Axonal Tolerance for Uniaxial Stretching

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Issues for Current Brain Injury Assessment

- Diffuse axonal injury is the most common type of pathology in traumatic brain injuries occurred in rotational impact.
- Many brain injury metrics such as DAMAGE are established based on brain strain.
- On one hand, strain and strain rate influenced to the axonal injury. *(STAPP 2017 Nakadate et al.)*
- Therefore, strain rate should be employed as well as strain.

Reference: 2017 STAPP Car Crash Journal paper

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Strain-rate Dependency of Axonal Tolerance for Uniaxial Stretching

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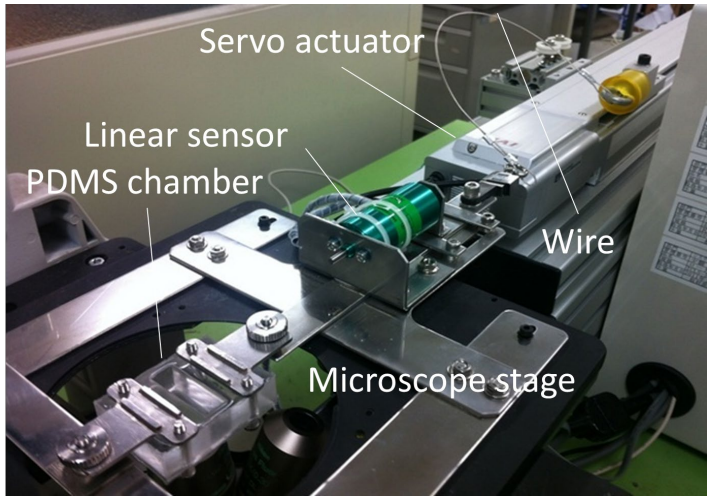
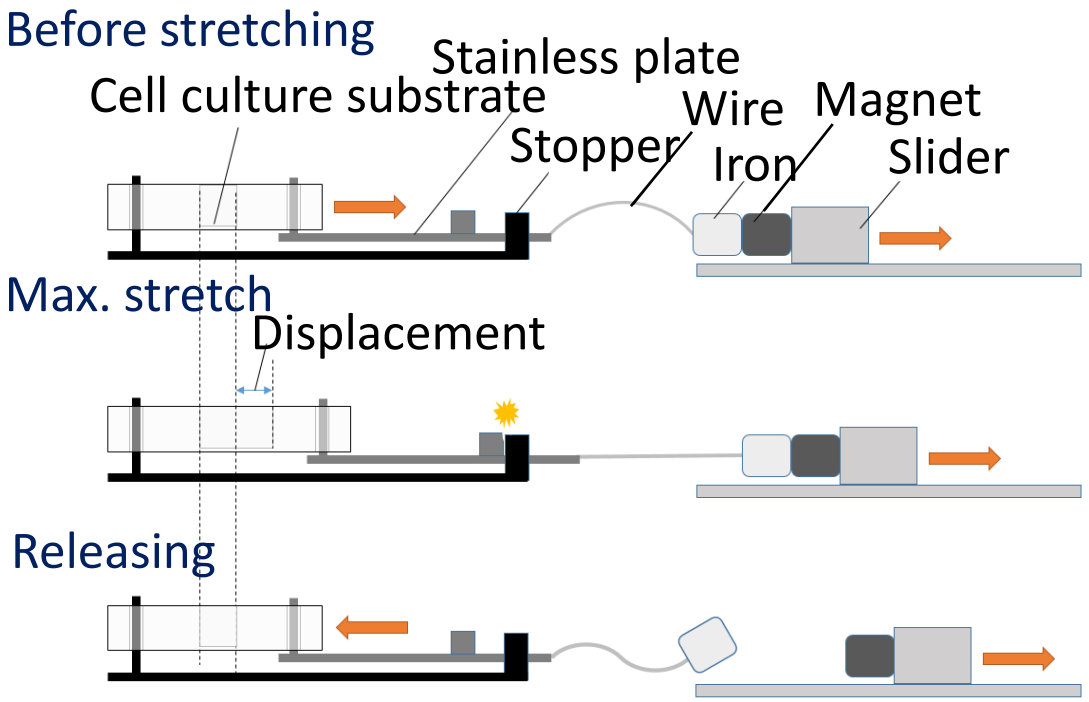
Method: Application of Stretching load

