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LETTER TO THE EDITOR

Challenges in Preparing Contrast Media for Videofluoroscopy

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To the Editor,

We congratulate Popa Nita et al. [1] for their article exploring the challenges of matching the rheological (i.e., flow) properties of contrast agents used in videofluoroscopy to thickened liquids used in dysphagia management. This article clearly illustrates the complexities of this challenge; however, there are three additional points that we feel would be clinically relevant and important to bring to the attention of the readers of *Dysphagia*:

(1) The rheological characteristics of barium preparations need to be understood with respect to how they map to clinical categories of liquid consistency.
(2) The concentration of barium in commercially available suspensions affects both its visibility on the radiographic image and the degree to which the suspension leaves a coating on the pharyngeal mucosa.
(3) Mixing barium powder into already thickened liquids may result in further thickening of the liquid.

We provide a brief elaboration on each of these points below.

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Rheological Characteristics of Readily Available Barium Preparations

Barium products for gastrointestinal imaging come in the form of powders or ready-mixed liquid suspensions. The Varibar® line of products (EZ-EM Canada, Bracco Diagnostics Inc., www.varibar.com) is specially formulated for oropharyngeal imaging and is offered in thin, nectar, thin-honey, thick-honey, and pudding consistencies. Varibar® products may, however, not be universally available to clinicians who perform videofluoroscopy. Regulatory approval has not yet been granted for the clinical use of Varibar® in countries outside the United States. When access to products like Varibar, which are tailor-made for oropharyngeal examination, is not possible, it is not uncommon to find clinicians using other imaging products in videofluoroscopy; these products may be mixed in ways that differ from the manufacturer guidelines for intended use. For example, Fink and Ross [2] describe an "ultrathin" barium suspension that they mixed by diluting thin liquid Varibar in a 50:50 ratio with water in an attempt to create a stimulus that represents a true thin liquid more closely.

Polibar (Bracco Diagnostics Inc., Princeton, NJ) is a ready-mixed liquid suspension with a barium concentration of 100 % w/v (g/ml) that is quite commonly assumed to be a nectar-thick liquid when it flows out of the bottle. In an article by Cichero et al. [3], the viscosity of room-temperature Polibar was reported to be 390 mPa s at a shear rate of 50 s^{-1}, i.e., just above the lower boundary for honey-thick liquids specified in the National Dysphagia Diet (NDD) [4]. The focus of that article was to compare the viscosities of contrast media to those of infant formulas, and they were found to be markedly different.

Recent rheological testing in our lab has explored the viscosity of liquid E-Z-Paque (EZ-EM Canada, Bracco

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Diagnostics Inc.), a 60 % w/v barium suspension, and a diluted version of E-Z-Paque, mixed with water to achieve a 22 % w/v barium suspension. These tests were conducted in triplicate on a TA Instruments AR2000 Advanced Rheometer using cone–plate geometry (40-mm, 2° cone) and temperature maintained at 20 °C. A shear rate ramp from 0.1 to 1,000 s^{-1} was used, with 1-min equilibration periods at each end of the sweep. These tests showed the viscosity of undiluted E-Z-Paque to be approximately 133 mPa s at 50 s^{-1} (therefore in the nectar-thick range) [4]. When diluted to 22 % w/v concentration, the viscosity dropped to the thin range [4] at approximately 17 mPa s at 50 s^{-1}. Therefore, the degree to which a barium product is diluted prior to use will affect its viscosity.

Coating Properties of Liquid Barium Suspensions

Barium products come in low-density and high-density preparations. The term "density" in these labels refers to the concentration of barium in grams per milliliter of solution. High-concentration barium products are also called "double contrast" and are designed to leave a coating on the mucosa of the gastrointestinal tract. E-Z-HD (Bracco Diagnostics Inc., Princeton, NJ) is one example of a high-density preparation; it has a 250 % w/v concentration when mixed with water according to the manufacturer's label instructions. Dantas et al. [5] have shown that oral and pharyngeal transit times for a 250 % w/v solution are significantly longer than for a medium concentration product at 140 % w/v. However, the question of where the threshold of mucosal coating begins in terms of barium concentration is not clear. Figure 1 shows three images taken from a videofluoroscopy of the same healthy young female swallowing 5-ml volumes of barium liquids with different concentrations. In Fig. 1a, a 100 % w/v concentration of barium (liquid Polibar) leaves a clearly visible thin line of residual coating along both the pharyngeal and esophageal mucosa. In Fig. 1b, a 60 % w/v concentration product (liquid E-Z-Paque) leaves a less visible coating. In Fig. 1c, a 22 % w/v concentration, prepared by diluting liquid E-Z-Paque with water, leaves no visible coating. It is important for clinicians to be aware that postswallow residue seen with products of 60 % w/v concentration or greater may be partly attributable to the barium rather than a pathophysiological phenomenon.

