Running title: A Question of Rheological Control

Title: Letter to the Editor: A Question of Rheological Control

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Letter to the Editor: A Question of Rheological Control

In their recent article, entitled “The Impact of Rheologically Controlled Materials on the Identification of Airway Compromise on the Clinical and Videofluoroscopic Swallowing Examinations”, [1] Groher and colleagues argue that for an accurate radiographic assessment of swallowing function, it is desirable that test fluids and clinical fluids are as closely matched as possible, if not identical. Given that barium is a solid, this is a very difficult task to manage. Groher and colleagues compared the prevalence of cough and voice changes in clinical (bedside) swallowing examination to the prevalence of aspiration in videofluoroscopy (performed within 72 hours) using stimuli that were reported to be rheologically “identical” [1].

Rheology is the study of the deformation and flow of material. Readers of the Dysphagia journal will be familiar with the term viscosity (specifically the resistance of a fluid to flow under an applied stress)[2] based on several recent articles discussing this property. Viscosity is mathematically defined as the ratio of shear stress to shear rate [2, 3]. Liquids can be further classified as Newtonian liquids (for which the force required to make the fluid flow is directly proportional to the amount of flow) or non-Newtonian liquids (for which shear stress is not directly proportional to the amount of flow). However, it is important to recognize that viscosity is only one of several parameters that need to be measured to define the rheological characteristics (or profile) of a liquid. Two other parameters, namely yield stress and density, have been proposed as potentially relevant for swallowing [4-9]. A fluid that has a yield stress has an inherent structure that must be broken down to allow the fluid to flow. Yield stress is the stress which must be applied to a fluid, above which flow occurs and below which flow does not occur [3]. Density is the mass per unit volume inherent in the material, and most closely relates
to the weight of the fluid [3]. Non-newtonian fluids typically have a yield stress, whereas Newtonian fluids do not.

In order to substantiate their claims that the barium stimuli used in their experiment were ‘rheologically identical’ to the non-barium stimuli, Groher and colleagues need to provide further information. Specifically, each liquid stimulus used in the experiment should be described in terms of its apparent viscosity, its yield stress and its density. The addition of barium sulfate powder to a water-based liquid is extremely likely to influence both yield stress and density, even if the apparent viscosity remains relatively unchanged [4].

In the stimulus development phase of their research, Groher and colleagues used a sensory panel to classify 20 liquid stimuli into two categories (thin and thick) based on the perceived mouth-feel of small volumes of these liquids. While a determination of the anchor points of sensory perception of the flow characteristics of a liquid is certainly of interest, this cannot be accepted as a valid method of determining relative viscosity. It is curious to note that the 6 liquids ultimately selected to represent the low, mid and high-points of viscosity for the two classes of thin and thickened liquid used by Groher and colleagues do not map clearly to the corresponding proposed National Dysphagia Diet categories for liquid viscosity [10] (see Table 1). The authors reported that V1-V3 were deemed to represent ‘thin fluids’, while V4-V6 where deemed to represent ‘thick fluids’. These assumptions do not appear to reflect the consensus of the National Dysphagia Task Force.

<< insert Table 1 about here >>

Recent research published in the Dysphagia journal has illustrated the influence of standing time on liquid viscosity, as well as the potential for different thickening agents to produce varying viscosities with a range of time-dependent changes in viscosity [11, 12]. In the
Groher study, a starch-based thickener was used to prepare the three thin liquids, while a gum-based thickener was used to prepare the thick liquids. The authors do not provide a rationale for using two different types of thickening agent. In addition, although the influence of time appears to have been controlled with respect to the rheological measurements that were performed, it is not clear that this same control was present when the liquids were used in the clinical or radiographic swallowing assessments.

The assumption of equivalent density between the non-barium and barium stimuli in this study is particularly troublesome. The authors report that they added 20g of a 40% w/v Barium Sulfate powder (E-Z-EM) to 176.8 grams of water when preparing the barium stimuli. The particular barium product in question is assumed to have been the Varibar® powder for thin liquid barium suspension, which is sold in bottles containing 148g of powder, with the instructions to add 370 ml of water to achieve a 40% w/v contrast density. Based on the information provided by Groher and colleagues, 20g of this powder was added to 176.8 grams of water (approximately 175 ml). This could be expected to yield a liquid with approximately 11% w/v contrast density. Although the participating speech-language pathologists in this study are reported to have judged this opacity to be adequate for identifying aspiration in the videofluoroscopies, this subjective impression is suspect, given that an 11% w/v density falls well below the current industry standard of 40% w/v. Even if their barium stimuli were too pale to clearly support high resolution videofluoroscopic judgements regarding aspiration, they would still have been of higher density than the non-barium comparison stimuli.

Clearly if two fluids are of different densities, there will be different forces required to generate fluid movement. The density in the barium stimuli may provide the patient with sensory information otherwise not available to them in a standard clinical stimulus, and hence alter their
swallow response. A pure research design for the ability of the clinical exam to demonstrate airway compromise as validated against videofluoroscopy would surely use barium fluids in both the clinical and radiographic arms of the procedure. With the effects demonstrated using an identical test stimulus, one can then go about the business of determining which aspects of the radiopaque solution (density, viscosity or yield stress) require manipulation to conform to a reliable test material that will yield clinically valid information.

In short, Groher and colleagues fail to provide sufficient evidence of rheological similarity between the non-barium and barium stimuli used in this study. While they claim that only one previous study has sought to use comparable stimuli between clinical and instrumental swallowing examination, they fail to acknowledge a growing body of literature in which there is growing consensus that it is at least futile, if not impossible, to establish true rheological similarity between barium-based radio-opaque stimuli and non-barium stimuli.
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<tbody>
<tr>
<td></td>
<td>Non-Barium</td>
<td>Non-Barium</td>
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<tr>
<td>Temperature</td>
<td>25°C</td>
<td>25°C</td>
</tr>
<tr>
<td>Shear-rate</td>
<td>50 s⁻¹</td>
<td>50 s⁻¹</td>
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<tr>
<td>Viscosity</td>
<td></td>
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<td>(1 cP = 1 mP.a.s)</td>
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<tr>
<td>Thin</td>
<td>1 to 50 cP</td>
<td>V1</td>
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<td>Nectar-thick</td>
<td>51 to 350 cP</td>
<td>V2</td>
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<td>Honey-thick</td>
<td>351 to 1750 cP</td>
<td>V3</td>
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<tr>
<td>Spoon-thick</td>
<td>&gt; 1750 cP</td>
<td>V4</td>
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References