GTR 7 Informal Working Group
September 10/11, 2013

Progress Report on Neck Injury Criteria Works for Discussion

Collaboration works with NHTSA(VRTC)

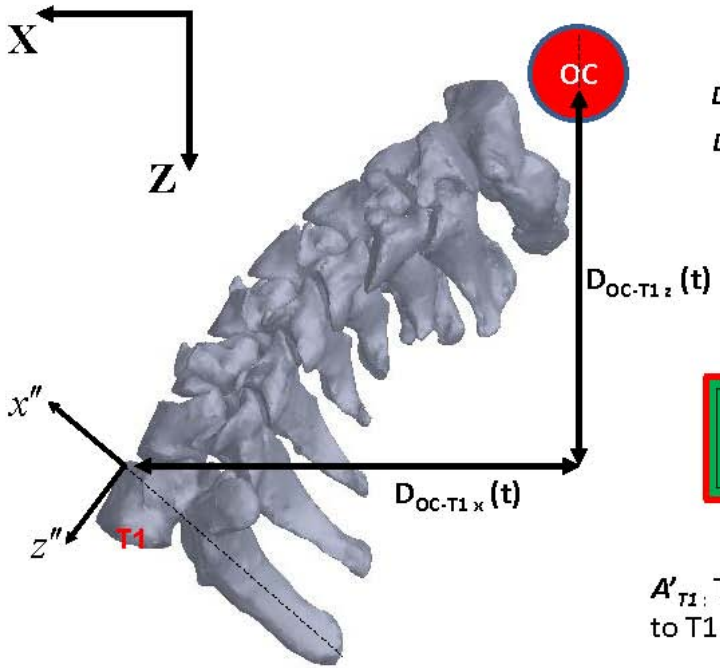
Part I

JAPAN
JMLIT/JASIC/JARI

＜Contents＞

Calculation method of NDC (defined by NHTSA/VRTC)

NDCx and NDCz w.r.t. T1 local frame (x”-z”)



$D_{OC\text{-}T1\,x}(t)$ = Global OC Dx (t) – Global T1 Dx (t)

$D_{OC\text{-}T1\,z}(t)$ = Global OC Dz (t) – Global T1 Dz (t)

$D'_{OC\text{-}T1\,x}(t) = D_{OC\text{-}T1\,x}(t) - D_{OC\text{-}T1\,x}(0)$

$D'_{OC\text{-}T1\,z}(t) = D_{OC\text{-}T1\,z}(t) - D_{OC\text{-}T1\,z}(0)$

$$\begin{bmatrix} NDCx\ wrt\ T1 \\ NDCz\ wrt\ T1 \end{bmatrix} = A'_{T1} \cdot \begin{bmatrix} D'_{OC-T1x} \\ D'_{OC-T1z} \end{bmatrix}$$

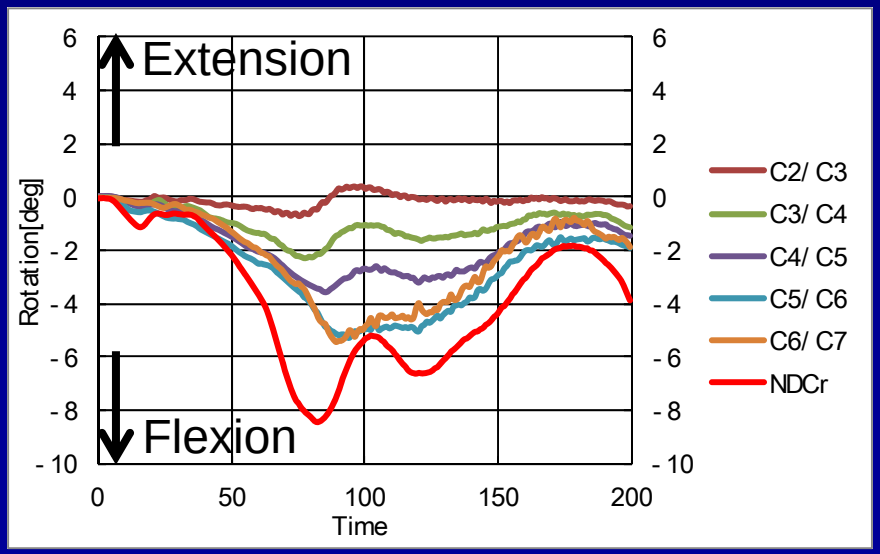
A'_{T1}: Transformation matrix from Global frame to T1 local frame

One example of the time histories for NDCr, NDCx and NDCz deduced by the 20 cases of the FE simulation is shown in the next page.

