Computed Tomographic Reconstruction and Bio-dynamics of Human Brain

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ABSTRACT

X-ray computed tomography (CT) reconstruction has become increasingly important for brain neurosurgery. The U.S. NIH (National Institute of Health) Image is very useful for visual analysis of medical images by CT and magnetic resonance imaging (MRI), however it does not provide the bio-dynamical aspect of clinical recovery. This study presents (1) CT reconstruction of human brain using biometrics by image processing and spline interpolation algorithm; and (2) bio-dynamics of human brain in clinical recovery utilizing auto regressive (AR) modeling. A CT image of the deformed brain in a case of chronic subdural hematoma was selected for this study. After surgical removal of the hematoma, the form of the cerabral ventricle was recovered larger symmetrically and also power contribution from the hematoma, was diminished. The result suggests a clinical evaluation of the post operative morphological and bio-dynamic recovery of the deformed brain.

1. INTRODUCTION

In the field of brain neurosurgery, the medical imaging has become an important tool for morphologic evaluation during clinical recovery of the deformed brain. Three months after receiving a head trauma from falling down steps, a female patient suffered a large, chronic subdural hematoma (SCDH),

In X-ray CT images taken before surgical removal of the SCDH (Fig. 1), the deformation of the cerebral ventricle (CV), which supplies nutrition to the brain and controls maintenance of the brain dynamic balance, is apparent. One-half year after the operation, the SCDH became smaller and CV recovered larger symmetrically (Fig. 2). For rapid medical diagnosis, such X-ray CT images are extremely useful.

This study demonstrates that additional utility can be achieved by using a 3-D CT reconstruction generated on a personal computer (PC). The comparison of SCDH and CV volumes before/after operation were visualized using biometrics by image processing of each CT image and 3-D computer graphics (CG) by the algorithms of photogrammetric projection and spline data interpolation.

CT brain image of CSDH patient

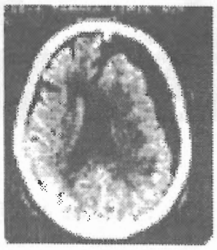

Fig. 1 CT brain image of CSDH patient
Before operation

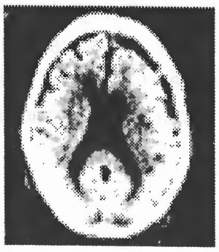

Fig. 2 CT brain image of CSDH patient
After operation

Using a new approach involving auto regressive (AR) modeling for bio-dynamical analysis of the medical image, it was determined that the relative noise power contribution of SCDH to CV was diminished after the operation.

This computer-assisted approach provides not only a clinical morphologic evaluation but also bio-dynamic evaluation in medical image analysis.

2. METHODS

2.1 Biometrics for X-ray CT Reconstruction

The structure of the CT scan 8 mm sliced on anthropological base line of the patient's brain us displayed (Fig. 3)

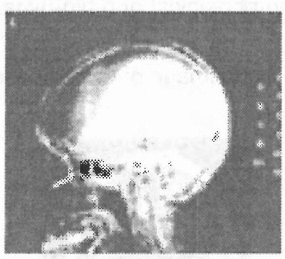

Fig. 3 The structure of CT brain

The 3-D coordinates system of the brain structure is very important to find the spatial location of a problem part in the brain. The CT scanning is generally done in planes parallel to a line connecting the medical definite line (Sugiura, 1989). For a space biometrics of 3-D CT reconstruction, a sliced CT image has 2-D coordinates of X and Y, the anthropological base line of the brain has the Z coordinates.

2.2 Biometrics for CT Image Processing

The each sliced brain CT image has same fiducial points, which were taken pictures by X-ray CT. They were edges of two plates right and left near the brain. The each brain image were trimmed as a same size, i.e. same pixel width and height. And also four fiducial points of each CT image were same location.. The principal view point of the image trimming, 3 common fiducial points are included in each image. This is a success key point to make a 3-D CT reconstruction of the brain.

CT image processing order was as followings:
Gray level histogram transformation, edge detection and trace, RGB color transformation, paint objects, return gray color, thresholding.

