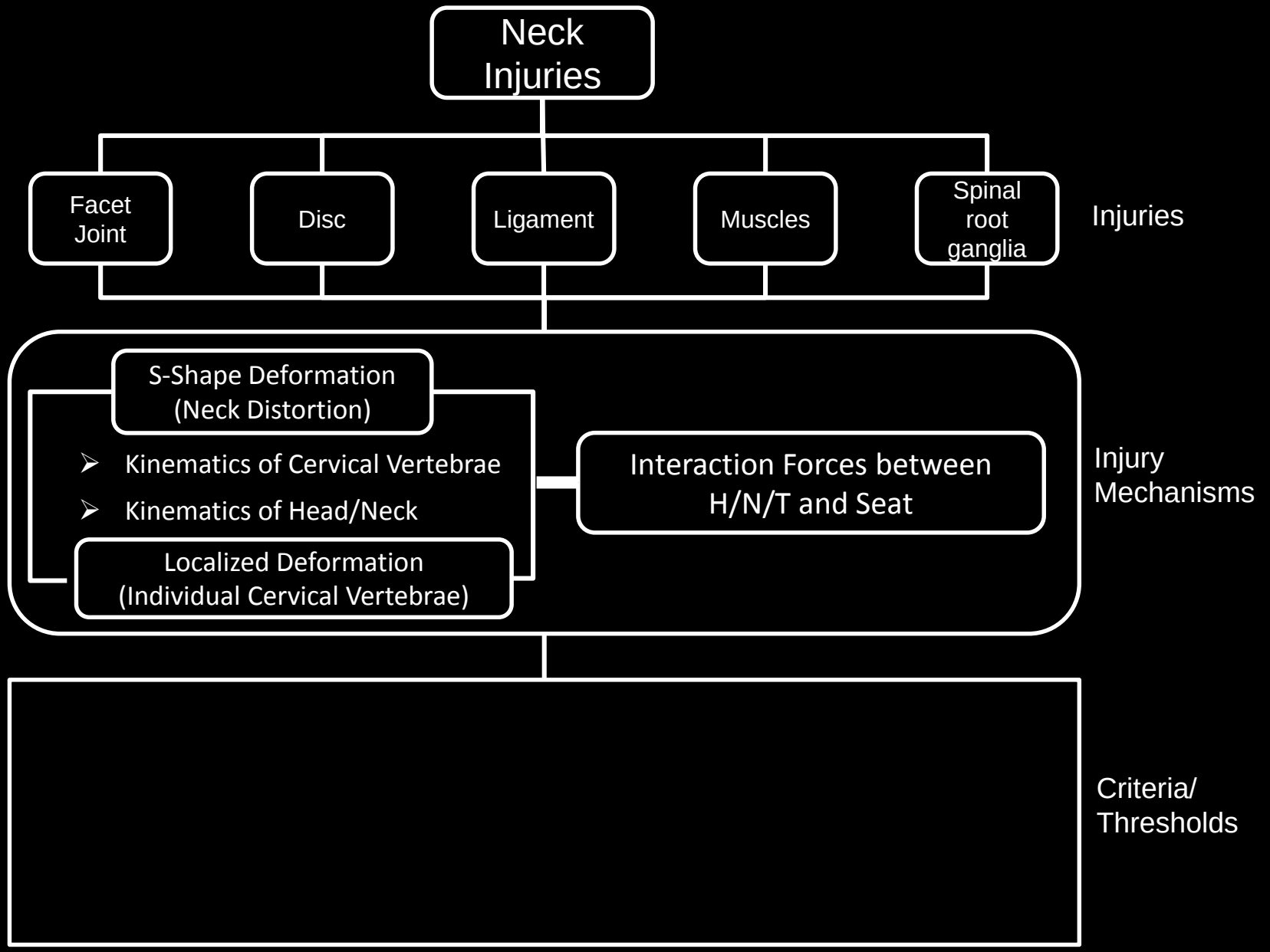


Articular surface

Joint inclusion
: Meniscoid,
Synovial fold

Sample shown by Autopsy Case

D) Flowchart for Clarifications of Neck Injury Criteria/Thresholds in Rear Impacts

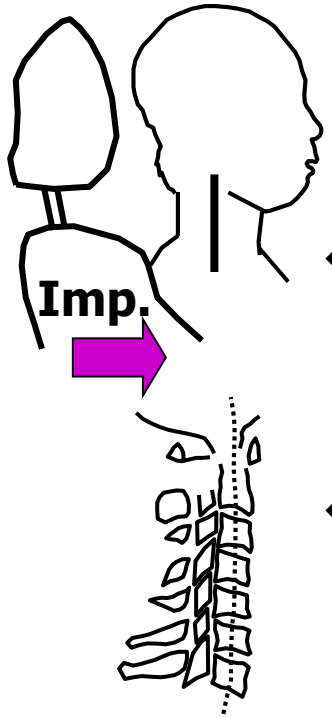


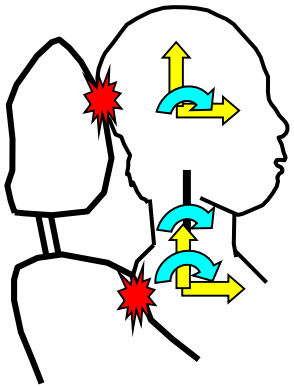
2. Injury Evaluation Parameters & Injury Criteria based on HVT & ARS

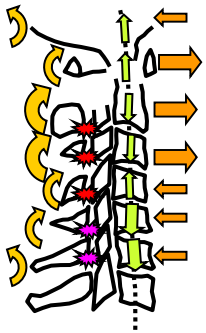
HVT : Human Volunteer Tests
ARS : Accident Reconstruction FE- Model Simulation

A) Necessary Method for Neck Injury Evaluation
B) Research Flow for Clarification on Minor Neck Injury Parameters & Criteria
C) Injured Regions in PMHS Tests and Clinical Findings

A) Necessary Method for Neck Injury Evaluation







- Impact loading to the neck is dependent on the interaction patterns between the H/N/T and the seat with HR.
- To assess the motion of cervical vertebrae caused by impact loading and the interaction between the H/N/T and the seat with HR.

B) Research Flow for Clarification on Minor Neck Injury Parameters & Criteria

Step 1

Volunteer Tests

6 Males

Validation

Analysis of cervical vertebral motions

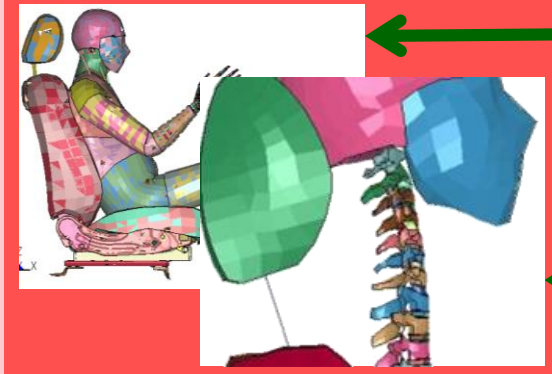
Cervical vertebrae motion
→Intervertebral strain

Step 3

JAMA Human FE Model

Seat Model

Accident Reconstructions



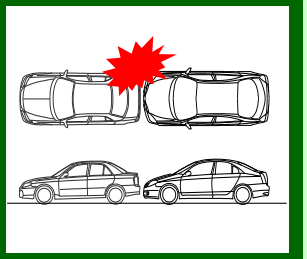
Step 2

Occupant (Height, Weight)

Seat information

Accident Data

Crush pulse



Injury level (WAD)

20 cases
⊿V8~28km/h

Discomfort in neck

Injury threshold of strain

Risk curve

Correlation between neck injury and intervertebral motion

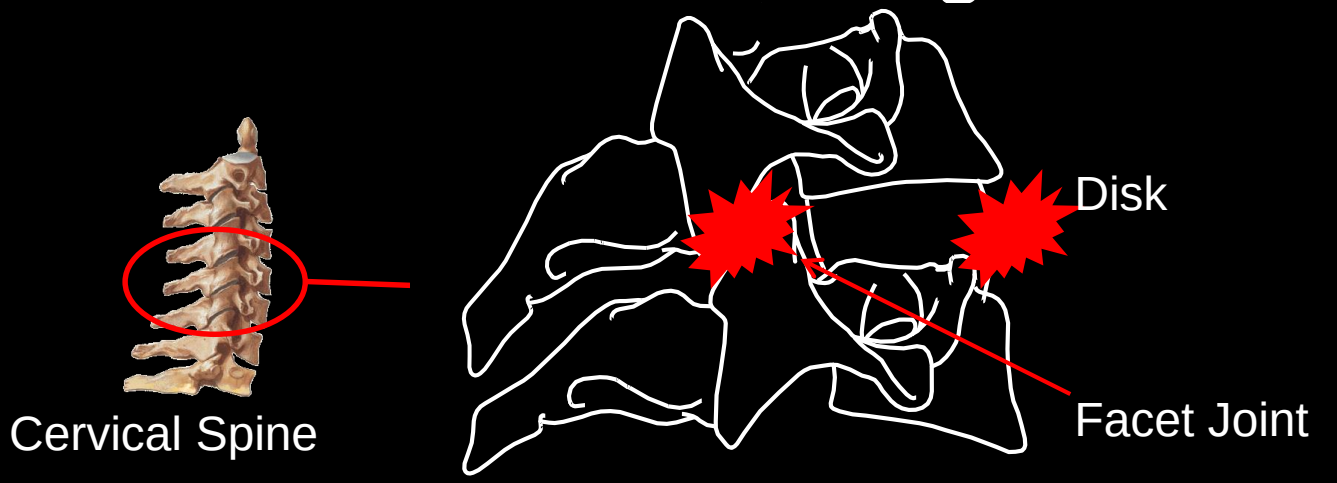
Step 4

Feedback on dummy

Parameters related with intervertebral strain
→Risk curve

Injury criteria based on neck injury

C) Injured Regions in PMHS Tests and Clinical Findings



PMHS tests : Excessive deflection → Soft tissue injury (Panjabi, 1997; Yoganandan ,1998 and etc.)

Clinical findings : Facet joint injury is most common (Manchikanti et al.,1995 Lord et al.1996, Barnsley et al. and etc.)

PMHS test : Strain rate affects rupture strength of soft tissue (Yoganandan), 2001)

Animal test : Stretch of Facet capsule is related with pain (Lee , 2004 and etc.)

Excessive deflection between vertebrae → Intervertebral soft tissue injury

Prediction of neck injury level by strain and strain rate of intervertebral soft tissue

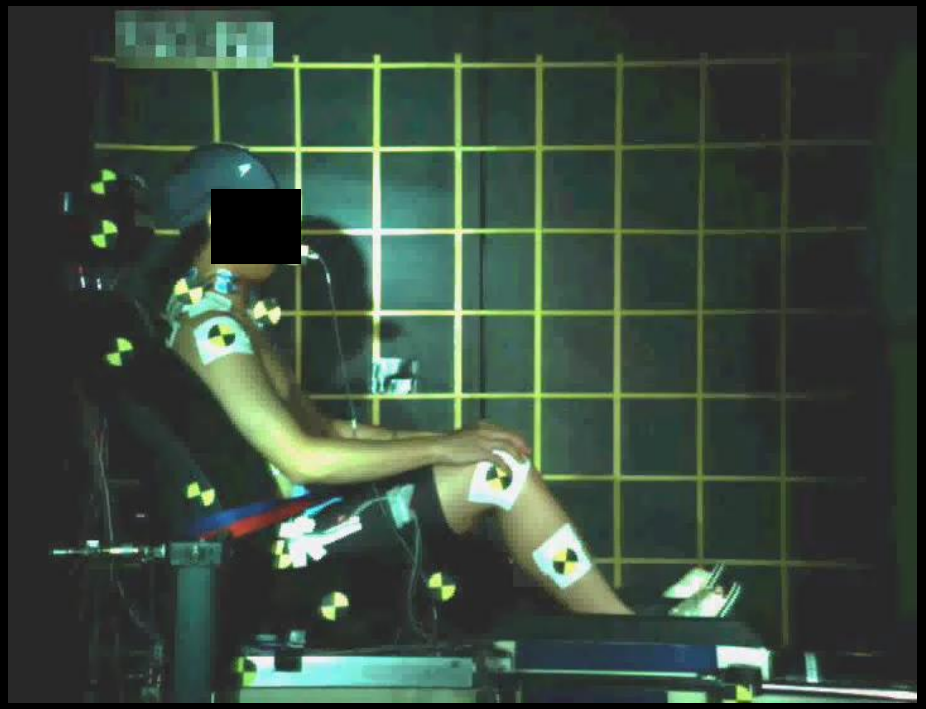
3. Step1: Human Volunteer Tests

A) Human Volunteer Test
B) Analysis of Cervical Vertebral Motion
C) Injury Thresholds based on Cervical Vertebral Motions
D) Comparison of Strains/Strain Rates reported by the References
E) Threshold of Strain and Strain Rate
F) Summary of the Correlations between the Injury Parameters and the Symptoms of the Human Volunteer Tests

