Title:
An Improved Vallecula Volume Estimation for Dysphagia Study

Purpose:
Dysphagia, the inability to eat or swallow correctly, is a significant but overlooked problem that can result in aspiration pneumonia. To understand the neuro-muscular interactions involved in swallowing, many researchers have correlated EMG measurements in the throat with x-ray fluoroscopy images of pigs drinking barium (Ba) mixed milk. To date, the amount of retention aspiration volume (RAV) in the pig vallecula has been estimated using area measurements from 2D x-ray. The aim of this work is to develop a more accurate estimation of RAV by calibrating the change of image intensity values of the swallowing bolus area in the 2D x-ray with a phantom.

Materials and Methods:
A custom made acrylic calibration phantom had 8 cylindrical holes ranging from 2 to 25mm in depth (see figure for more details) and filled with Ba milk was imaged along with a pig cadaver using a flat panel x-ray C-arm (FD20, Philips Healthcare, Best, The Netherlands). The pig had a number of Ba milk filled pouches with known volumes (1, 2, and 3mL) placed in the vallecula. Calibration was performed as follows: (1) image intensity attenuation coefficient was calibrated by fitting a log-linear line between intensity values and the known phantom cylinder depths; (2) magnification was corrected to a metal ball of known diameter; (3) the swallowing bolus area and surrounding tissue were segmented by a region growing method and mathematical morphological dilation (ImageJ, NIH, Bethesda, MD); (4) RAV was calculated by the summation of the intensity reduction of the swallowing bolus area divided by the intensity attenuation coefficient.

Results:
The log-linear correlation between intensity values and the known phantom cylinder depths was very good ($R^2=0.97$). In the cadaver, calculated volumes of the Ba milk pouches were 0.929, 1.93, and 3.09mL for the 1, 2, and 3mL pouches (4.5% average error).
Conclusion:

The custom made phantom and calibration allow for a more accurate RAV volume estimation from 2D x-ray. We plan to apply this to a live animal study.

Clinical Relevance:

Dysphagia could result in pneumonia and ultimately death. Our method provides a more quantitative measure of RAV related to dysphagia.

Figure:

(a) Calibration phantom schematic. (b) Calibration phantom filled with barium milk (c) X-ray images with (c) 1, (d) 2, and (e) 3mL barium milk pouches. (f) Determination of intensity attenuation coefficient by linear regression line fitting for log intensity values vs. Ba milk phantom thicknesses. (g) Comparison of actual and estimated volumes of the three Ba milk pouches in the pig cadaver.