Time history of NDCr

NDCr is the rotation angle (RA) for the Head O.C. relative to the T1 as shown in the figure. In the figure, the relative angles of each cervical vertebrae (CV) are also shown.

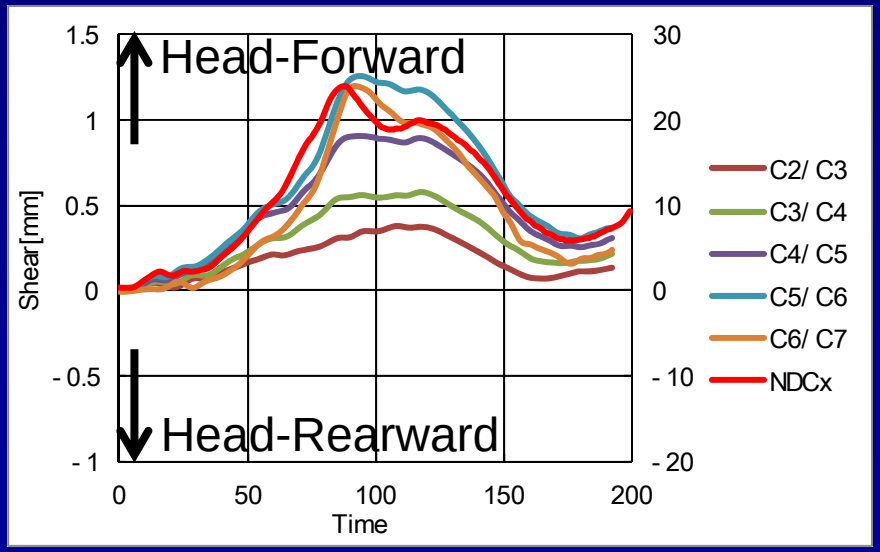
- As for the RA on NDCr and each CV, the extension by the simulation was not so apparent, but the flexion typically appeared.
- As for the FMVSS202a, the head backward rotational motion relative to the T1 (extension) is set as the regulation (12 degrees).
- On the other hand, the head flexion motion by the simulation typically appeared
- As for the Head backward rotational motion relative to the T1 (during the interaction between the head and the headrest), it should be pointed out that there is the more important issue as to which phase (flexion or extension) will influence the occurrence of the neck injury.



Time history of NDCx

NDCx is the x-axis displacement for the Head O.C. relative to the T1 as shown in the figure. In the figure, the X axis displacements of each CV are also shown.

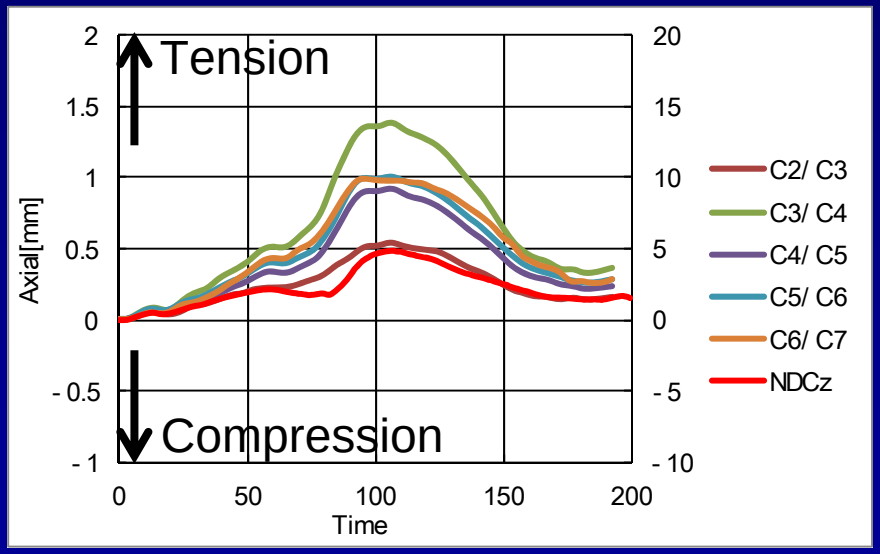
➢As for the displacement on NDCx and each CV by the simulation, the head rearward motion (HRM) was not so apparent, but the head forward motion typical l y appeared.
➢The peak value of the head rearward and the head forward motion were also calculated.