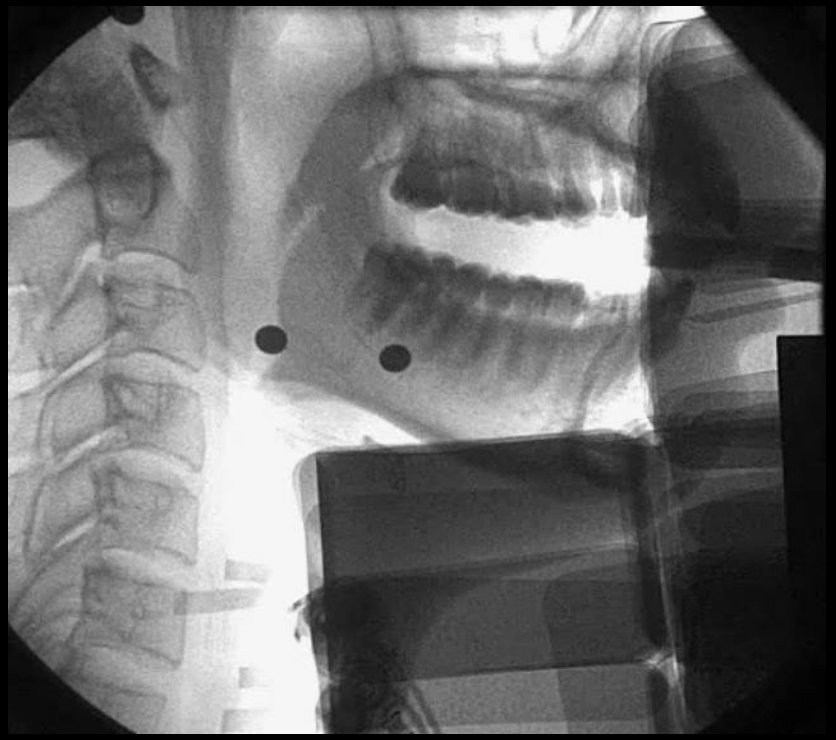
A) Human Volunteer Test

Test Conditions:
Seatback Angle：25 degree, Sled Acc.：40m/s^2 , Muscle Tone: Relaxed Condition

Volunteer Motion

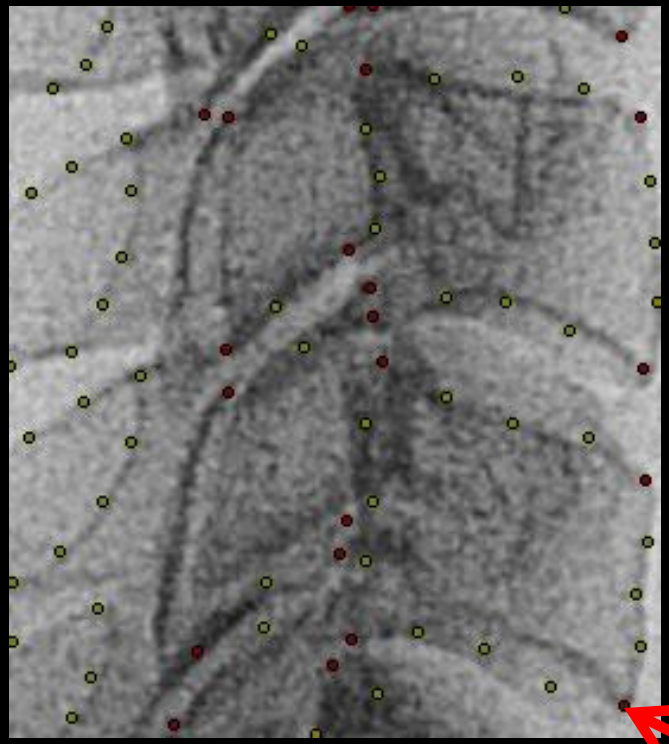


Cervical Vertebral Motion



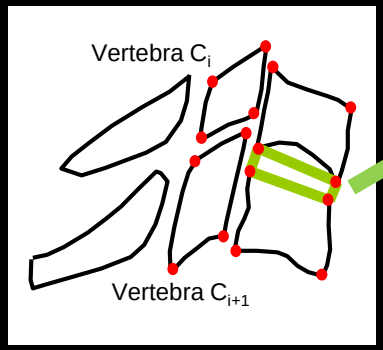
B) Analysis of Cervical Vertebral Motion

Localized deformation between cervical vertebrae

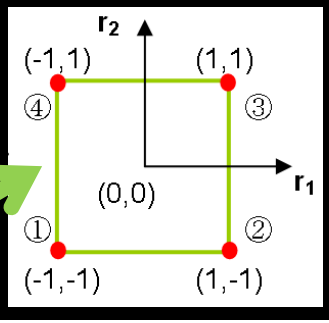


Sequential X-ray image

Representative point



Strain calculation



$$\varepsilon_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) + \frac{1}{2}\left(\frac{\partial u_i}{\partial x_i}\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\frac{\partial u_j}{\partial x_j}\right)$$

Cervical strain, strain rate

Max. principal strain

$$\varepsilon_{MP} = \frac{\varepsilon_{11} + \varepsilon_{22}}{2} + \sqrt{\left(\frac{\varepsilon_{11} - \varepsilon_{22}}{2}\right)^2 + \varepsilon_{12}^2}$$

Max. shear strain

$$\varepsilon_{MS} = \sqrt{\left(\frac{\varepsilon_{11} - \varepsilon_{22}}{2}\right)^2 + \varepsilon_{12}^2}$$

Strain rate : Temporal differentiation of strain

C) Injury Thresholds based on Cervical Vertebral Motions

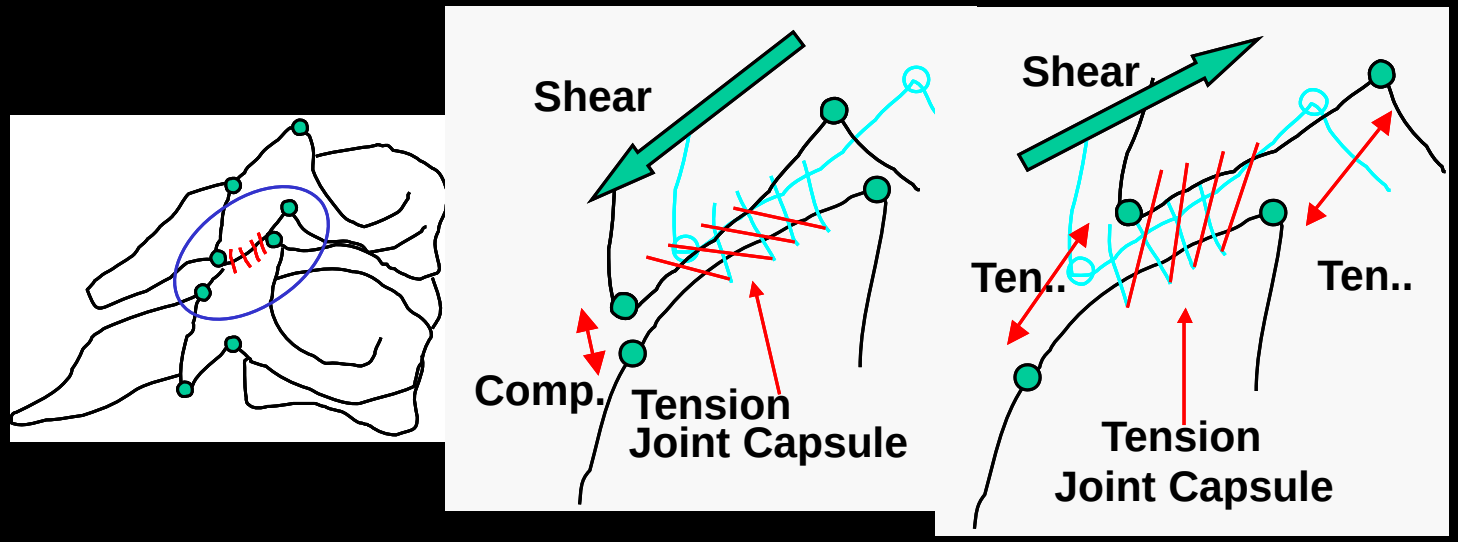
Neck discomfort after experiments

Subjects (Human Vol.)	Neck discomfort
I	Stiff shoulder on test day
II	Stiff shoulder on test day
III	None
IV	None
V	None
VI	Pain in the neck while sleeping on test day

Strain ratios to limitation of physiological motion (%)

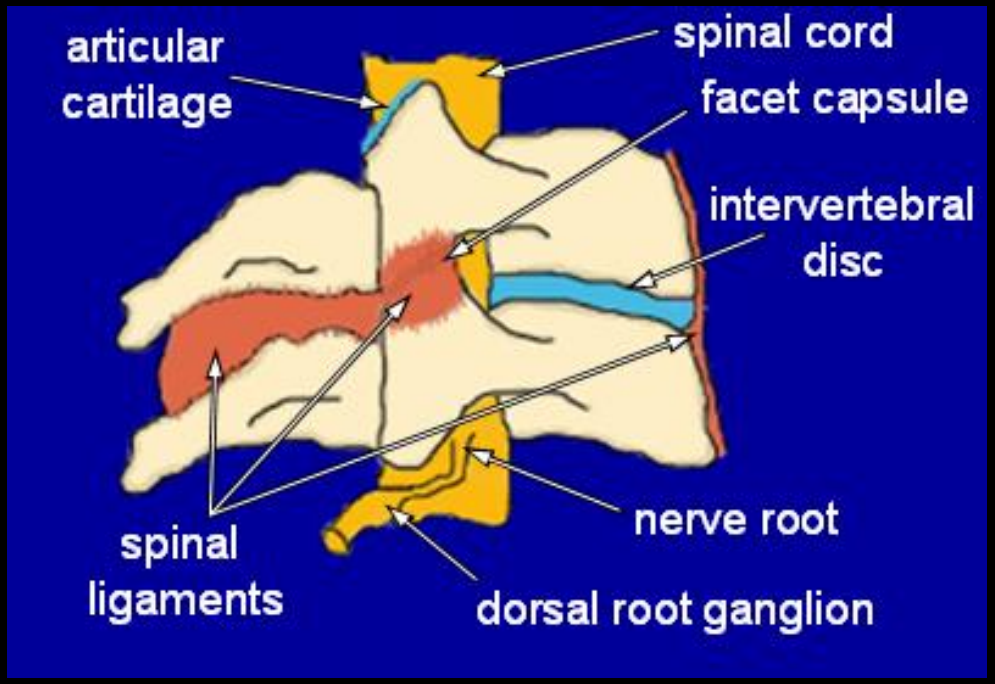
D) Comparison of Strains/Strain Rates reported by the References

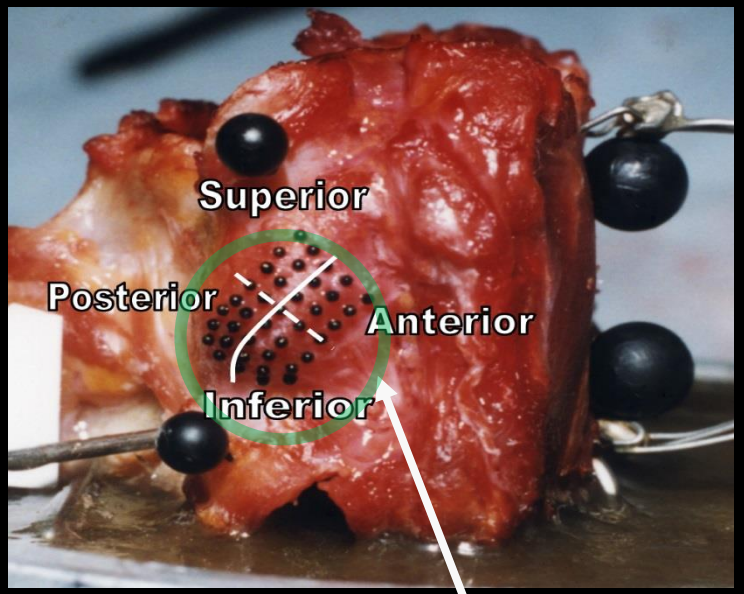
Reference	Specimen	Symptom	Strain [%]	Strain rate [mm/s]
This study	Human volunteer	Slight discomfort in neck	129	63
Yoganandan N. et al. (1998)	Human cadaver	Catastrophic failure	149	10
Winkelstein B. A. et al. (1999)	Human cadaver	Catastrophic failure	118±103	100
		Subcatastrophic failure	67±26	100
Siegmund G. P. et al. (2000)	Human cadaver	Catastrophic failure	94±85	0.01
		Subcatastrophic failure	35±21	0.01
Lu Y. et al. (2005)	Goat	Pain in facet joint capsule	47±10	0.5
Lee K. E. et al. (2004)	Rat	Pain in facet joint capsule	28±12	0.1