The X,Y coordinates of CSDH and CV outline were measured automatically using NIH Image soft wear.

2.3 Photogrammetic projection for 3-D CG

The principal method of 3-D CG was used by the photogrammetric projection method (Murai, 1989). The principal equation is defined as followings:

$P(X,Y,Z)$: object location, $E(X_0, Y_0, Z_0)$: view point location
$P'(X',Y',Z')$: projected location, f: distance from E to projected plane

$$Z=f$$
$$X=X'/Y'f \qquad (2.3.1)$$
$$Y=Z'/Y'f$$

$$x=-f\frac{a_{11}(X-X_0)+a_{12}(Y-Y_0)+a_{13}(Z-Z_0)}{a_{31}(X-X_0)+a_{32}(Y-Y_0)+a_{33}(Z-Z_0)}$$
$$y=-f\frac{a_{21}(X-X_0)+a_{22}(Y-Y_0)+a_{23}(Z-Z_0)}{a_{31}(X-X_0)+a_{32}(Y-Y_0)+a_{33}(Z-Z_0)} \qquad (2.3.2)$$

2.3 Bio-dynamics

The morhological information of the brain by CT and MRI mages became very understandable, but it does not let be certain bio-dynamics aspect of the brain. The role of CV is important, its improvement helps the brain. It is certain that CSDH gives dynamical impulse to CV by the result of morphological analysis. This study presents a new approach, using AR modeling, the relative power contribution of CSDH to CV were analyzed.

2.4.1 Relative Power Contribution

The basic equation of Akaike's AR modeling (Akaike, 1988) is defined as following :

$$X_i(s) = \sum_{j=1}^{K}\sum_{m=1}^{M} a_{ij}(m)X_j(s-m) + U_j(s) \quad (2.4.1.1)$$

X_i, X_j: variable, s: *time*, m: time lag
$a_{ij}(m)$:coefficient, $U_j(s)$: white noise

Relative power contribution (RPC) is given by:

$$r_{ij} = \frac{q_{ij}(f)}{P_{ij}(f)} \quad (2.4.1.2)$$

$$P_{ij}(f) = \sum_{i=1}^{k} q_{ij}(f)$$

$$q_{ij}(f) = \left|A^{-1}(f)_{ij}\right|^2 s_{ij}^{2}$$

$$A(f)_{ij} = 1 - \sum_{m=1}^{M} a_{ij}(m)\exp(-i2\pi fm)$$

where,
$P(f)$: power spectrum density function
$exp(-\iota 2\pi fm)$: Fourier transform

In this study, CSDH and CV is selected as two valuables, for analysis of bio-dynamic relationship of CSDH and CV. The measured X,Y-coordinates of CSDH and CV outline are time series data in the brain.

3. RESULTS and DISCUSSION

3.1 3-D CT Reconstruction

The original CT brain images were taken in 12 slices before and after operation. The numerical sequence of CT brain images begins near the top of the brain based on anthropological line. The CSDH appeared in image slices to 9 and the CV appeared in images slices 6 to 9, before and after operation. These figures explain enough the present study aim.

After image processing, the 2-D shape of CSDH and CV within the brain before and after the operation is shown in Figs. 4 and 5, respectively. After the operation, the 2-D form of CSDH diminished exactly and the form of CV improved larger symmetrically, similar to the letter H.

CT brain image after image processing

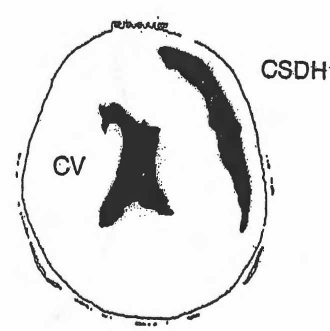

Fig. 4 Before operation

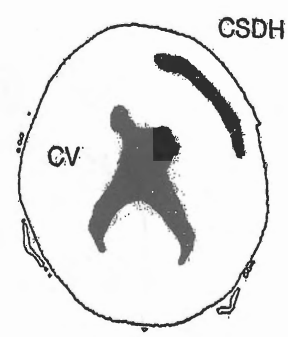

Fig. 5 After operation

3.2 3-D CT Reconstruction

The X,Y coordinates of 15 points of edges around CSDH and CV from 3rd to 9th sliced image were measured. The 3-D CT reconstruction of CSDH and CV were layered, each having the same 8 mm height from the 9th to the 3rd image slice.

in the 3-D reconstruction of CSDH and CV before the operation (Fig.6); After the operation, the 3-D form of CSDH diminished exactly and that of CV became larger, i.e. the marked improvement is evident (Fig. 7) .