Time history of NDCz

NDCz is the z-axis displacement for the Head O.C. relative to the T1 as shown in the figure. In the figure, the z-axis displacement of each CV are also shown.

- As for the displacement on NDCz and each CV by the simulation, the compression was not apparent, but the tension typically appeared.
- The peak value of the compression and the tension were also calculated.



The peak value of NDCr, NDCx, and NDCz are summarized in next page.

Calculation Results of NDCr, NDCx and NDCz

The peak value of NDCr, NDCx and NDCz by the FE simulation are as follows:

ID No.	⊿V [km/h]	Mean Acc. [g]	Peak Acc. [g]	WAD	NDCr (Ext.) [deg]	NDCr (Flx.) [deg]	NDCx (Head-R) [mm]	NDCx (Head-F) [mm]	NDCz (Comp.) [mm]	NDCz (Ten.) [mm]
1_D	28.2	5.8	10.6	2	2.09	8.06	5.56	20.04	0.01	6.54
4_D	26.0	5.6	12.6	3	0.00	6.60	0.00	13.12	0.11	7.64
4_P	26.0	5.6	12.6	3	2.31	6.47	3.87	12.75	0.02	6.52
2_D	23.3	6.7	14.7	2	3.29	6.75	0.00	20.03	0.00	5.10
8_D	20.4	5.2	12.8	1	0.41	8.00	0.00	24.83	0.07	2.54
8_P	20.4	5.2	12.8	2	0.00	8.44	0.00	23.94	0.02	4.82
7_D	19.5	4.0	9.2	0	3.11	5.02	4.59	8.05	0.01	4.93
7_P	19.5	4.0	9.2	1	2.92	5.92	0.18	15.11	0.32	2.53
10_D	17.6	5.0	12.4	1	0.83	9.31	0.00	27.15	0.06	3.46
10_P	17.6	5.0	12.4	2	2.66	6.29	0.15	17.54	0.04	3.55
6_D	16.3	4.9	12.1	0	1.88	5.45	0.22	13.66	0.04	3.03
6_P	16.3	4.9	12.1	1	0.00	6.47	0.00	21.27	0.06	2.61
11_D	16.3	6.5	15.2	0	0.00	10.51	0.00	25.86	0.01	3.58
11_P	16.3	6.5	15.2	0	4.02	6.18	0.00	9.47	0.00	3.81
21_D	14.3	4.5	10.6	0	0.68	6.28	0.00	12.63	0.07	3.52
23_D	11.1	3.7	8.9	1	0.22	6.06	0.00	18.92	0.07	2.33
20_D	10.8	3.7	7.1	1	0.63	6.53	0.00	14.31	0.03	3.10
20_P	10.8	3.7	7.1	0	0.43	6.09	0.00	16.37	0.16	2.63
24_D	8.8	3.5	7.5	1	0.78	2.79	0.14	7.49	0.07	2.45
3_D	14.7	5.2	7.5	2	1.63	4.19	0.04	14.53	0.10	3.18

Summary of relationships between NDCr/NDCx/NDCz and WAD

NDCr：
The correlation coefficient between NDCr (Extension and Flexion) and WAD was quite low (0.1).

NDCx：
The correlation coefficient between NDCx (Head-Rearward and Head-Forward) and WAD was also quite low (around 0.1).