Relationship between FJ and FJC/Ligament Strains

D1) Lateral view of right facet joint

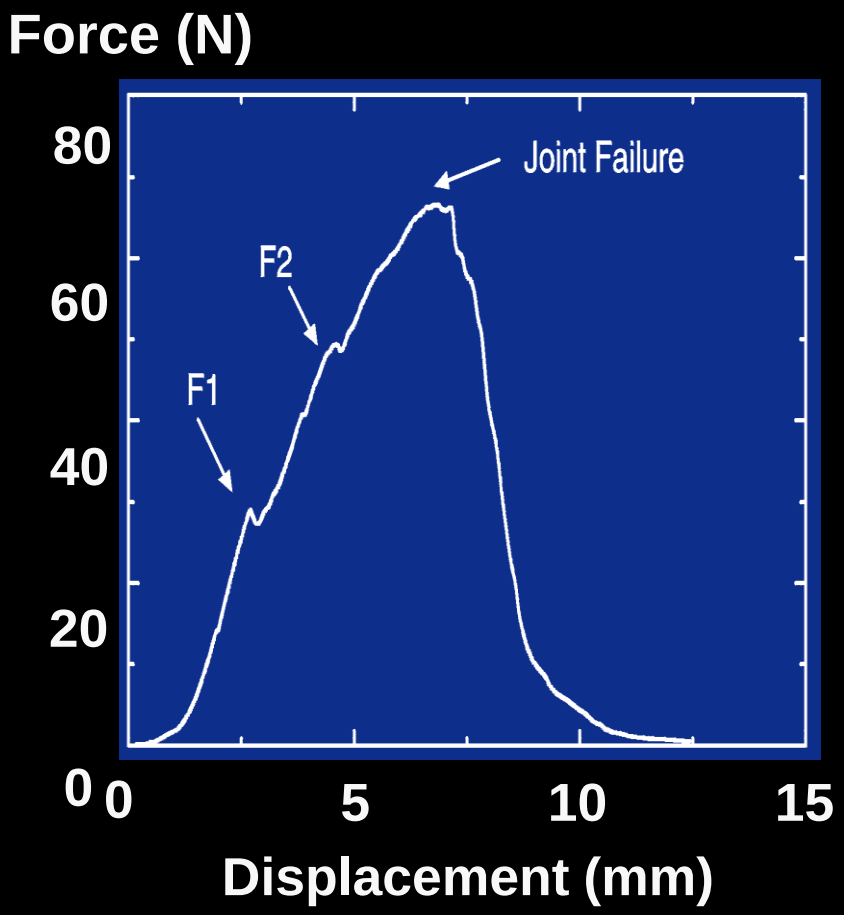


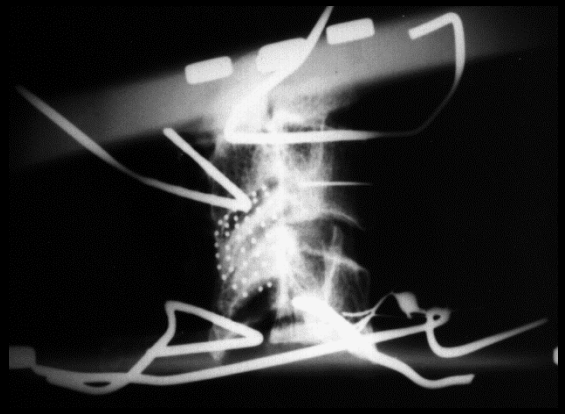


Facet capsule

G. Siegmund et.al.; 2007 IBR Proceedings of 35th International Workshop

D2) Facet capsule configuration at failure points

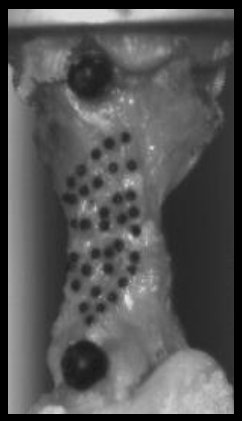




0 min

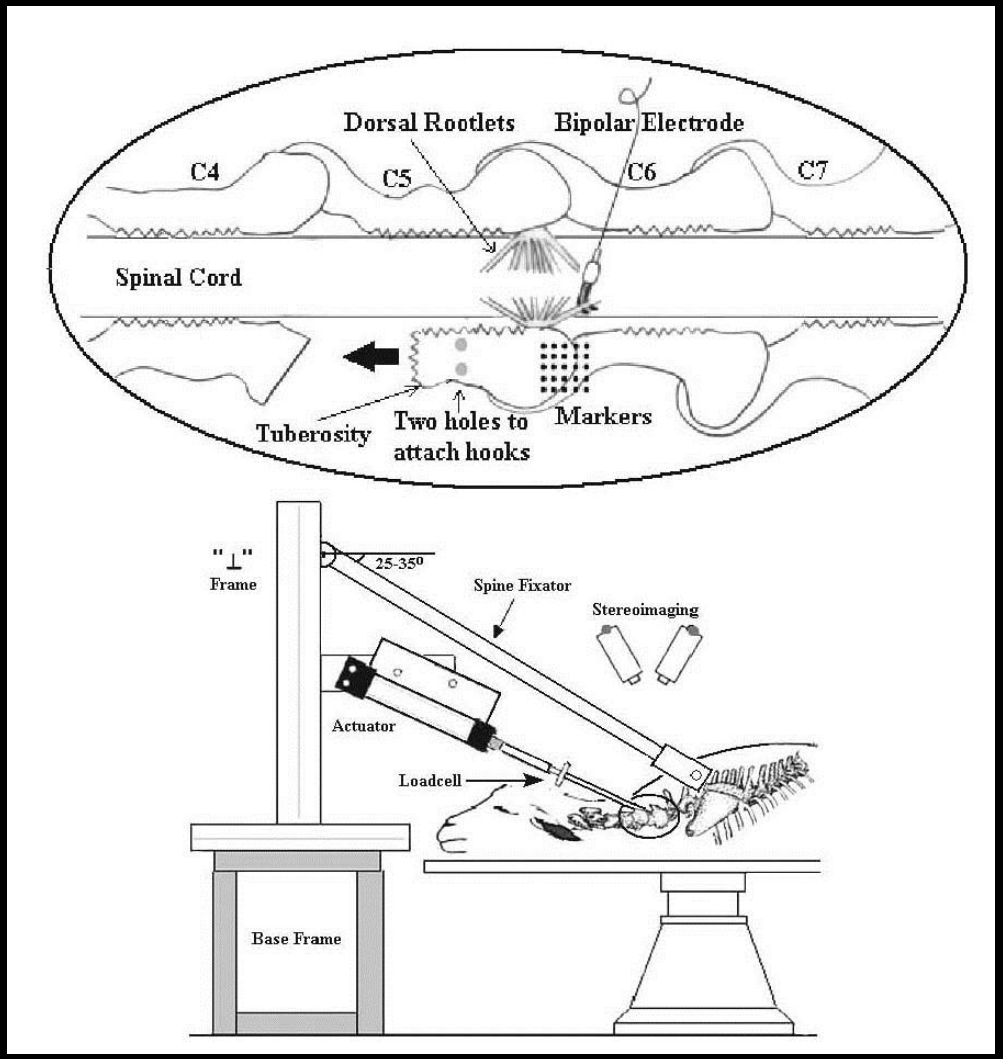
5.75 min (F1)

14 min (Failure)



Winkelstein et al, *Stapp* 1999.
Winkelstein et al, *Spine* 2000.

D3) Correlation Experiments between the Pain Sensation and the Strain of FJ Capsular of Animal (Goat)



Lu(WSU)-2005STAPP

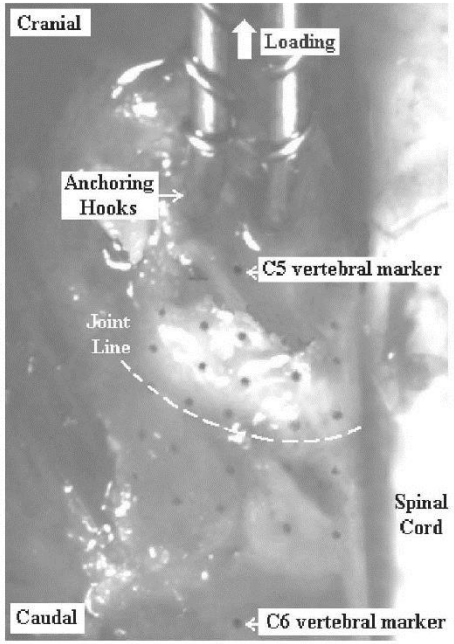
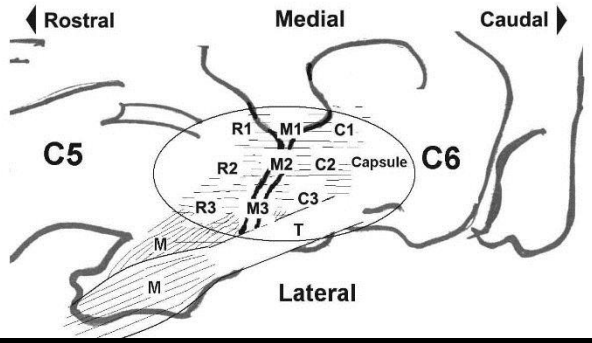
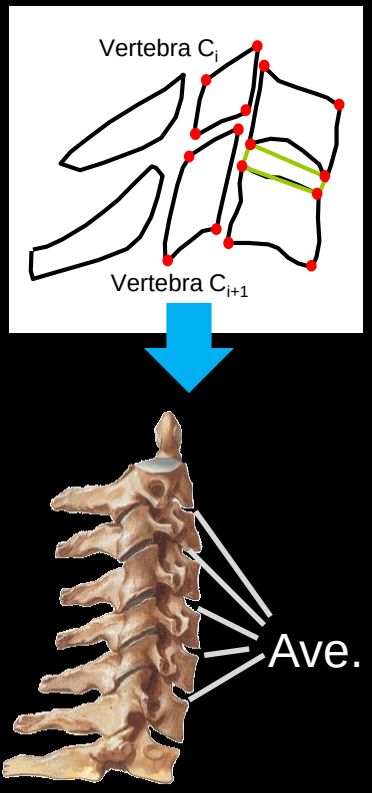


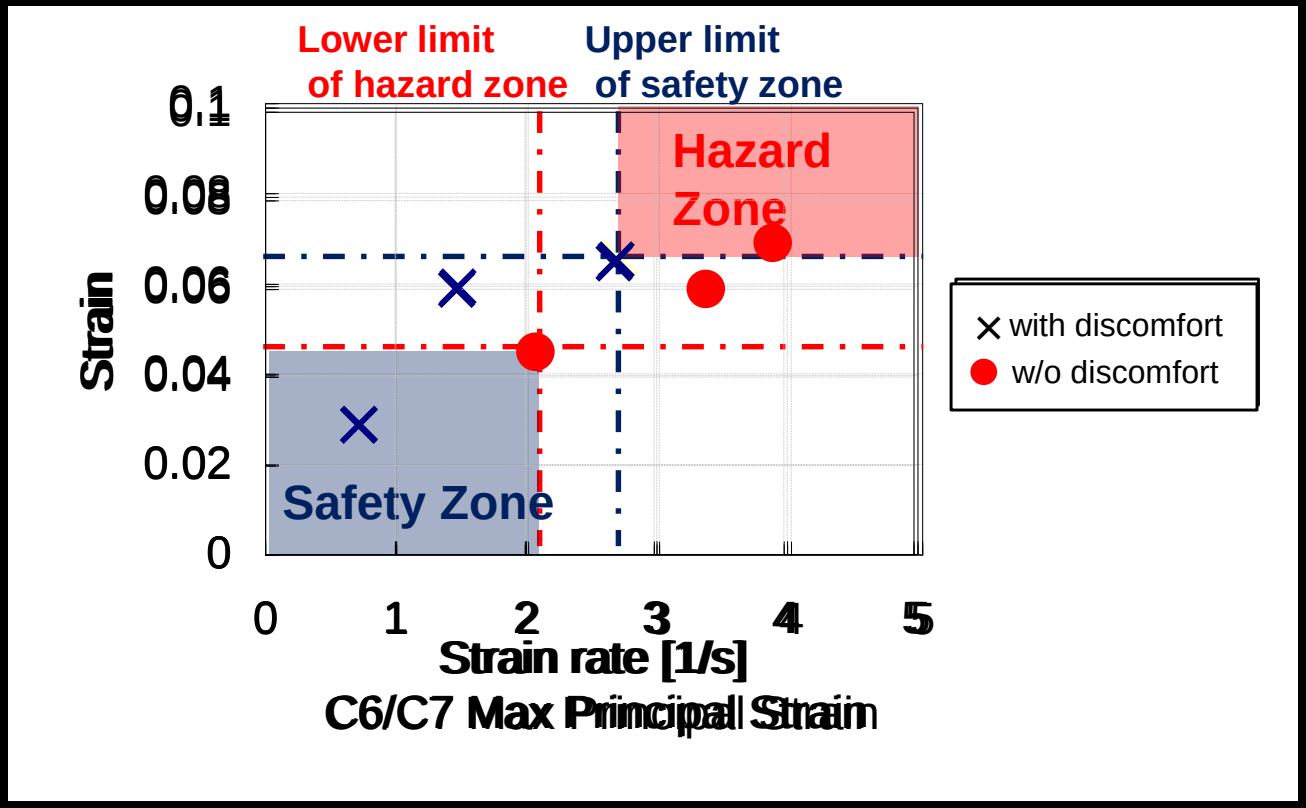
Figure 2: Deformation of a left C5-C6 FJC at 6 mm stretch. The spinal cord is denoted on the right. Also shown are the C5 anchoring hooks, an array of 5 x 5 tantalum spheres and two vertebral markers. (from Lu et al., 2005b)