Fig. 1 **a** Residual coating following a 5-cc swallow of 100 % w/v liquid barium suspension. **b** Residual coating following a 5-cc swallow of 60 % w/v liquid barium suspension. **c** Residual coating following a 5-cc swallow of 22 % w/v liquid barium suspension

Mixing Barium Powder into Already Thick Liquids

The Popa Nita article [1] explores the issue of mixing thickened contrast media for videofluoroscopy by adding thickening powders to liquid contrast media. This is one way of preparing thickened barium stimuli. However, another approach is to begin with thickened liquids (either commercially or kitchen prepared) and mix barium powders (such as E-Z-HD) into these already thickened liquids. This can be a pragmatic approach, using the very same thickened liquids that are provided to patients from a hospital kitchen

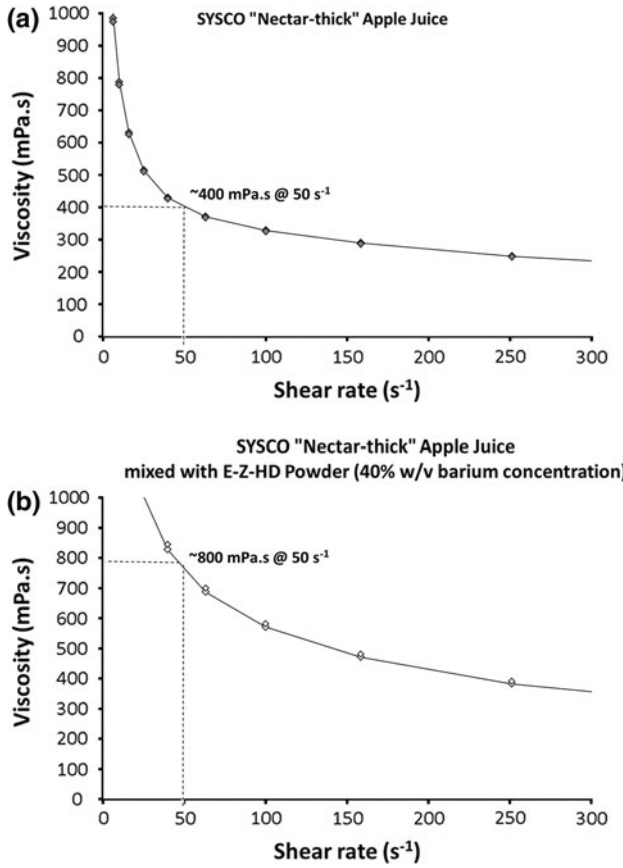

Fig. 2 **a** Rheogram showing the viscosity of a commercially available thickened apple juice (Sysco brand). **b** Rheogram showing the viscosity of a commercially available thickened apple juice (Sysco brand) mixed with E-Z-HD barium powder for a 40 % w/v barium concentration

