学位論文の要旨

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論文内容の要旨

INTRODUCTION

Decompressive craniectomy is undertaken to avoid brain herniation caused by acute brain swelling. Brain stiffness can be estimated by palpating the decompressive cranial defect and can provide some relatively subjective information to the neurosurgeon. The goal of the present study was to objectively evaluate transcutaneous brain stiffness of the cranial defect using a tactile resonance sensor and to describe the values in patients with a decompressive window in order to characterize the clinical association between brain edema and stiffness.

MATERIALS AND METHODS

Data were prospectively collected from 13 of 37 patients who underwent a decompressive craniectomy in our hospital from April 2006 to March 2011. Brain stiffness was measured once a day at the time of dressing change and on the day of follow-up computed tomography (CT) scan. For measurement of stiffness, a tactile resonance sensor (Venustron II®, ver. 2.5, Axiom Co. Ltd, Fukushima, Japan) was utilized for brain stiffness. Measurements were expressed in terms of three variables: depth (Dp; in mm), pressure (Pr; in gf), and change in frequency (dF; in Hz). The Pr and dF values obtained at each depth were averaged individually. In order to generalize the pressure for a depth, the shear elastic modulus (G) was calculated according to the Lee and Radok correspondence principle, expressed by the equation: $G = 3P_r / 16h(Rh)^{1/2}$ (R; indenter radius = 2.5 mm, h; indenter height = Dp). Assessment of stiffness was conducted through measurement of the change in frequency (dF) and shear elastic modulus (G) calculated from the Pr-value, which reflects the elasticity of the brain. Stiffness variables (dF_maxDp and

G_maxDp) were determined at the maximum depth.

To evaluate brain edema, we measured cerebrospinal fluid (CSF) pressure and head CT parameters. Cisternal pressure (CP) was used as an alternative indicator of CSF pressure and was measured using the cisternal drainage with a 4 Fr-sized tube. Eleven data sets from eight patients were available for correlation analysis between stiffness and CP. CT parameters employed were brain shift, width of cranial defect, scalp protrusion, dura protrusion, and swelling distance. Brain shift (CT_shift) was measured on a CT slice through the third ventricle. The width of cranial defect (CT_width) was measured as the maximum width of the cranial defect of decompressive craniectomy on a CT slice. Scalp protrusion (CT_scalp) was defined as the vertical maximum distance between the scalp surface and the inner bone table line of the skull defect. Dura protrusion (CT_dura) was defined as the same distance up to the dural surface. The swelling distance was defined as the vertical maximum distance from the most elevated skin surface of a decompressive craniectomy site to the contralateral inner skull bone table.

All statistical studies were performed using commercially available statistical software(Dr. SPSS® for Windows version 11.01J SPSS, Inc. Chicago, Il, USA and JMP®9, SAS Institute, Inc. Cary, NC, USA). Differences at $P < 0.05$ were considered to be statistically significant.

RESULTS AND DISCUSSION

Thirty-five sets of data were collected from the 13 patients. Values related to Pr_maxDp were mean ± SD = 96.14 ± 52.41, median = 76.08, and 95% CI = 78.14–114.15. Values related to dF_maxDp were mean ± SD = 101.71 ± 36.42, median = 98.67, and 95% CI = 89.20−114.22. Values related to G_maxDp were mean ± SD = 1.99 ± 1.11, median = 1.71, and 95% CI = 1.60−2.37.

The correlation between stiffness variables and CP was r = −0.30 (P = 0.374) for dF_maxDp and r = 0.81 (P = 0.002) for G_maxDp (n = 11, Pearson's correlation coefficient). G_maxDp significantly correlated with CP. Next, the correlation between stiffness variables and CT parameters were analyzed by Pearson's correlation coefficient testing. Thus, G_maxDp significantly correlated with both CT_shift and CT_dura. The G_maxDp tended to be associated with CP and CT_shift.

The time course of G_maxDp was determined among 13 participants and revealed two discrete groups: 1) those with G_maxDp consistently <3.0 and 2) those with G_maxDp >3.0 on at least one measurement. G_maxDp > 3.0 was noted during the acute phase and these patients required intensive medical care for brain edema. By contrast, brain edema associated with G_maxDp < 3.0 was mild. These results suggest that the G-value correlated with the clinical severity of brain swelling. The stiffness measured using a tactile resonance sensor may thus provide a quantitative assessment of brain edema.

CONCLUSION

The elasticity of stiffness of a decompressive site correlated with brain edema, cisternal cerebrospinal fluid pressure, and brain shift, all of which are related to acute brain edema. Measurement of transcutaneus brain stiffness with our tactile resonance sensor can provide valuable information to help the patients from brain herniation. We believe that this sensor is a simple and useful tool for assessing acute brain swelling in patients with decompressive cranial defects.