E) Threshold of Strain and Strain Rate

- with/without discomfort around neck
  →Region of cervical intervertebral strain for occurrence of neck discomfort





Threshold	Max. Principal Strain	Max. Shear Strain	Max. Principal Strain rate	Max. Shear Strain Rate
Average (Ave. between C2/C3～C6/C7)	0.06	0.05	2.68	1.81

F) Summary of the Correlations between the Injury Parameters and the Symptoms of the Human Volunteer Tests

Order	Injury Parameters	Max. P. Strain	Max. P. Strain Rate	Correlation with Symptom
		R	R	
1	NIC Max	0.439	0.592	+
2	U Neck My	0.318	0.000	+
3	OC-T1(Disp.)	0.297	0.578	+
4	L Neck My	0.290	0.190	+
5	H-T angle	0.158	0.389	+
6	NDCr	0.156	0.388	+
7	L Neck Fx	0.105	0.764	+
8	L Neck Fz	0.100	0.114	+
9	U Neck Fx	0.089	0.735	+
10	U Neck Fz	0.077	0.095	+
11	T1G Max	0.828	0.580	-
12	Rebound V	0.170	0.032	-
13	LNL Max	0.077	0.455	-
14	Nkm Max	0.071	0.522	-

Order	Injury Parameters	Shear Strain	Shear Strain Rate	Correlation with Symptom
		R	R	
1	NIC Max	0.821	0.570	+
2	OC-T1(Disp.)	0.742	0.533	+
3	U Neck Fz	0.514	0.193	+
4	L Neck Fz	0.486	0.219	+
5	U Neck Fx	0.476	0.271	+
6	L Neck Fx	0.448	0.351	+
7	U Neck My	0.368	0.347	+
8	L Neck My	0.285	0.478	+
9	NDCr	0.191	0.393	+
10	H-T angle	0.191	0.394	+
11	T1G Max	0.704	0.831	-
12	LNL Max	0.514	0.477	-
13	Nkm Max	0.175	0.434	-
14	Rebound V	0.151	0.447	-

For the J-NCAP assessment program of injury parameters, NFM and NIC were selected. The kinematics of OC-T1 (Disp.) as undefined measurement method was omitted.

4. Step2: Accident Analysis

A) Accident Data
B) Accident Reconstruction - FE Model Simulations

A) Accident Data

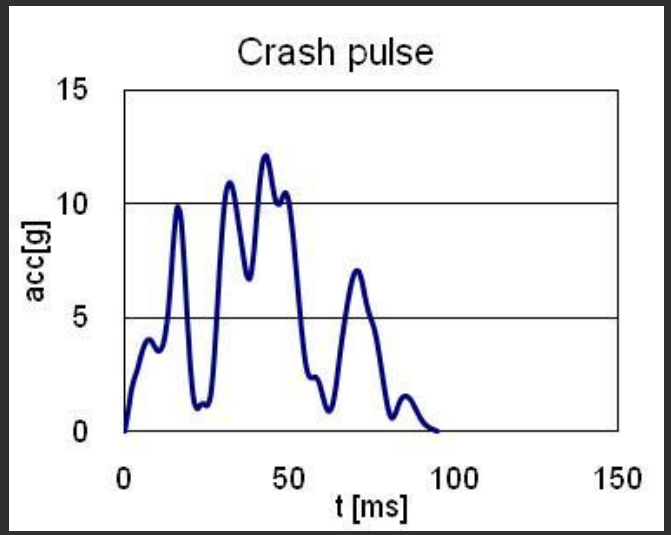
Acceleration
Crash Pulse

Injury Level
WAD

Occupant
Height・Weight

CASE		RECORDED CRASH PULSE			REPORTED INJURY			PASSENGER CHARACTERISTICS			
No.	D/P	⊿v [km/h]	Mean Acc.[g]	Peak Acc. [g]	Neck/Spine	Symptoms	WAD	Gender	Age	Height	Weight
1	Driver	28.2	5.8	10.6	Injured	1-6 m	2	F	26	175	55
4	Driver								57	178	100
4	Passenge								57	168	80
2	Driver								59	156	60
8	Driver								22	171	63
8	Passenge								18	179	80
7	Driver								67	167	84
7	Passenge								72	165	63
10	Driver								74	175	62
10	Passenge								74	160	57
6	Driver								59	165	65
6	Passenge								88	170	70
11	Driver								61	176	77
11	Passenge								61	154	69
21	Driver								50	171	85
23	Driver								35	178	65
20	Driver								65	176	82
20	Passenge								68	176	77
24	Driver								35	165	55
3	Driver	14.7	3.2	7.3	Injured	>6 m	2	M	35	165	55

20 Cases

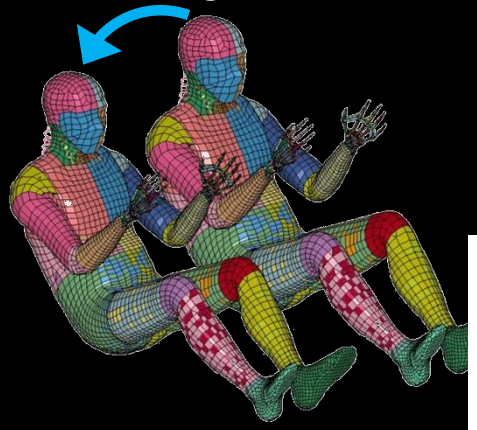


Car acceleration measured with Crash Pulse Recorder

⊿V 8 ~ 28 km/h

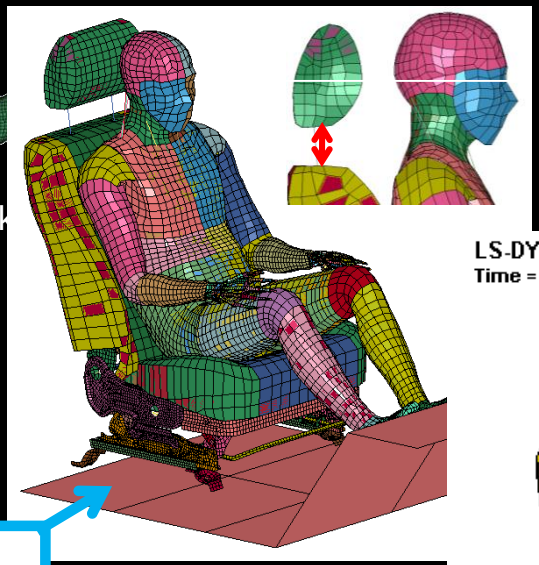
B) Accident Reconstruction - FE Model Simulations

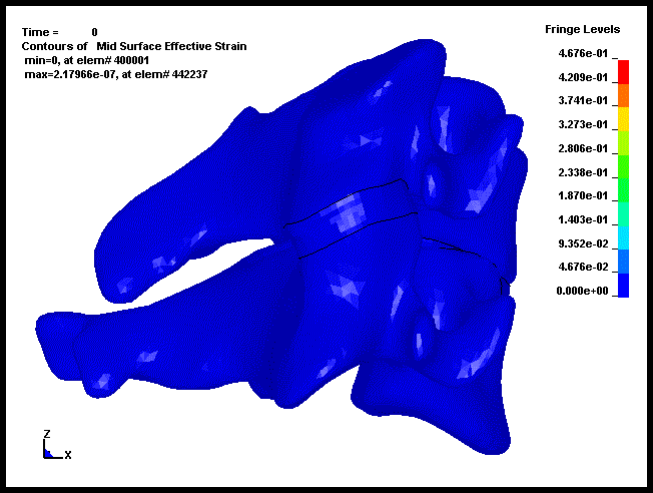
Scaling

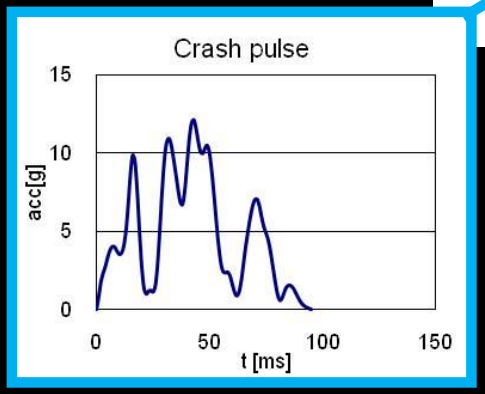


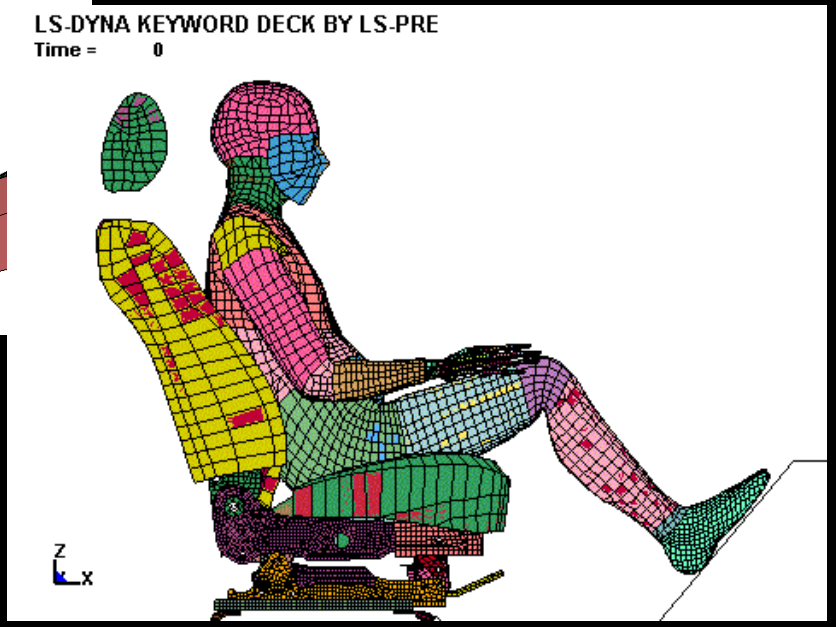
165cm/65kg 175cm/75k

Positioning







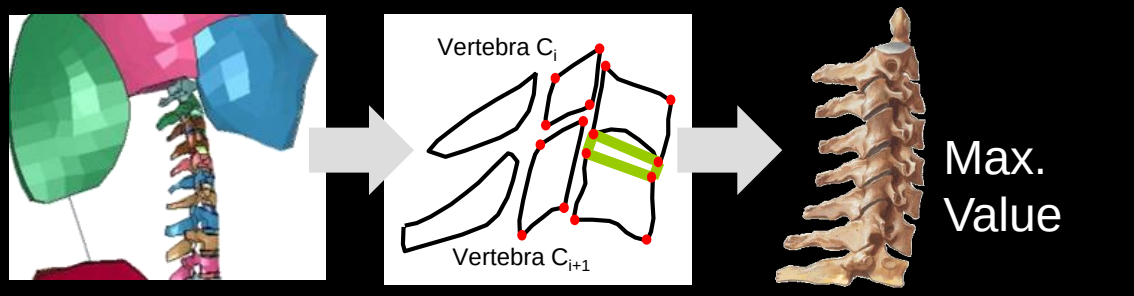


5. Step3: Accident Reconstruction based on FE model

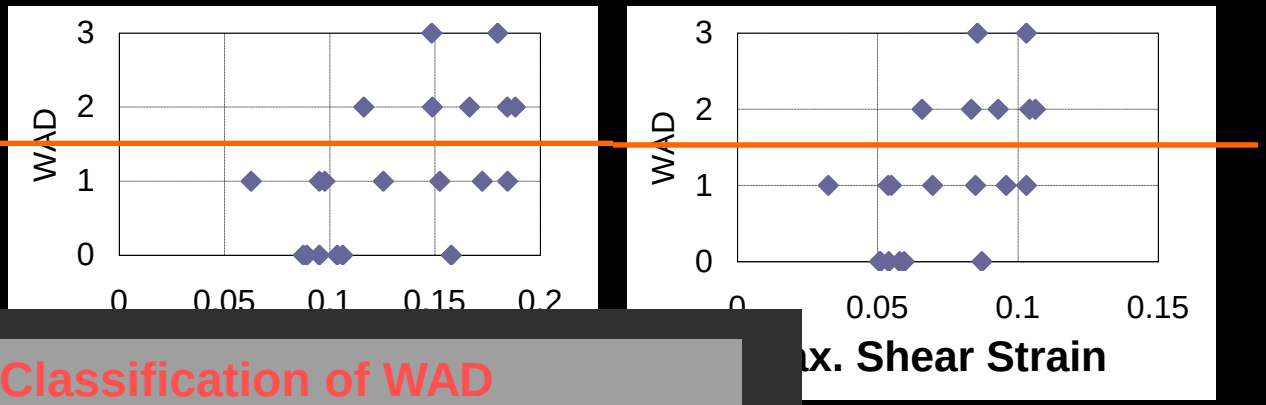
A) Relationship between Cervical Strain and WAD
B) Risk Curves (Cervical Strain and WAD)
C) Selection of Neck Injury Evaluation Parameters
D) Neck Injury Risk Curve
E) Injury Risk Curve (WAD2+/IV-NIC Flx.) CAE: Accident Reconstruction）

