Tracking of Hyoid Bone in Post-stroke Dysphagia using Deep Learning

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Purpose

Analysis of the hyoid bone movement is critical in evaluating the swallowing function. The patients with post-stroke dysphagia (PSD) frequently show inadequate movement of the hyoid bone. However, it is often difficult to identify and pursuit it in fast-moving videofluoroscopic swallow study (VFSS) images by human eyes and accurate measurement of hyoid bone movement is not well established in current clinical setting. In a previous study, we proposed a deep learning model that can track the hyoid bone in VFSS video accurately and efficiently. This study aims to investigate the movement of the hyoid bone in the patients with post-stroke dysphagia (PSD) using the deep learning model.

Methods

● Subjects

1. Inclusion criteria
- Stroke patients within 6 weeks after onset
- Patients who showed dysphagia symptom and evaluated by VFSS

2. Exclusion criteria
- Patients with history of other neurologic disorders affecting swallowing function
- Patients who have significant cognitive dysfunction

● Grouping

1. Non aspiration group (noASP) : subjects with PAS score 1-3
2. Aspiration group (ASP) : subjects with PAS score 7 or 8

Table 1. Characteristics of subjects

		ASP (n=22)	noASP (n=27)	*p*-value
Age, yr		70.95±11.95	67.22±13.29	.311
Gender (M:F)		17:5	15:12	.112
Cause	**Ischemic**	6	12	.215
	Hemorrhagic	16	15	

p-values by Chi square test for gender, cause, hemisde, Mann whitney U test for age
Abbreviation: *noASP* non aspiration group *ASP* aspiration group

● Process of Hyoid bone tracking

1. **Segmentation of objects (hyoid bone, cervical spinal column, coin) by BiFPN-U-Net(T) network** from frame images of VFSS video. (Fig. 1)

2. **Measurement of relative distance** in three directions between center of cervical spinal column and hyoid bone (Fig. 2)

3. **Distance normalization** relative to coin with 24mm diameter

4. **Measurement of maximum distance** (Fig. 2, Fig.3.)

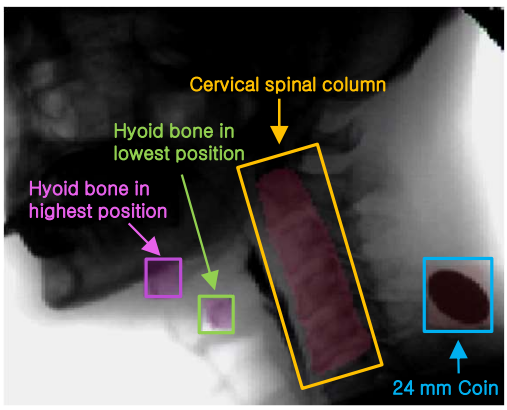

Fig. 1. The salient objects are segmented by BiFPN-U-Net(T) network model in the VFSS video images. For understanding, hyoid bones at different position are displayed on a single frame image.

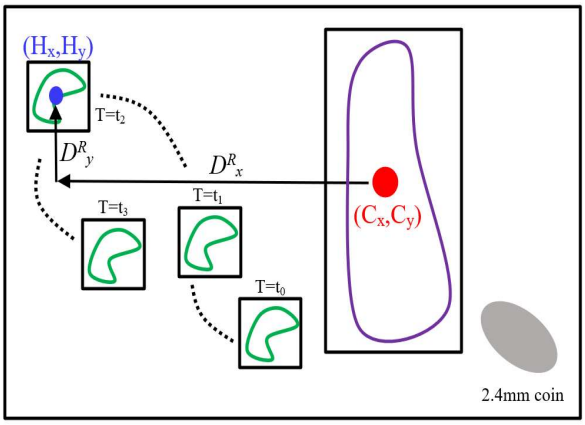

Fig. 2. Relative distance of hyoid bone measured by BiFPN-U-Net(T) network. Green objects indicate hyoid bone over time and purple object indicates C2-C5 spine. (Cx, Cy) is coordinate of C-spine center (red dot) and (Hx, Hy) is coordinate of hyoid bone (blue dot).
D^R_x ,D^R_y = Relative distance from C_x, C_y to H_x, H_y

Results

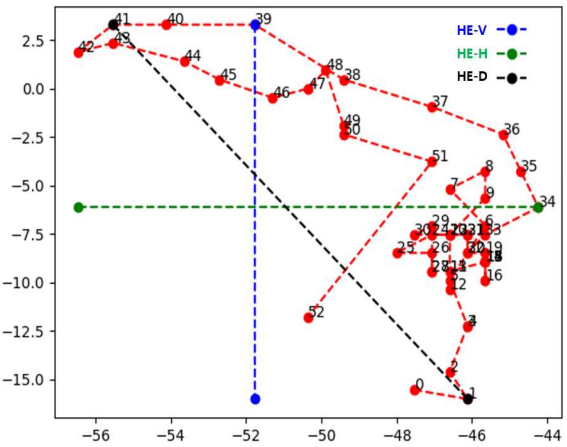

Fig. 3. An example of trajectory of the hyoid bone movement in a single patient. The red dots indicate position of the hyoid bone every 1 frame in 30 frame per second. The numbers next to red dots mean frame numbers. Maximum distances in 3 directions are calculated automatically by the deep learning model. Green dotted line shows maximum horizontal distance of the hyoid bone movement **(HE-H),** blue dotted line shows vertical distance **(HE-V),** and black dotted line shows diagonal distance **(HE-D)**.

Table 2. Maximum distance of hyoid bone movement in VFSS

Parameters	ASP (N=22)	noASP (N=27)	p-value†
HE-V	1.63 ± 0.73	2.11 ± 0.98	**.024**
HE-H	1.08 ± 0.32	1.60 ± 0.85	**.005**
HE-D	1.81 ± 0.74	2.27 ± 0.92	**.028**

Values are mean ± standard deviation in centimeter.
†*p*-value by Mann Whitney U test

Conclusion

The results demonstrated that the movement of the hyoid bone can be impaired in the PSD patients with evident aspiration. This study also suggests that the deep learning model could be useful in evaluation of PSD by tracking the hyoid bone and measuring the distance of its movement accurately and automatically in VFSS video images.

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