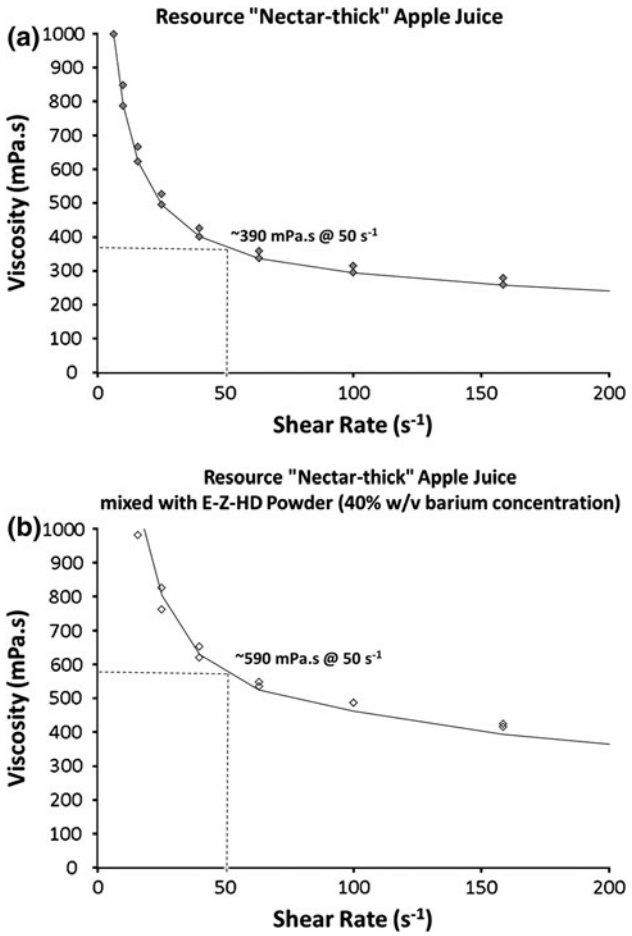

Fig. 3 **a** Rheogram showing the viscosity of a commercially available thickened apple juice (Nestlé Resource® Nectar-thick Apple Juice). **b** Rheogram showing the viscosity of a commercially available thickened apple juice (Nestlé Resource® Nectar-thick Apple Juice) mixed with E-Z-HD barium powder for a 40 % w/v barium concentration

and making a barium version of these liquids. However, it is a mistake to assume that the addition of barium to these liquids does not alter their viscosity. Figures 2 and 3 illustrate this scenario with two different commercially prethickened liquids for which rheological testing was conducted at a chilled temperature of 10 °C according to the same procedures described above. In Fig. 2a, the viscosity of a commercially prethickened apple juice (Sysco Imperial Thickened Juices, Lyons, Fresno, CA) is shown as approximately 400 mPa s at a shear rate of 50 s^{-1}, i.e., close to the NDD lower boundary for honey-thick liquids. However, in Fig. 2b, the same product was mixed with E-Z-HD powder (102 g of 98 % w/w powder per 250-ml cup of solution) in order to achieve a 40 % w/v barium concentration, similar to the concentration of the Varibar barium product line. Here it is shown that the viscosity of the resulting product is approximately 800 mPa s at 50 s^{-1}. Although this viscosity still technically falls within the NDD boundaries of honey-thick consistency, it is approximately twice as thick as the nonbarium product. Figure 3a and b illustrate the same phenomenon with Resource® nectar-thick apple juice (Nestlé Health Science, North York, ON, Canada), albeit not to the same degree. Discussion of this phenomenon with rheologists suggests that the starch molecules inside these commercially thickened liquids are probably forming complexes around the barium molecules, leading to further thickening. Other thickening agents, such as those that use xanthan gum, may not be as susceptible to this chemical reaction. Furthermore, in order to get good dispersion of barium throughout a thickened liquid, or of thickener throughout a barium suspension, magnetic stirring over a prolonged time frame (e.g., 30 min) may be needed.

Evidence of further thickening following the addition of barium to thickened liquids is troubling because it shows that the barium-thickened liquid can no longer be considered representative of the viscosity of the thickened liquid. Clinical decisions that are made based on the observation of swallowing with the barium-thickened liquid may be inaccurate in two ways: (1) the additional thickening of the

barium product may have therapeutic value for limiting penetration-aspiration and may mask a safety risk that exists with the nonbarium-thickened liquid, and (2) the thicker barium product may be more prone to leave residue after the swallow [6], masking adequate or nonimpaired bolus clearance with the nonbarium-thickened liquid. At this time, we are unaware of any recipes for barium preparation with thickened liquids that satisfactorily overcome these concerns. We recommend that clinicians choose a desired concentration for their barium stimuli and develop or follow recipes to achieve this concentration whenever they are mixing barium for use in videofluoroscopy. However, clinicians should be cognizant of the fact that their stimuli may not be truly representative of nonbarium liquids. Further research will be needed to develop and test recipes for off-label barium preparation.

In conclusion, we would like to echo the sentiments of the Popa Nita et al. [1] article in emphasizing that contrast media for videofluoroscopy need to be chosen and prepared with care. Preparing contrast media that match nontest products is not a simple or straightforward matter. Clinicians need to consider the limitations of this challenging situation when conducting and interpreting videofluoroscopies.

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