3-D CT Reconstruction of deformed brain
CSDH vs CV

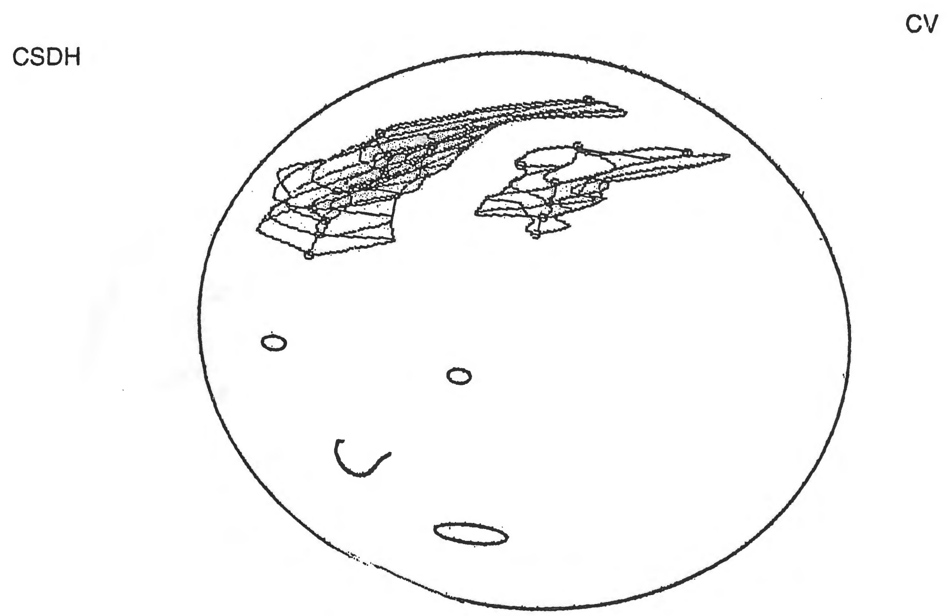

Fig. 6 3-D reconstruction of deformed brain
Before operation

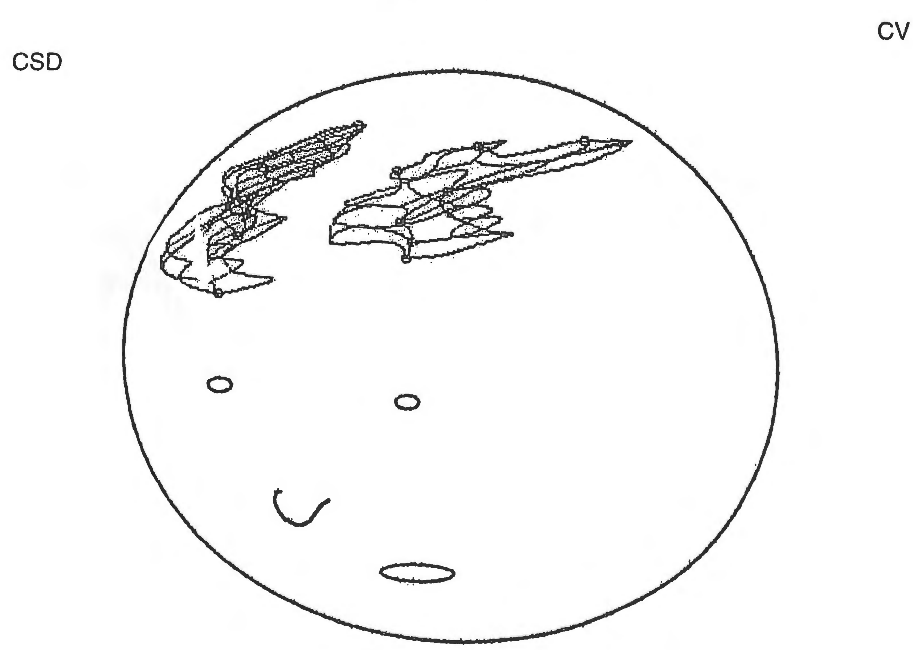

Fig. 7 3-D reconstruction of deformed brain
After operation

3.3 Bio-Dynamics

The application of multivariate AR modeling for human body mechanisms are efficient for its understandable appearance of the result (Wada, 1988, Tsuruoka, 1997). In this study for analysis of medical image brought also understandable result.

Before the operation, the RPC of CSDH to CV in X-coordinate direction (Fig. 8) and Y-coordinates direction (Fig. 9) were showed more larger than that of X-coordinates direction (Fig. 10) and Y-coordinates direction (Fig. 11) were showed.

RPC of CSDH to CV