A) Relationship between Cervical Strain and WAD

- Method to Calculate cervical strain with Volunteers
- Extract max. value of the strain (C2/C3～C6/C7)



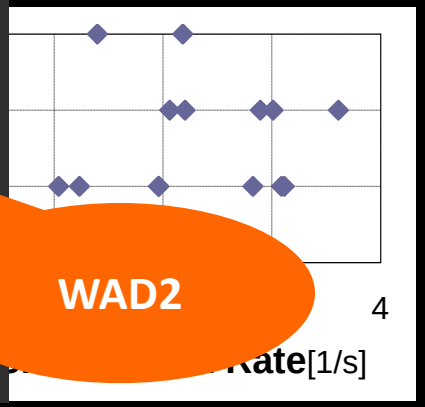
Cervical Strain



Classification of WAD
(Whiplash-associated disorders)

grade 0：No complaint
grade 1：Pain, stiffness(no physical sign(s))
grade 2：Musculoskeletal sign(s)
grade 3：Neurological sign(s)
grade 4：Fracture or dislocation

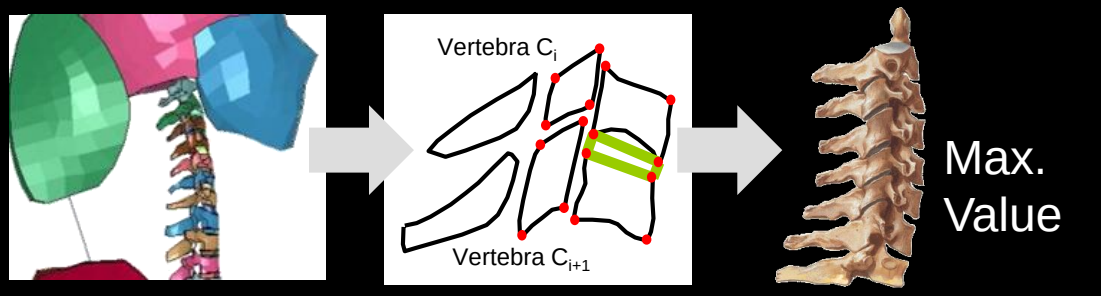
Ce



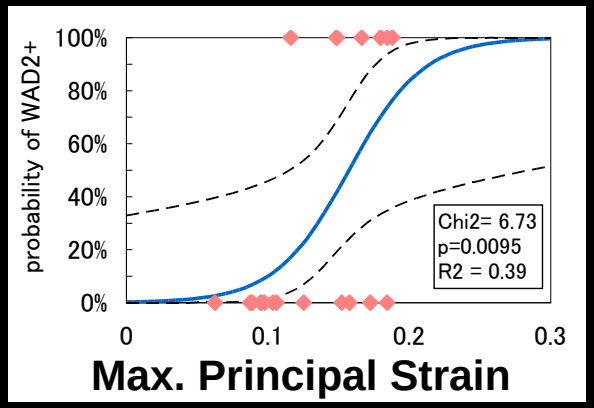
WAD2

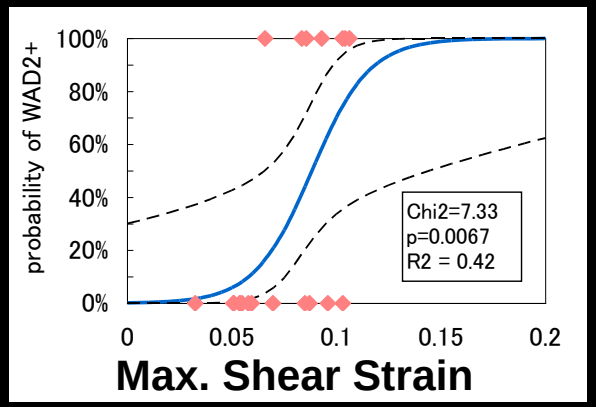
B) Risk Curves (Cervical Strain and WAD)

- Method to Calculate cervical strain with Volunteers
- Extract max. value of the strain (C2/C3～C6/C7)

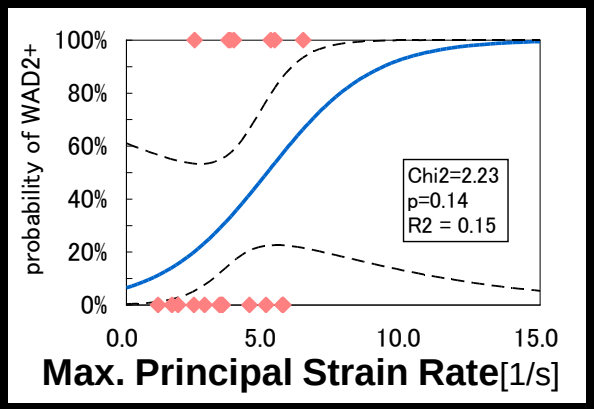


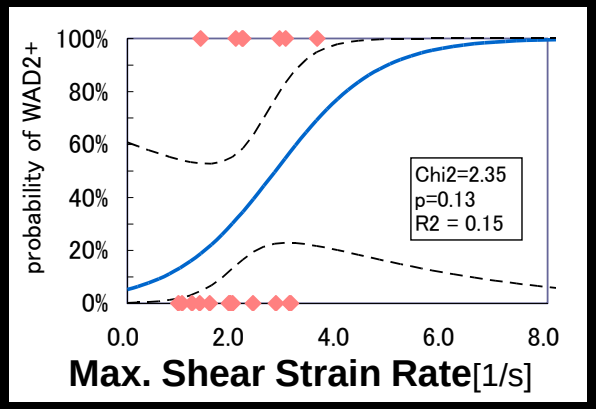
Cervical Strain





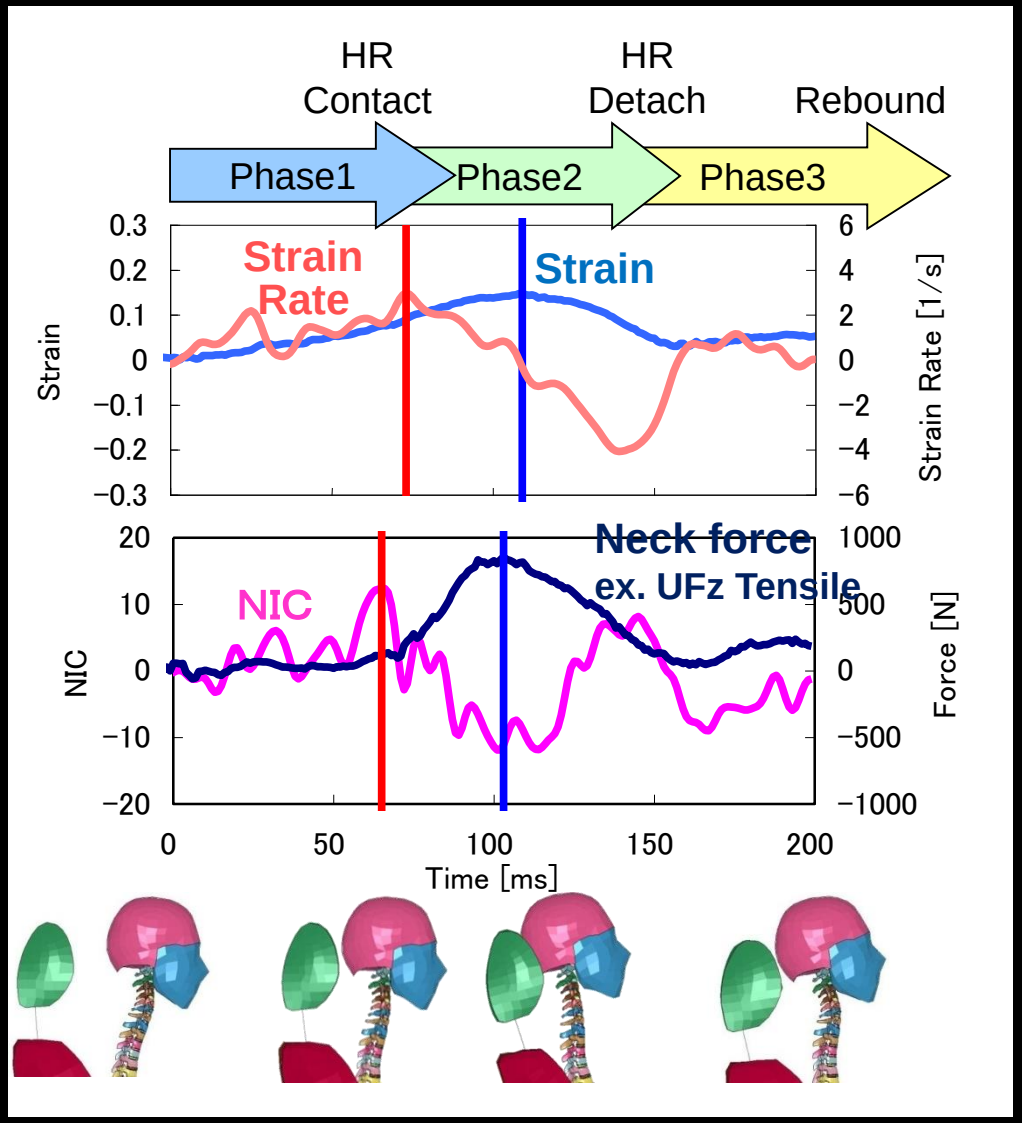
Cervical Strain rate



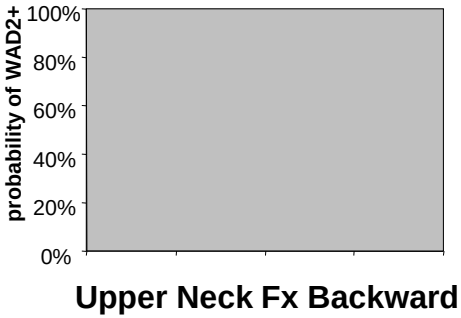


C) Selection of Neck Injury Evaluation Parameters

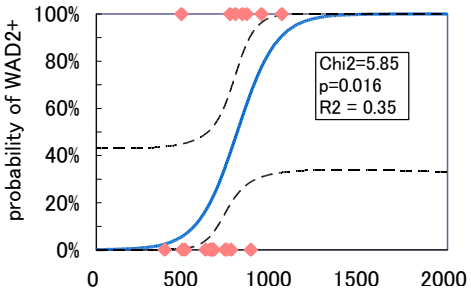
Neck Force	Upper	Fx	Forward
			Backward
		Fz	Tensile
			Compression
		My	Extension
			Flexion
	Lower	Fx	Forward
			Backward
		Fz	Tensile
			Compression
		My	Extension
			Flexion
NIC			
T1G			
Nkm			
LNL			
Rebound V			
OC-T1 disp			
Head-Chest rot. ang.			