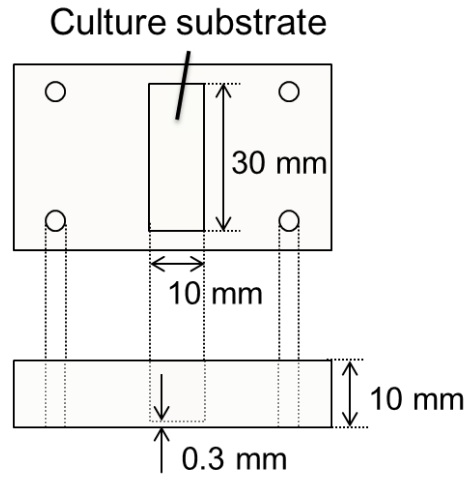
Uniaxial stretching device

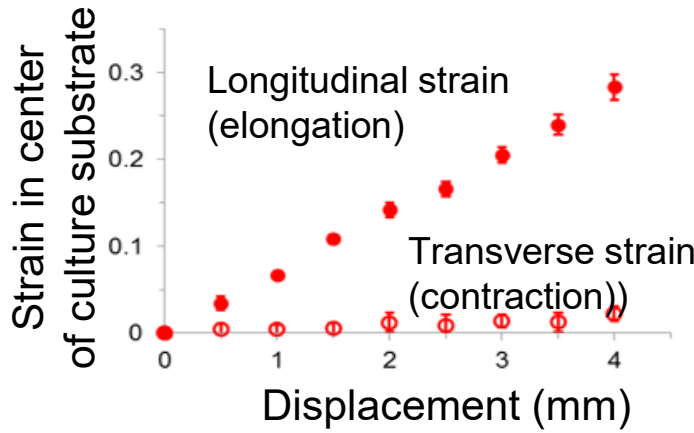


Stretching mechanism



Chamber (silicon)



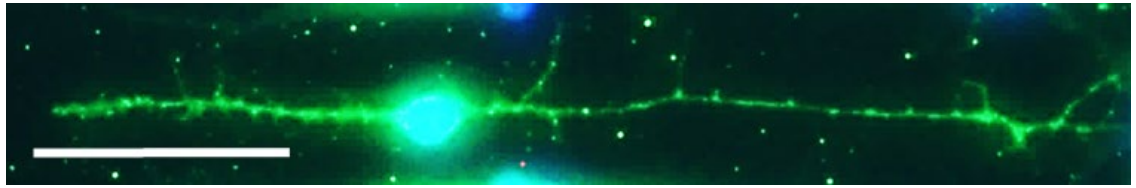


- The nerve cells of rat were adhered to the culture substrate.

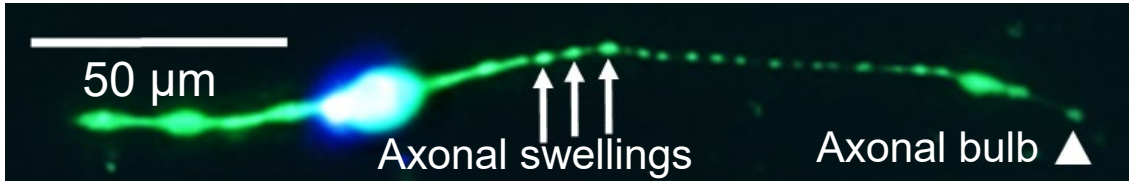
Method: Evaluation of Axonal Injury

- We conducted four experiments in each condition (n=4).
- Neurons of 100–150 in each condition were measured for the formation of axonal swellings and bulb.
- Three hours after stretching, the Tau protein was stained, and the formation of the axonal swellings and bulb were counted.

