Promoting the effect of fibrinolytics with Ho: YAG laser-induced liquid jet.

Takayuki Hirano, Makoto Komatsu, Hiroshi Ueno, Akira Takahashi, Kazuyoshi Takayama, and Takashi Yoshimoto.

Department of Neurosurgery, Tohoku University Graduate School of Medicine, Sendai 980-8574, JAPAN (T.H., T.Y.), Shock Wave Research Center, Institute of Fluid Science, Tohoku University, Sendai 980-8577, JAPAN (M.K., K.T.), Department of Neurosurgery, National Sendai Hospital, Sendai 983-8520, JAPAN (H.U.), Department of Neuroendovascular Therapy, Tohoku University Graduate School of Medicine, Sendai 980-8574, JAPAN (A.T.)

Key words: Brain attack, Cerebral embolism, Drug delivery, Holmium: YAG laser, Liquid jet, Shock wave

1. Background and Objective
There are several problems inherent in the treatment of cerebral embolisms, such as the narrow therapeutic time window and the severe side effects of fibrinolytic drugs. It is thus necessary to develop a new method of removing a cerebral thrombus more rapidly using smaller amounts of fibrinolytics.

2. Materials and Methods
Behaviour of Ho: YAG laser-induced bubble in a capillary tube filled with pure water was observed at various stand-off distances (L: distance between the optical fiber end and the capillary exit). After that, the liquid-jet generator was made by insertion of an optical fiber (diameter: 0.6 mm) into a catheter (6 Fr) filled with pure water. A pulsed holmium YAG laser (pulse duration time = 350 μs) was used as a laser source. The maximum penetration depth of a liquid jet generated with this device into a gelatin artificial thrombus was measured at various stand-off distances (L: distance between the optical fiber end and the catheter exit). Moreover, the phenomenon and the pressure around the catheter were observed with a shadowgraph and PVDF needle hydrophon, respectively.

3. Results
A laser-induced bubble in a capillary tube rapidly grew forward and generated a liquid jet (Figure 1). Maximum penetration depth with the liquid-jet generating catheter increased in proportion to L and reached a maximum value (9 mm) when L was around 13 mm (Figure 2). A shock wave whose overpressure at a point 4 mm away from the catheter exit was over 12 MPa was captured with shadowgraph (Figure 3).

Figure 1. Sequential records of the Ho: YAG-laser-induced bubble in a capillary tube whose diameter was 1.0 mm; the stand-off distance was 14 mm. The interframe time and the exposure time were 64 μs and 32 μs, respectively.

4. Conclusions
Ho: YAG laser irradiation within a capillary tube filled with water causes liquid jet formation. This device will be applied to an endovascular system for cerebral fibrinolysis in the near future.