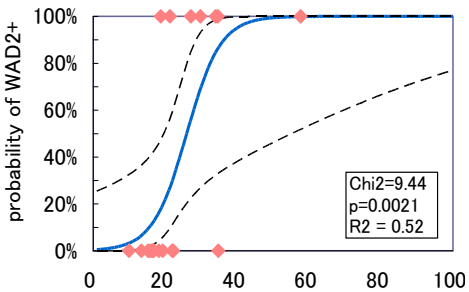
D) Neck Injury Risk Curve



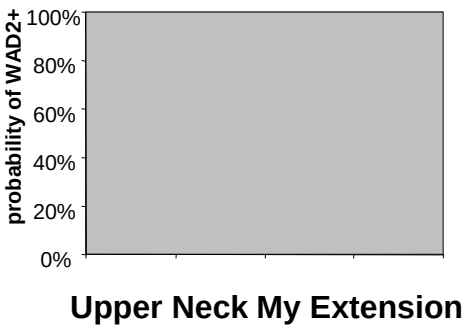
Upper Neck Fx Backward



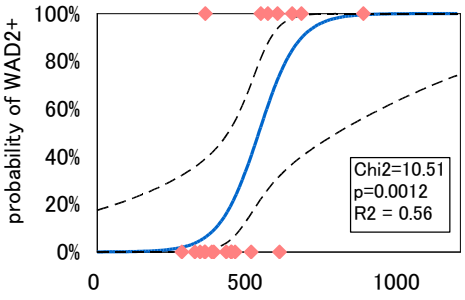
Upper Neck Fz Tensile



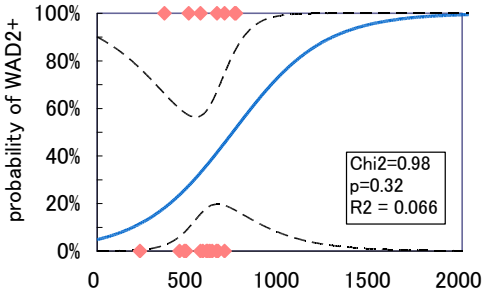
Upper Neck My Flexion



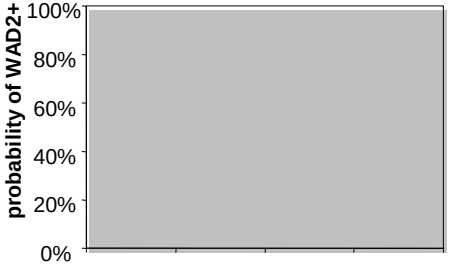
Upper Neck My Extension



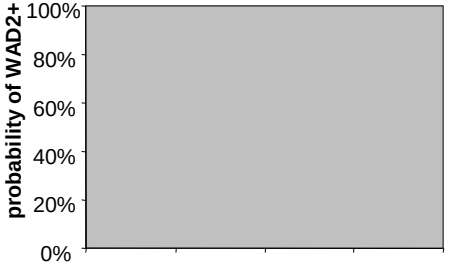
Lower Neck Fx Backward



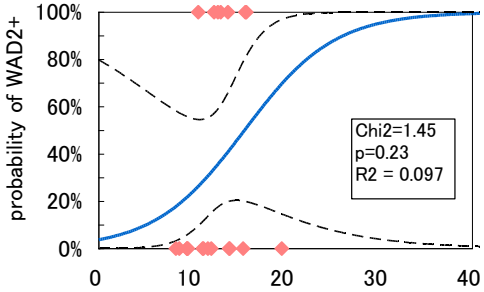
Lower Neck Fz Tensile



Lower Neck My Flexion

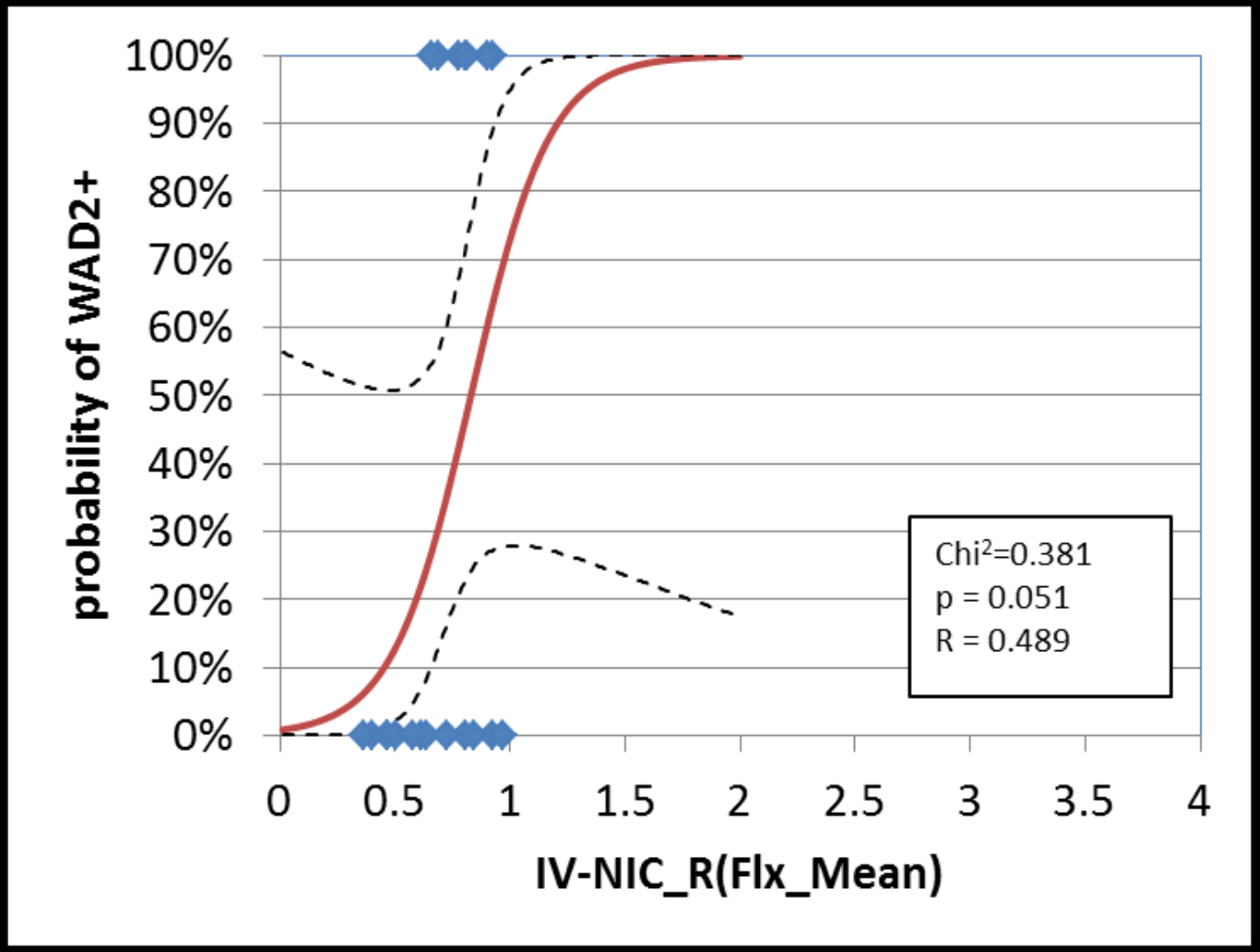


Lower Neck My Extension



NIC

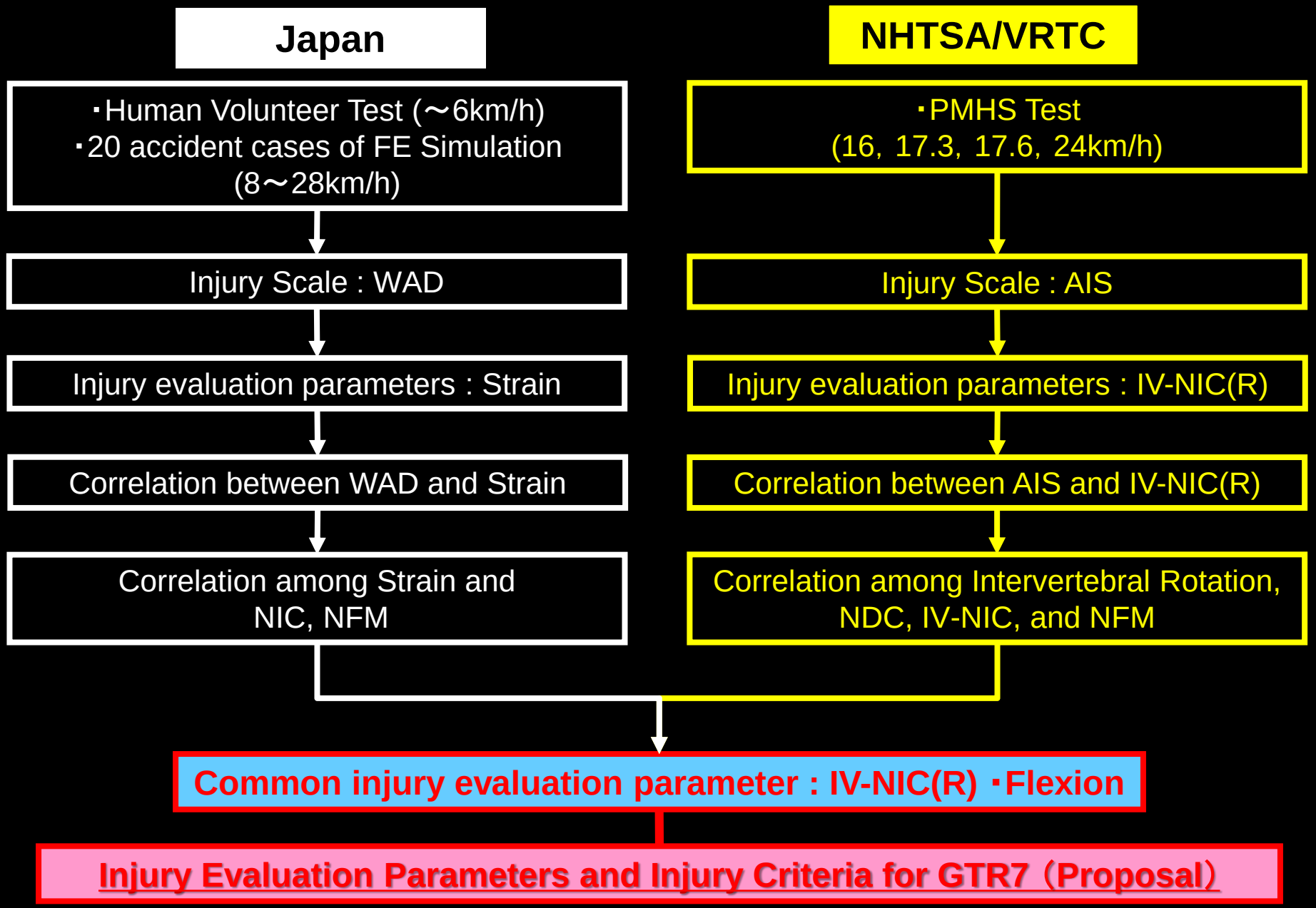
E) Injury Risk Curve (WAD2+/IV-NIC Flx.)
CAE: Accident Reconstruction）



6. Draft Proposal on Evaluation of Injury Parameters and Injury Risk Curve, a Collaborative Undertaking between NHTSA and Japan

A) Common injury evaluation parameter : IV-NIC(R)・Flexion
B) Setting methods of neck injury criteria
C) Correlations between the Injury Parameters and the Symptom of the Human Volunteer Subjects
D) Injury Evaluation Parameters and Injury Criteria
E) Injury Evaluation Parameters and Injury Criteria for GTR7（Proposal）

A) Common Injury Evaluation Parameter : IV-NIC(R) ・Flexion



B) Setting Methods of Neck Injury Criteria

- Fig. 1 shows that IV-NIC value corresponding to the AIS1+ 50% on the risk curve obtained by the PMHS Tests (Production seat)
- The IV-NIC value 1.1 corresponds to the AIS1+50% on the risk curve obtained by the PMHS tests shown in Fig.1. This IV-NIC value 1.1 also corresponds to 82.9% of WAD2+ risk curve wrt the IV-NIC.
- The IC of NFM, NIC, and NDCr will be created by WAD2+82.9% based on the risk curve of WAD2+ wrt IV-NIC (see Table on the next E) page).