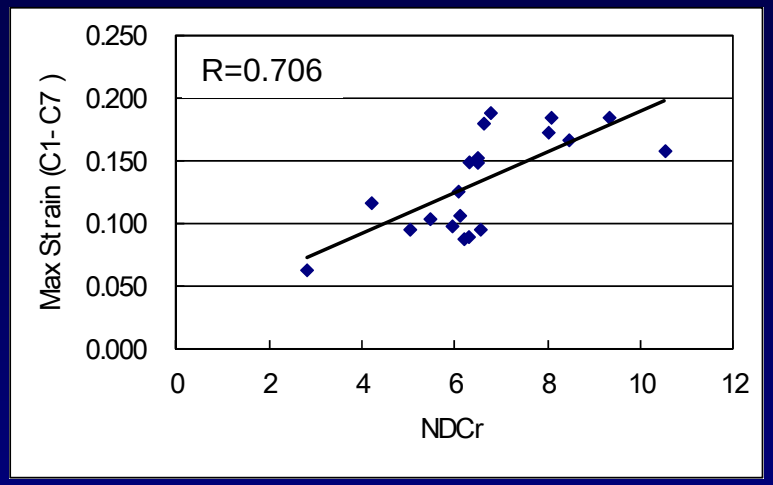
NDCz：
The correlation coefficient between NDCz (Compression) and WAD was quite inversed. However, the relationship between the Tension and the WAD had a higher correlation (0.632).

As shown in these results, there is only findings of correlation between NDCz・Tension and WAD.

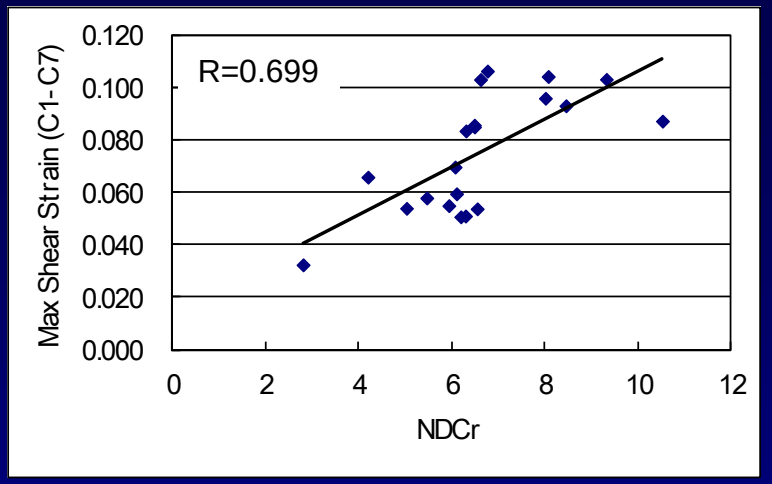
In order to verify the relationship between NDCr/NDCx/NDCz and Strain(Rate) the following survey was also done.

Relationship between NDCr・ Flexion and Strain(Rate)

