Extent of Hyoid Movement and Epiglottis Inversion as Correlates of Dysphagia Severity in Post-Treatment Head and Neck Cancer Patients

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INTRODUCTION

Swallowing is the coordinated effort of several structures, including the hyoid and larynx, to move the bolus (i.e., the food or drink being swallowed) from the mouth, through the throat, and to the stomach. The hyoid is involved in moving the larynx up and forward, while the epiglottis inverts to protect the airway.

Dysphagia is a delay or disruption in the timing or control of swallowing and can lead to part of the bolus entering the larynx (penetration) or even entering the lungs (aspiration).

Head and neck cancer patients often experience some degree of dysphagia following chemoradiation therapy and/or surgery. This can have a significant impact on the patient's mortality and quality of life.

PURPOSE

While hyoid excursion and epiglottis inversion seem to be important to normal swallowing function, previous studies did not find a significant correlation between these two kinematic events and dysphagia (Kraaijenga et al. 2017). With computer tracking methods applied to videofluoroscopic swallowing studies (VFSS), a more detailed investigation is possible. This may reveal whether decreased mobility of the structures in question indeed relates to increased dysphagia severity.

The presence of a negative correlation between hyoid/epiglottis kinematics and dysphagia severity could suggest they are important factors for successful swallowing. Such an understanding would help guide treatment decisions and improve post-treatment outcomes.

METHOD

Participants. Records of adult head and neck cancer (HNC) patients at the Institute for Reconstructive Sciences in Medicine (iRSM) were considered in this retrospective cross-sectional analysis. Ethics approval was obtained to search the patient records, beginning with the most recent. Those meeting inclusion criteria were stratified into three groups based on their treatment types. This yielded three groups of patients who began treatment between June 2011 and March 2016. Notably, the hyoid and epiglottis were not both trackable in all videos.

	Male	Female	Total
Surgery Only (SO)	12	7	19
Radiation Only (RO)	8	2	10
Surgery + Radiation (SR)	16	11	27
Total	**36**	**20**	**56**

Table 1. Participants by Gender and Treatment Group

	Hyoid Included	Epiglottis Included
SO Group	18	18
RO Group	10	9
SR Group	27	23
Total	**55**	**50**

Table 2. Videos Included for Analysis by Treatment Group
N.B. two videos from the epiglottis group were later excluded during analysis due to inconsistencies in the tracking data.

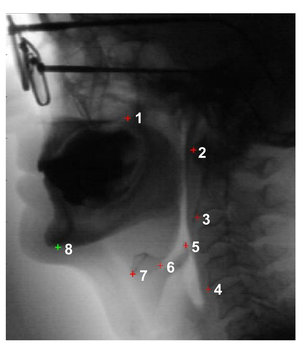
Procedure. Researchers identified the first thin liquid swallow in which the complete behaviour (from rest, through swallowing, and back to rest) was observable and all target points were consistently in view. These videos were annotated using a software tool (Natarajan et al., 2017) that facilitated tracking of each anatomical point frame-by-frame over time, allowing for subsequent kinematic analysis. The hyoid bone and epiglottis were annotated as primary points of interest. The mandible, hard palate, valleculae, C1, C2, and C4 were annotated to serve as points for geometric reference and anatomical normalization.

Inclusion Criteria:

- Patients with tumours in the base of tongue and/or oropharynx
- Patients who received surgery and/or radiation therapy
- VFSS available at 9-18 months after treatment onset, as these were expected to be relatively stable and beyond the influence of spontaneous recovery
- VFSS included all anatomical points of interest from beginning to end and was of adequate quality for annotation
- Dysphagia severity rating on the Penetration-Aspiration Scale (PAS) available for the VFSS in question (Rosenbek et al., 1996)

Exclusion Criteria:

- VFSS unavailable or of insufficient quality for annotation
- Patients who underwent other surgical or radiological treatments to the head and neck area, either previously or concurrently
- Patients for whom the hyoid bone or epiglottis were resected

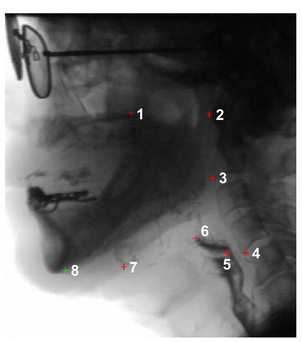


Pre Swallow

Image 1. VFSS before swallow

Points Annotated:

1. Maxilla
2. C1
3. C2
4. C4
5. Epiglottis
6. Valleculae
7. Hyoid Bone
8. Mandible



Mid Swallow

Image 2. VFSS at midpoint of swallow

RESULTS

Analysis. Variables examined were maximal hyoid advancement and epiglottis inversion, and dysphagia severity as represented by Penetration-Aspiration Scale (PAS) scores (Rosenbek et al., 1996). Hyoid motion was interpreted in relation to each patient's C2-C4 distance for anatomical normalization. Epiglottis inversion was measured in terms of degrees of rotation using the valleculae and epiglottis tip to describe the rotating plane (Paik et al. 2008).