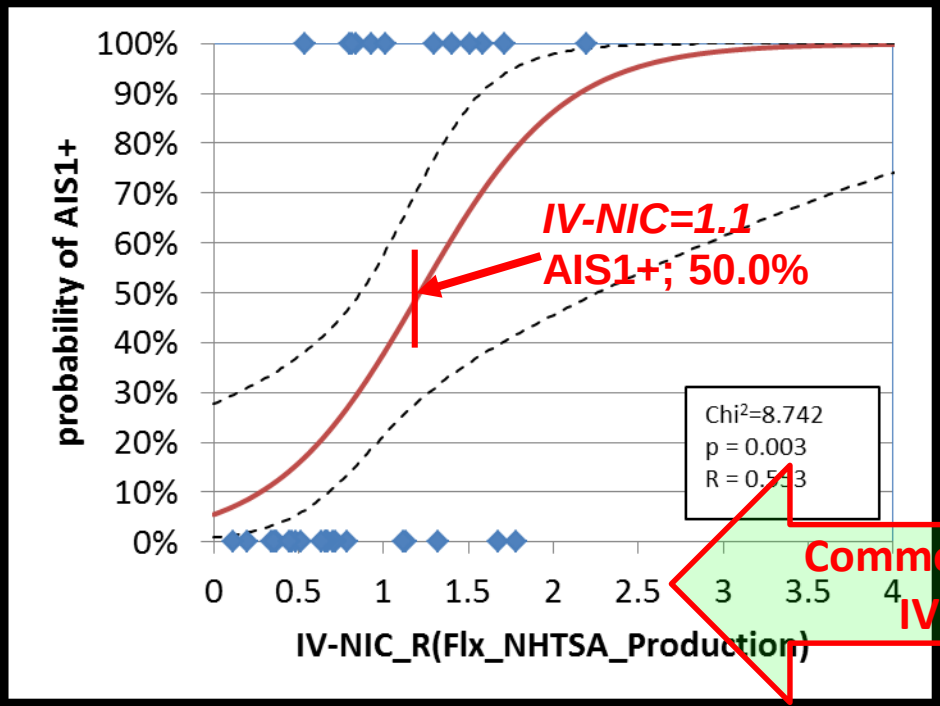


Fig. 1 Injury Risk Curve (AIS1+; PMHS: Production Seat)

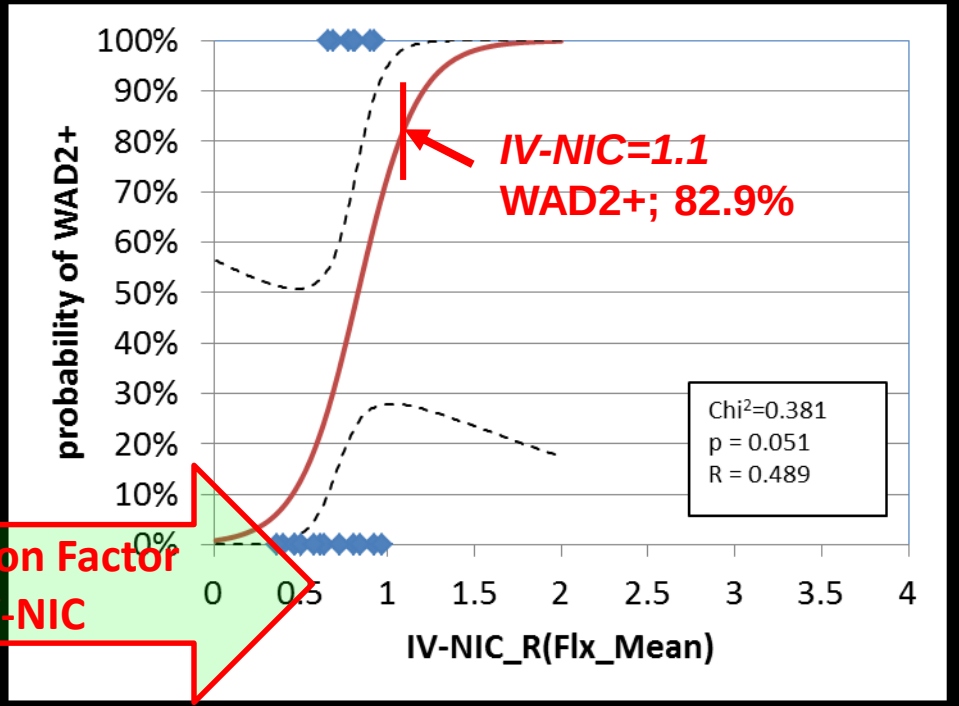


Fig. 2 Injury Risk Curve (WAD2+; CAE: Accident Reconstruction)

Common Factor
IV-NIC

C) Correlations between the Injury Parameters and the Symptom of the Human Volunteer Subjects

Order	Injury Parameters	Max. P. Strain	Max. P. Strain Rate	Correlation with Symptom
		R	R	
1	NIC Max	0.439	0.592	+
2	U Neck My	0.318	0.000	+
3	OC-T1(Disp.)	0.297	0.578	+
4	L Neck My	0.290	0.190	+
5	H-T angle	0.158	0.389	+
6	NDCr	0.156	0.388	+
7	L Neck Fx	0.105	0.764	+
8	L Neck Fz	0.100	0.114	+
9	U Neck Fx	0.089	0.735	+
10	U Neck Fz	0.077	0.095	+
11	T1G Max	0.828	0.580	-
12	Rebound V	0.170	0.032	-
13	LNL Max	0.077	0.455	-
14	Nkm Max	0.071	0.522	-

Order	Injury Parameters	Shear Strain	Shear Strain Rate	Correlation with Symptom
		R	R	
1	NIC Max	0.821	0.570	+
2	OC-T1(Disp.)	0.742	0.533	+
3	U Neck Fz	0.514	0.193	+
4	L Neck Fz	0.486	0.219	+
5	U Neck Fx	0.476	0.271	+
6	L Neck Fx	0.448	0.351	+
7	U Neck My	0.368	0.347	+
8	L Neck My	0.285	0.478	+
9	NDCr	0.191	0.393	+
10	H-T angle	0.191	0.394	+
11	T1G Max	0.704	0.831	-
12	LNL Max	0.514	0.477	-
13	Nkm Max	0.175	0.434	-
14	Rebound V	0.151	0.447	-

The OC-T1 (Disp.) as undefined measurement method was omitted. The H-T angle was also excluded due to overlapping with the NDCr.

D) Injury Evaluation Parameters and Injury Criteria

Japan

- Human Volunteer/Accident Reconstruction
- Injury scale : WAD
- Injury Evaluation Parameters
- Neck Forces/Moment, NIC

NHTSA/VRTC

- PMHS tests
- Injury scale : AIS
- Injury Evaluation Parameters
- Intervertebral Rotation, IV-NIC, NDC, NFM

Common injury evaluation parameters : IV-NIC(R)・Flexion

AIS 1+ = 50%

Common Indicator - IV-NIC(R)・Flexion value = 1.1

WAD 2+ = 82.9%

Decision made by the Correlations between the Injury Parameters and the Symptoms of the Human Volunteer Tests

Injury evaluation parameters for BioRID-II :

NIC

UpperNeck-FX

UpperNeck-MY(Flx/Ext)

LowerNeck-FX

LowerNeck-MY(Flx/Ext)

Harmonization
(Suggest Common Criteria)

Injury evaluation parameters for BioRID-II :

NIC

IV-NIC (R)・Flexion

Intervertebral Rotation・Flexion

NDCrot

NDCx

Neck Forces/Moments In progress

Injury Evaluation Parameters and Injury Criteria for GTR7（Proposal）

E) Injury Evaluation Parameters and Injury Criteria for GTR7（Proposal）

Injury Criteria		WAD2+ 82.9% Value (IV-NIC=1.1)	AIS1+ 50.0% Value (IV-NIC=1.1)	Literature Human Tolerance
NDCrot		?	12.2 deg.	
NIC Max		22	29.7	-
Upper Neck	FX	640	?	845[1), 2)]
	MY(Flx/Ext)	34	?	50.2[2)]
Lower Neck	FX	640	?	600～800[3)]
	MY(Flx/Ext)	34	?	-
		Japan works	NHTSA works	

Units:
Force (N)
Moment (Nm)

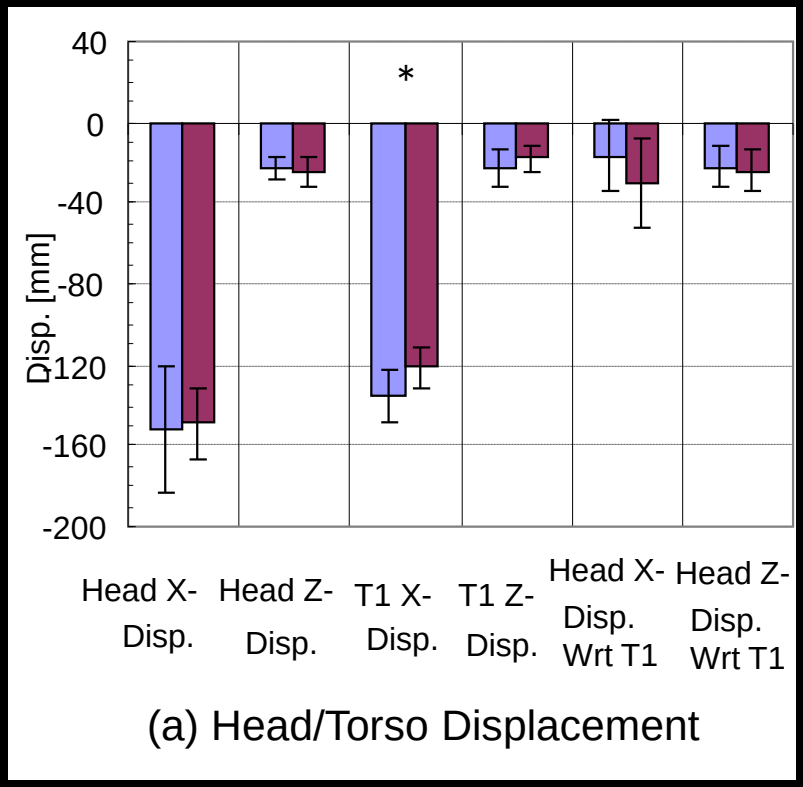
References:

1) Mertz, 1971, Strength and Response of the Human Neck, 15th STAPP
2) SAE J885, 2003, Human Tolerance to Impact Condition as related to Motor Vehicle Design
3) Stemper, 2009, Verification of Lower Neck Shear Force as a Rear Impact Injury Criterion

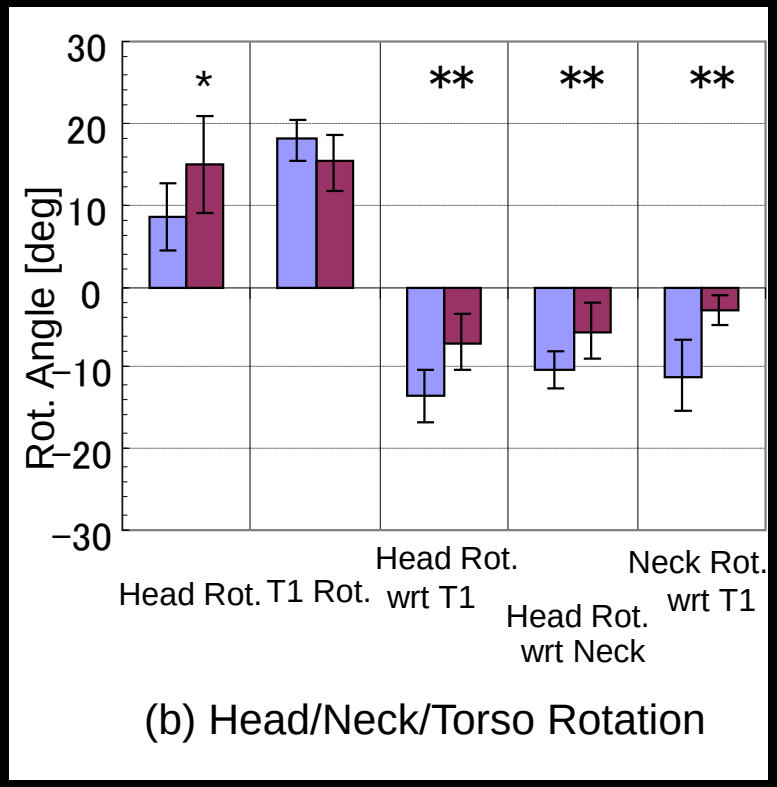
7. Influence of Muscle Conditions to Cervical Vertebral Motions

A) Comparison of Head/Neck/Torso behavior between the relaxed and tensed conditions
B) Comparison of Cervical vertebral motion between the relaxed and tensed conditions
C) Influence of Muscle Conditions to Cervical Vertebral Motions

A) Comparison of Head/Neck/Torso behavior between the relaxed and tensed conditions