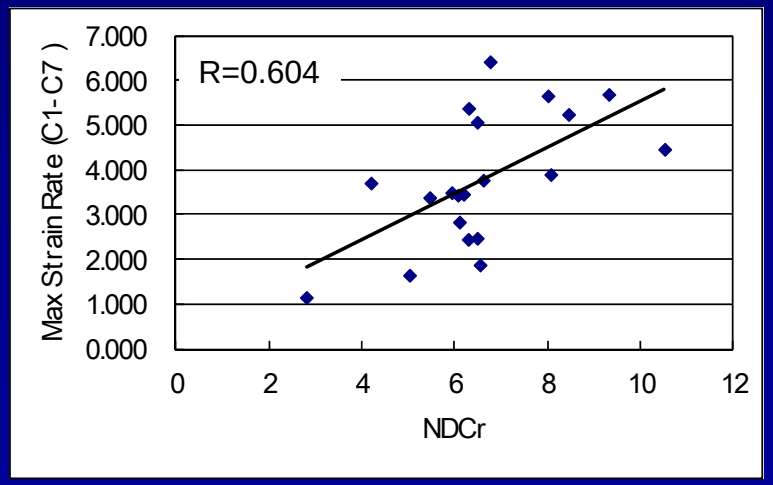
Max Principal Strain



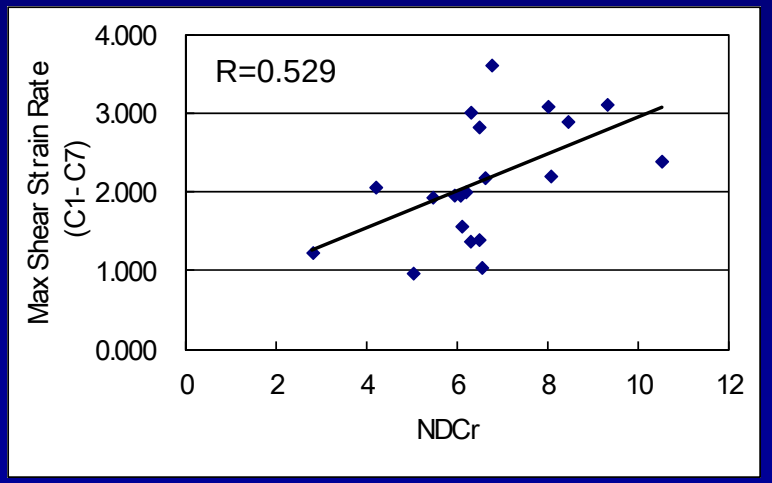
Max Shear Strain



Max Principal Strain Rate



Max Shear Strain Rate



- Correlation coefficient of Strain was around 0.7.
- Correlation coefficient of Strain Rate exceeded 0.5.

Relationship between NDCr/NDCx/NDCz and Strain(Rate) (Correlation Coefficient)

Correlation Coefficient (R)	NDCr		NDCx		NDCz	
	Extension	Flexion	Head- Rear	Head- For	Compression	Tension
Max Principal Strain	0.191	0.706	0.116	0.759	0.249	0.500
Max Shear Strain	0.166	0.699	0.133	0.735	0.250	0.531
Max Principal Strain Rate	0.044	0.604	0.300	0.804	0.109	0.040
Max Shear Strain Rate	0.036	0.529	0.323	0.761	0.118	0.028

1.0≦ R < 0.7	0.7≦ R < 0.4	0.4≦ R < 0.2	0.2≦ R < 0

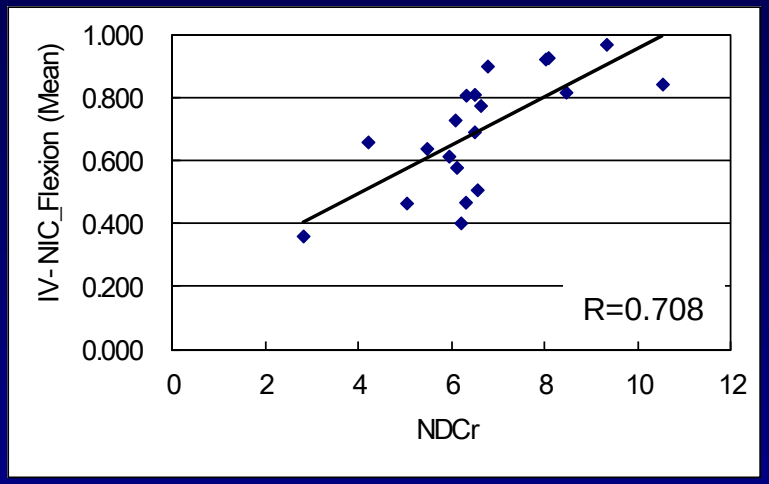
NDCr :
Correlation coefficient of Flexion and Strain(Rate) was around 0.5 to 0.7.

NDCx :
Correlation coefficient of Head-Forward and Strain(Rate) exceeded 0.7.