Intact



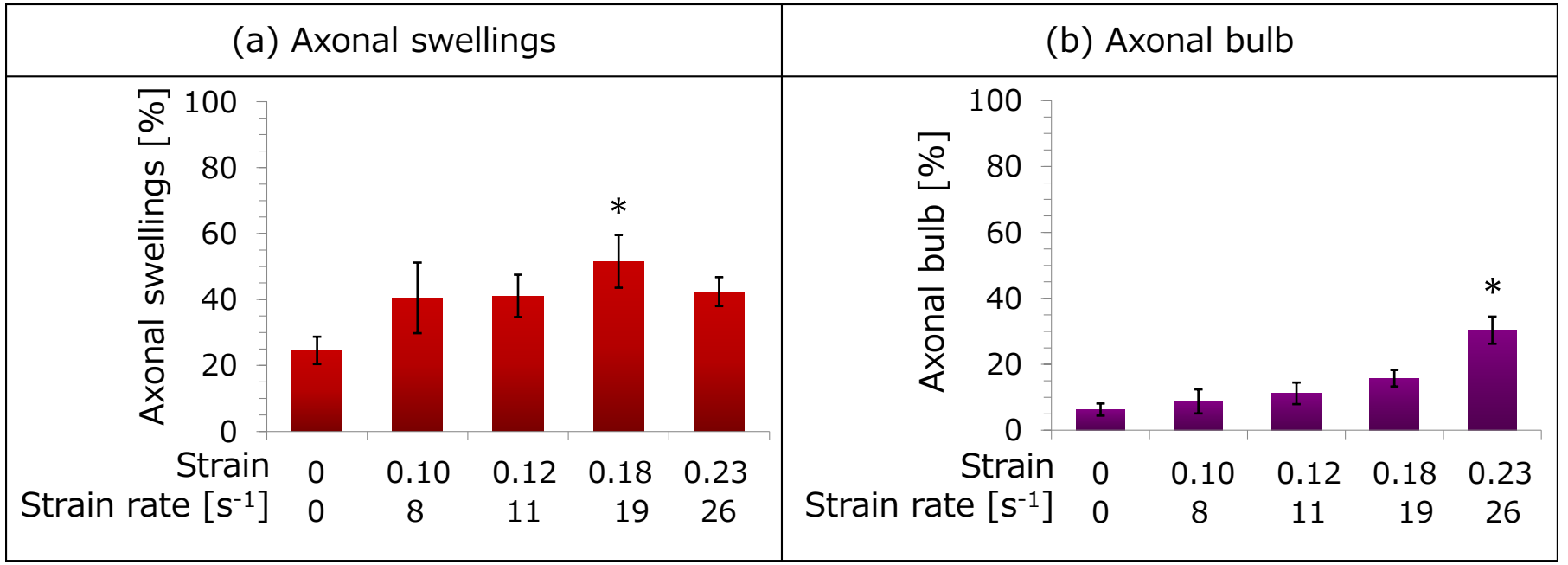
Injured



*green: Tau protein

Swellings were formed along the axon, and bulb were formed at the end of the axon.
Tau protein aggregated in swellings and bulb.