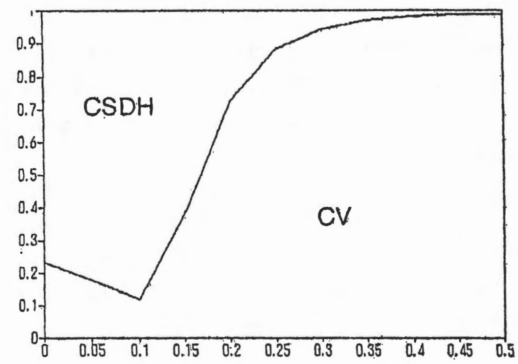

Fig. 8 X coordinate direction
Before operation

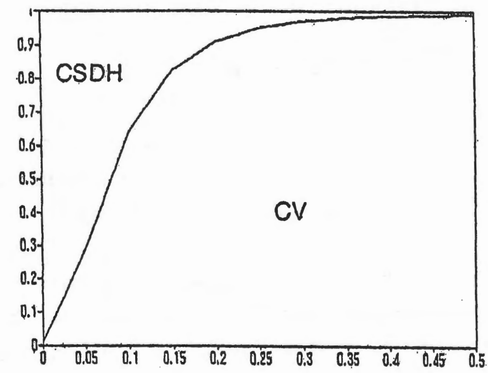

Fig. 10 X coordinate direction
After operation

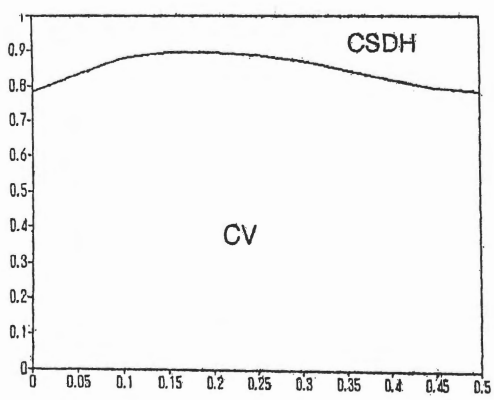

Fig. 9 Y coordinate direction
Before operation

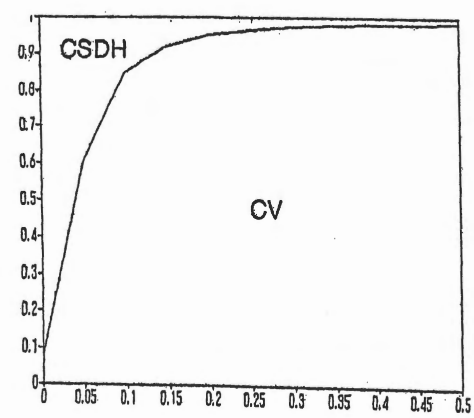

Fig. 11 Y coordinate direction
After operation

CONCLUSION

This present results show that 3-D reconstruction and bio-dynamics of human brain based on PC provide understandable and useful information for medical evaluation. Small number of X-ray CT sliced images gave us efficient result. In further our study, more applications by same method will be done for the 3-D reconstruction and bio-dynamics of human body..

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