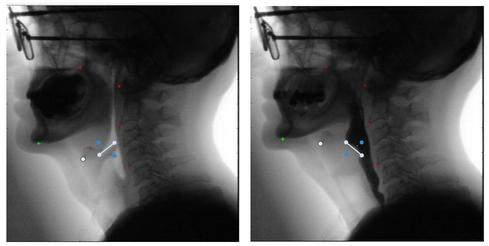


Image 3. Hyoid displacement and rotational definition of epiglottis inversion

Two correlational analyses were performed on the data using Spearman's *rho*. Hyoid advancement × PAS and epiglottis inversion × PAS were investigated. In the total sample group, hyoid advancement × PAS did not show a significant correlation (*N*=55, *rho*=-.15, p=.15). Similarly, epiglottis inversion × PAS did not show a significant correlation (*N*=48, *rho*=-.23, p=.11).

Within individual treatment groups, hyoid advancement × PAS showed a negative correlation for the surgery + radiation (SR) group (*N*=27, *rho*=-.39, p=.04), a positive correlation for the radiation only (RO) group (*N*=10, *rho*=.85, p=.002), and no correlation for the surgery only (SO) group (*N*=18, *rho*=0, p=1).

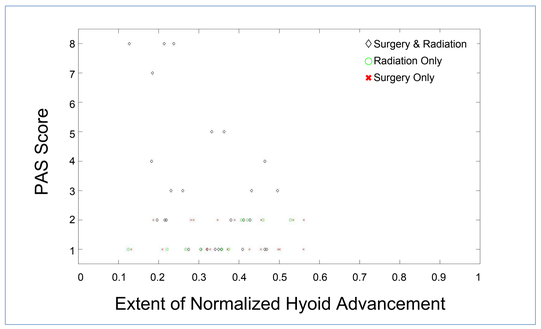


Figure 1. Scatterplot of hyoid advancement × PAS

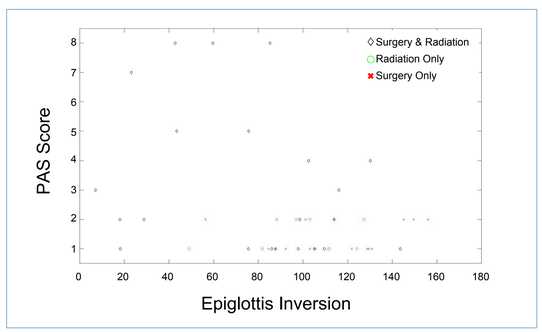


Figure 2. Scatterplot of epiglottis inversion × PAS

DISCUSSION

Conclusions. The current results do not show a clear correlation between dysphagia severity and hyoid advancement or epiglottis inversion. The SR group (hyoid × PAS) showed a significant negative correlation between hyoid advancement and dysphagia severity. However, the sample does not possess adequate power to support a -.39 correlation. The RO group (hyoid × PAS) showed a significant positive correlation, but had very low statistical power and a narrow range of PAS scores, making it particularly subject to interference from other variables. Thus these results do not constitute strong evidence.

Limitations.

Tracking: Soft tissues, such as epiglottis and valleculae, are difficult to track in VFSS.

Operationalizing epiglottis inversion: The spatial relationship between valleculae and epiglottis may change throughout the swallow as tissues stretch or relax, introducing error.

Operationalizing airway closure: Angular rotation of the epiglottis is an imperfect estimate of the degree of airway closure, as it does not confirm contact with the arytenoids.

Thin liquid swallows: Thin liquid swallows alone do not characterize patients' full degree of function.

Diagnostic heterogeneity: Variables beyond treatment group, such as site and size of lesions, were not considered.

Duration variability: Repeated swallows within a single behaviour may result in misleading data, (e.g., a maximal displacement that is not representative of any single swallow).

PAS score (in)variability: 77% of PAS scores were ≤2. Only the SR group showed scores >2. Skewed scores could obscure a relationship between kinematics and dysphagia severity.

Future Directions. Computer tracking of VFSS kinematics can efficiently yield detailed data. Though still subject to human error, this method makes visualization and analysis of frame-by-frame motion for multiple points of interest feasible.

The small sample size and other limitations above preclude any current clinical implications of this study. More research is needed to evaluate other factors that may influence dysphagia severity. Size and location of tumour, type of bolus, and duration and efficiency of swallows are areas for future investigation.

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