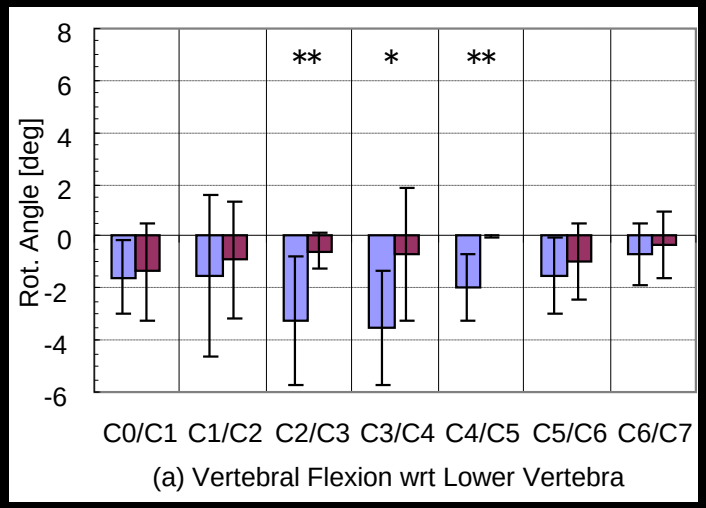


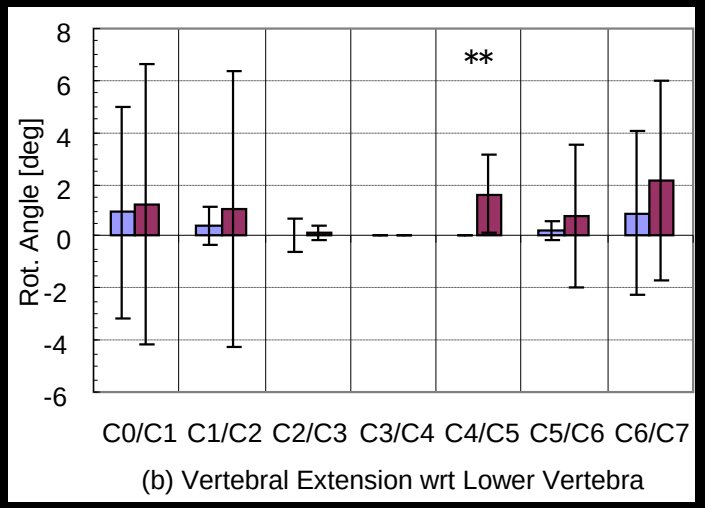
(a) Head/Torso Displacement

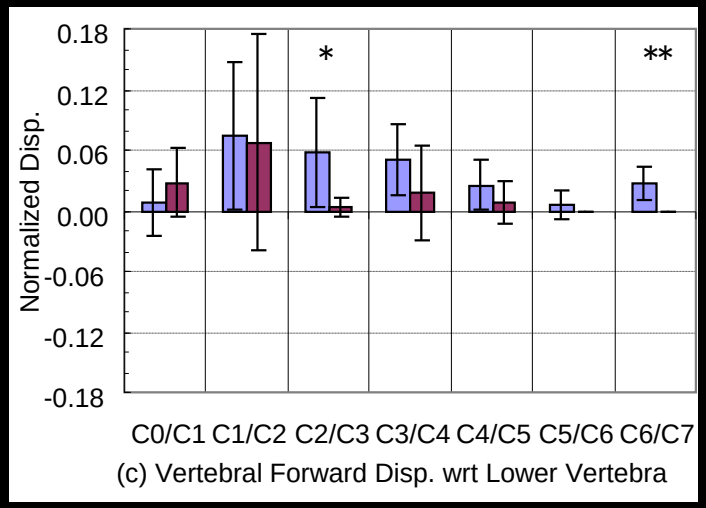


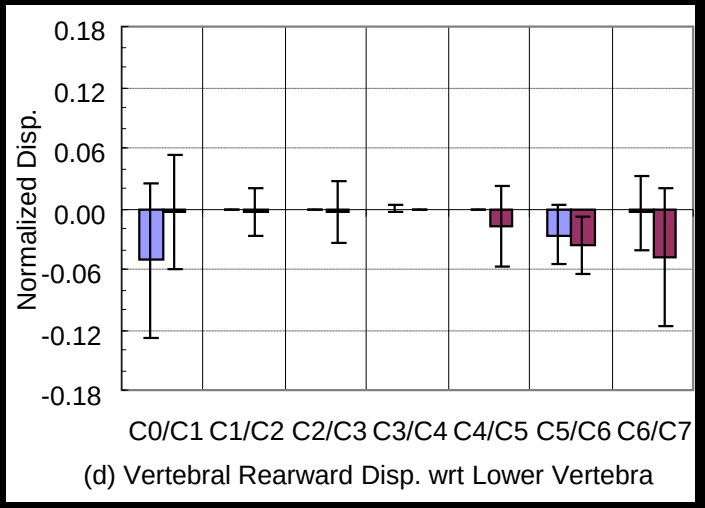
(b) Head/Neck/Torso Rotation

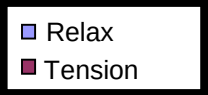
B) Comparison of Cervical vertebral motion between the relaxed and tensed conditions

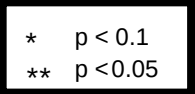






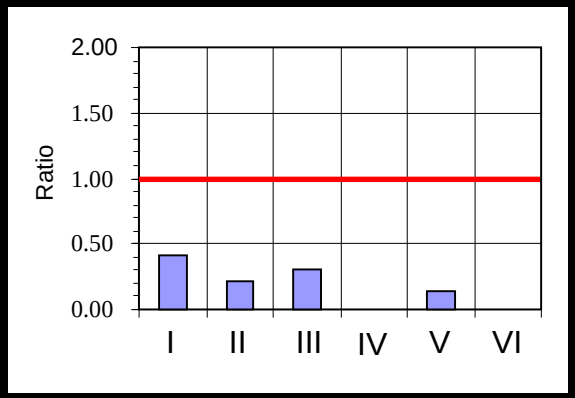




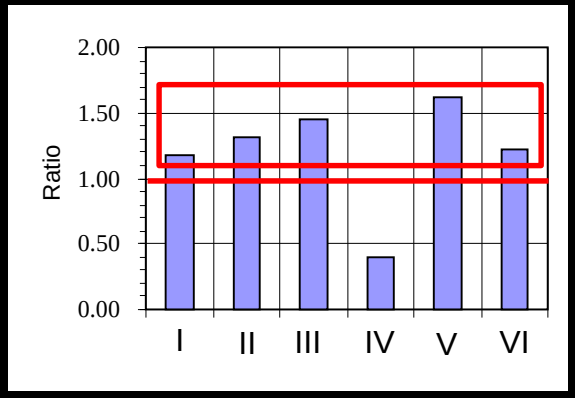


C) Influence of Muscle Conditions to Cervical Vertebral Motions

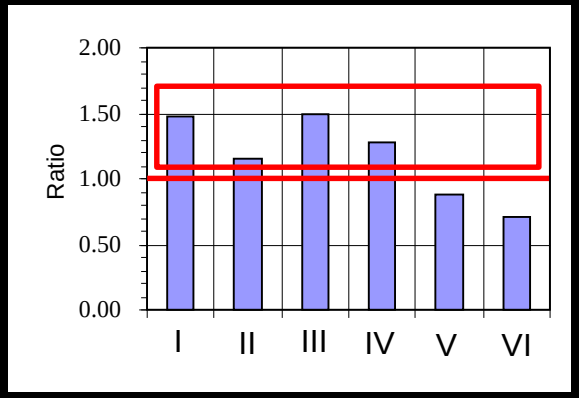
Comparison of Strains between Relaxed and Tensed Muscle Conditions



Upper Facet Joint Strains
(Tension Strains)



Lower Facet Joint Strains
(Rearward Shear Strains)



Lower Facet Joint Strains
(Compression Strains)

Upper Facet Joint Strains (Tension)

$$\text{Ratio} = \frac{\text{Strain by Tensed Condition}}{\text{Strain by Relaxed Condition}}$$

It is definite to point out that it is very hard to evaluate the minor neck injuries only by OC-T1 kinematics.

L

Relaxed < Tensed

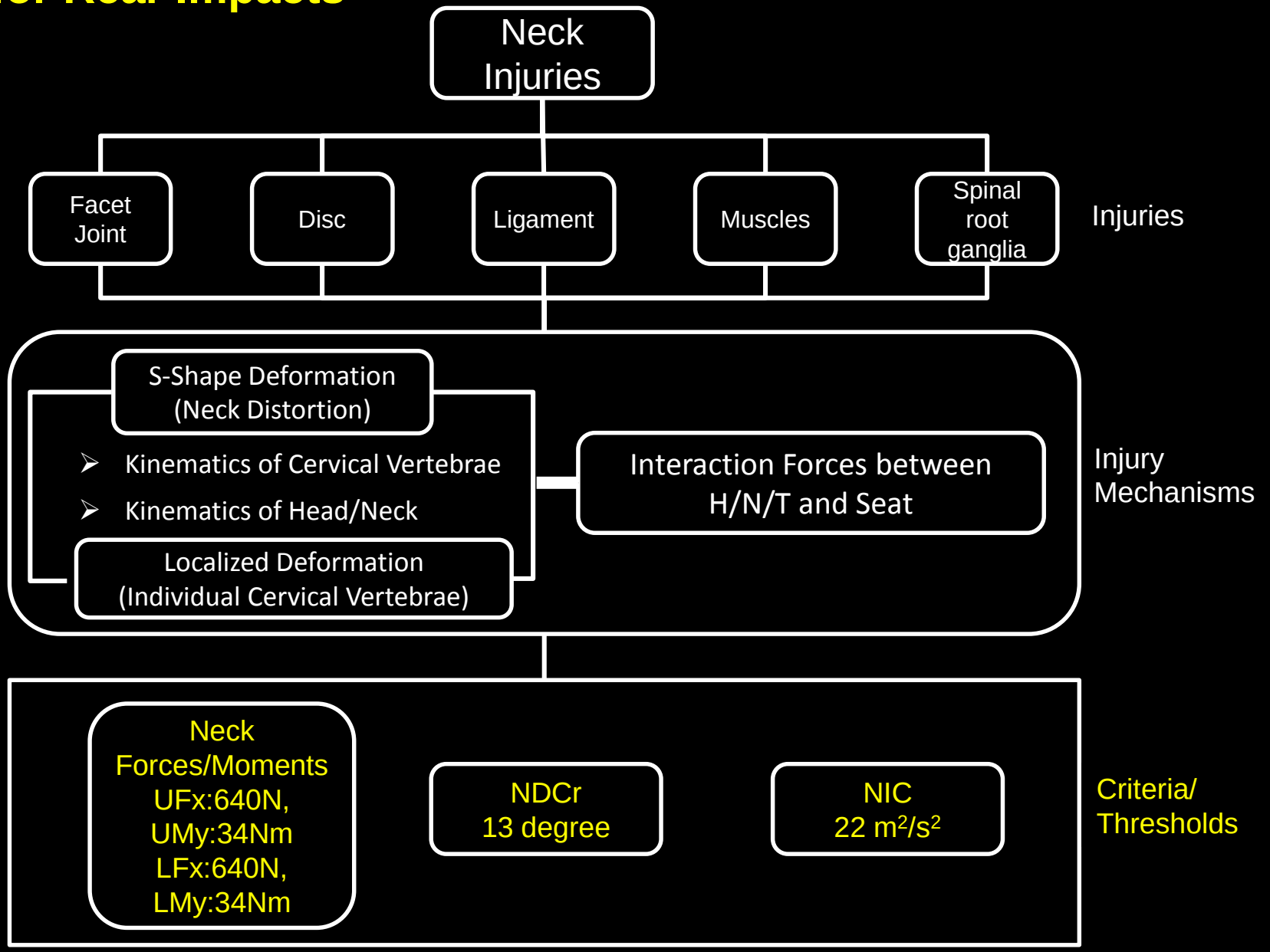
)

Relaxed < Tensed

Conclusions

In the past, an evaluation method for minor neck injuries did not exist. Now, the evaluation parameters and thresholds for the reduction of minor neck injuries are obtained.

Summarized Minor Neck Injury Parameters & Criteria for Rear Impacts



Conclusions (Continued)

- The published papers including the data and the current available knowledge for a reduction of minor neck injuries on rear-end impacts was successful reviewed.
- The proper neck injury evaluation parameters and the injury criteria based on HVT, ARS, and PMHS into the regulation documents of the informal GTR7 was well clarified.
- Based on the results of volunteer tests, the threshold of the strain and the strain rate that caused subjects to feel neck discomfort (minor neck injuries) during the tests were well defined.
- The relationship between the strain/strain rate and parameters was investigated based on the results of HVT, ARS, and PMHS. The parameters which have good correlations with the strain/strain rate were selected as evaluation parameters (IV-NIC) for neck injury.
- The IV-NIC value 1.1 corresponds to the AIS1+50% on the risk curve obtained by the PMHS tests. This IV-NIC value 1.1 also corresponds to 82.9% of WAD2+ risk curve wrt the IV-NIC.

Conclusions (Continued)

- The IC of NFM, NIC, and NDCr will be created by WAD2+82.9% based on the risk curve of WAD2+ wrt IV-NIC.
- The risk curve for causation of neck injuries were clarified as neck injury criteria based on HVT, ARS, and PMHS into the regulation documents of the informal GTR7.
- The risk curve of WAD2+ concerning neck forces/moments, NIC, and NDCr based on the results of HVT, ARS, and PMHS was recommended.
- It is definite to point out that it is very hard to evaluate the minor neck injuries only by OC-T1 (NDCr) kinematics.
- A draft proposal on injury evaluation parameters and injury risk curve, based on the collaboration with NHTSA and Japan was suggested.
- It should similarly be proposed as the neck injury evaluation parameters and the neck injury criteria for the informal GTR7.

Thank you for your attention.

If you have any comments and questions,
please feel free to contact me: Koshiro Ono.
mailto: kono@jari.or.jp
Tel: +81-29-856-1114