Test Results: (1st step) Percentage of Injuries



*: $p < 0.05$
vs. no stretching

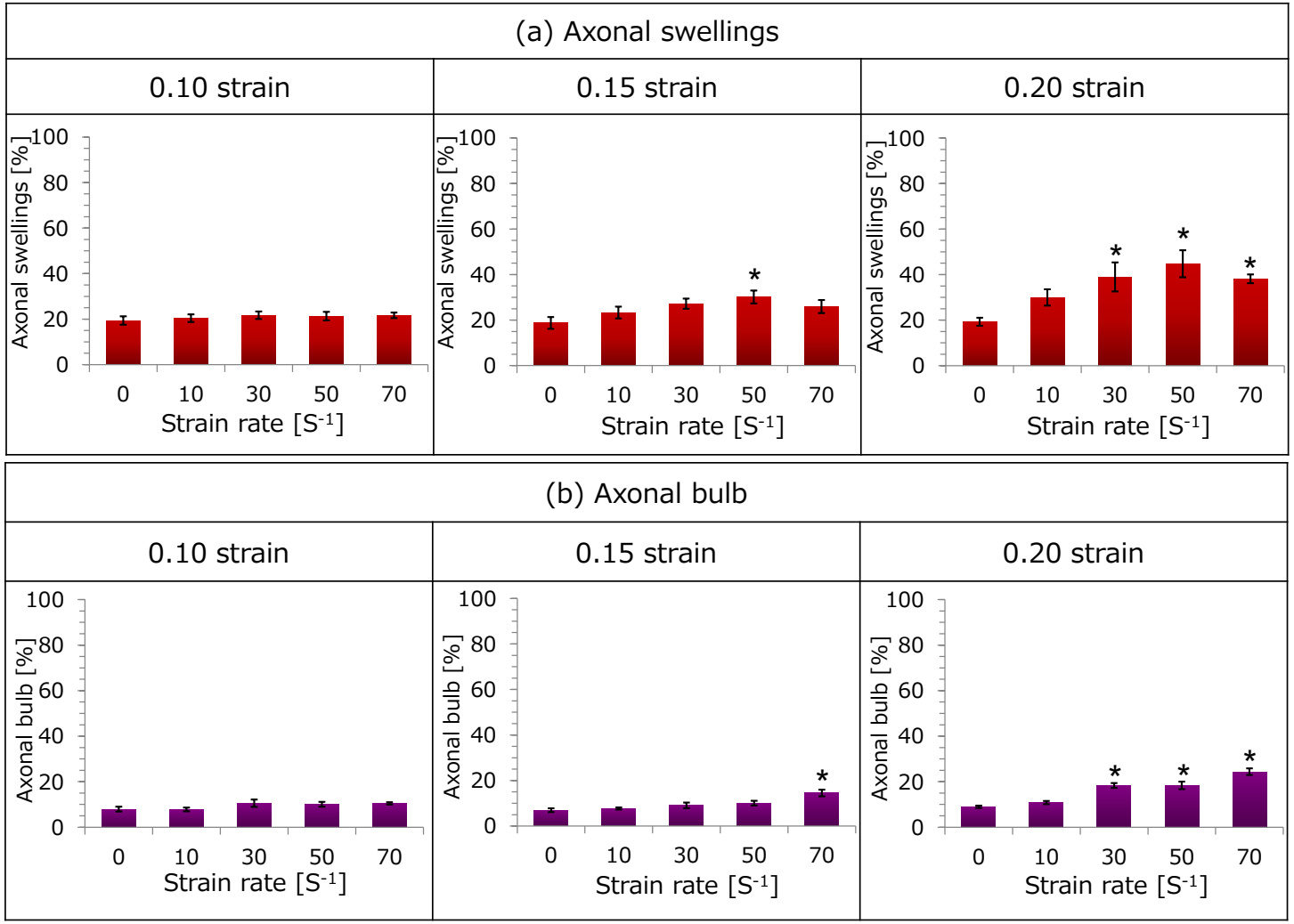
- **The axonal injury was observed at more than 0.18 of the strain.**
- **The increase in strain may be affected by the strain rate.**

Literature

- 0.15 strain: 50% risk of DAI by using a finite element head model (Sahoo et al., 2016)
- 0.18 strain : Electrophsiological impairment of the *in vivo* optic nerve of guinea pig (Bain and Meaney, 2000)
- 0.20 strain : Cell death of the *in vivo* hippocampus of the rat brain slice culture (Morrison et al., 2003)

Test Results: (2nd step) Percentage of Injuries

The percentages of injuries under the various strain-rates in a fixed strain condition were investigated.



*: $p < 0.05$
vs. no stretching

Summary

- Under a strain of 0.15, the percentage of axonal injury at a strain rate of over 50 s^{-1} was significantly higher than that at a strain rate of 0 (no stretching).
- Under a strain of 0.20, the percentage of axonal injury at a strain rate of over 30 s^{-1} was significantly higher than that at a strain rate of 0.

- For the assessment of traumatic brain injuries, the injury tolerance of axonal injury should be determined based on a combination of the strain and strain rate.

(STAPP Car Crash Journal 2017.)

Extension and Application for Brain Injury Assessment

- EqOP IWG/Task force 5: Extension to new injury types
- TF 5 will discuss how to evaluate brain injuries.
- Fundamentally, “strain” is the basic factor affecting to brain injury. Many brain injury metrics such as DAMAGE are established based on brain strain.
- “Strain” and “strain rate” affect to brain injury.
- When using a human head model, “strain” and “strain rate” need to be incorporated into the brain injury assessment.