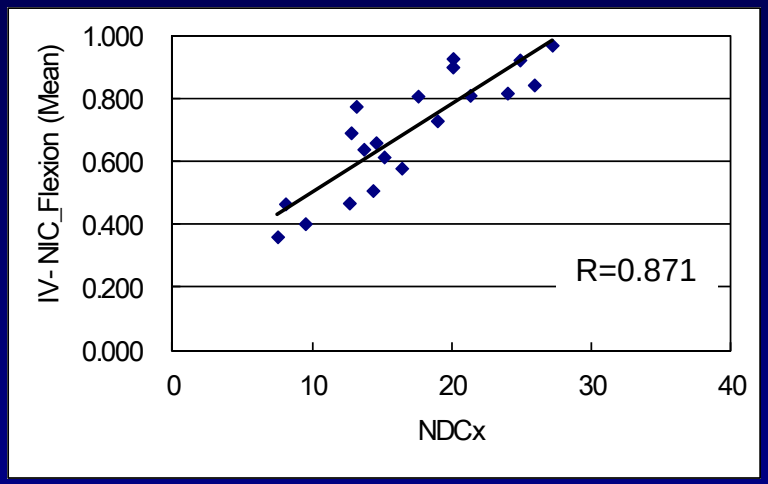
NDCz :
Correlation coefficient of Tension and Strain was around 0.5.

Relationship between NDCr・ Flexion/NDCx・ Flxsion and IV-NIC(R)

IV-NIC（R）・ Flexion



IV-NIC（R）・ Flexion



- Correlation coefficient of IV-NIC(R)・ Flexion was 0.708.
- Correlation coefficient of IV-NIC(R)・ Flexion was 0.871

Relationship between NDCr/NDCx/NDCz and IV-NIC(R) (Correlation Coefficient)

Correlation Coefficient (R)	NDCr		NDCx		NDCz	
	Extension	Flexion	Head- Rear	Head- For	Compression	Tension
IV- NIC_Extension_Mean	0.230	0.014	0.538	0.128	0.091	0.068
IV- NIC_Flexion_Mean	0.236	0.708	0.028	0.871	0.132	0.254

1.0≦ R < 0.7	0.7≦ R < 0.4	0.4≦ R < 0.2	0.2≦ R < 0

NDCr：
Correlation coefficient of NDCr・ Flexion and IV-NIC(R)・ Flexion was around 0.708.

NDCx：
Correlation coefficient of Head-Forward and IV-NIC(R)・ Flexion was around 0.871.

NDCz：
Correlation coefficient of Tension and IV-NIC(R)・ Flexion was quite low (0.254).

Summary of Relationship between NDCr/NDCx/NDCz and IV-NIC(R) (Correlation Coefficient)

- As for the relationship between NDC and WAD, only NDCz・ Tension had correlation with WAD.

- As for the relationship between NDC and Strain(Rate), only NDCx・ Head-Forward had correlation with Strain(Rate).

- As for the relationship between NDC and IV-NIC(R), NDCr・ Flexion and NDCx・ Head-Forward had correlation with IV-NIC(R)・ Flexion.

Conclusion

- The correlation coefficient between WAD and IV-NIC is quite high. On the other hand, it is quite low for the correlation coefficient between WAD and NDC.
- The correlation among the Strain, the NDC, and the IV-NIC as predictors of the cervical vertebral motion is quite high.
- According to the significant correlation among those parameters shown as the cervical injury risks, it is possible to predict cervical injuries with the common indicator of IV-NIC based on the results among the human volunteer tests, the CAE (20 cases of accident reconstruction simulations), and the PMHS tests.

The injury risk curves on both of WAD and IV-NIC based on the CAE, and AIS and IV-NIC based on the PMHS tests are established. Although it is under review by NHTSA and JAPAN, the injury evaluation parameters and the injury criteria for informal GTR7 are tentatively reported as shown in Part II, for your consideration.

Further discussion
(if needed)

Clarification of the concepts on the NDC and the neck injury parameters proposed by Japan

➢Concept of the NDC

Neck soft tissue injuries are induce by the energy accumulation of the whole relative motion between the Head O.C. and T1 during the head-headrest interaction.

The total displacement of the cervical vertebrae come up with “the total motion of the Head O.C. relative to the T1". In other words, it assumes that any minor neck injuries are possible to be evaluated by the entire neck motion.

➢Concept of the neck injury parameters proposed by Japan

Neck soft tissue injuries are caused by the relative motion of the cervical vertebrae, and also the soft tissues surrounding to cervical vertebrae as it is stretched by the relative motion of the cervical vertebrae.

It assumes that the relative cervical vertebral motion is one main causation of minor neck injuries.