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TOPIC HIGHLIGHT

Thickened Liquids for Children and Adults with Oropharyngeal Dysphagia: the Complexity of Rheological Considerations

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ABSTRACT

Dysphagia clinicians use thickened liquids in the medical management of oropharyngeal dysphagia across the age span. Mixing instructions to create thickened liquids are deceptively simple, suggesting these products are as easy and reliable to make as a cup of tea. Research has shown, however, that thickened liquids are anything but a homogenous commodity. Although thickness or viscosity is often the focus of measurement, other material property characteristics of the internal structure of the liquid, such as density and yield stress, affect the way that thickened liquids move and behave. This paper discusses the structural or rheological properties of thickened liquids and thickening agents. It describes the effects of thickening agents on mouthfeel and flavor release, both of which contribute to compliance with a prescription for all liquids to be consumed in a thickened state. The most common levels of liquid thickness used in dysphagia management are described along with challenges to naming these levels of thickness. A common standardized terminology and definitions for thickened liquids is recommended for improved patient safety.

Key words: Rheology; Deglutition disorders; Viscosity; Oropharyngeal dysphagia

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INTRODUCTION

Difficulties with the oral and pharyngeal phases of swallowing influence the likelihood of food and liquids reaching the stomach, as intended, rather than the lungs; and the amount safely consumed. Dysphagia is defined here as difficulty or inability to swallow. It is listed by the World Health Organization in both the International Classification of Diseases (ICD-10) and the International Classification of Functioning Disability and Health. Dysphagia is more likely to affect individuals at either end of the life continuum. Twenty five to 55% of premature infants[1] and 60% of infants born with a developmental disability[2] are noted to present with dysphagia. At the other end of life, 10-30% of individuals older than 65years[3] and approximately 55% of the aged care population present with oropharyngeal dysphagia[4]. Internationally there is consistent evidence from Japan[5], Spain[6] and Germany[7] that 23-33% of individuals older than 80 years experience dysphagia either in the community or hospitals. Conditions such as stroke[8], dementia[9], Parkinson's Disease[10], brain injury[11] and Chronic Obstructive Pulmonary Disease[12] are also associated with dysphagia.

Whilst there are many promising rehabilitation treatment approaches being investigated[13], modifying the texture of food and the thickness of fluids remains a cornerstone of dysphagia management. Altering food particle size, food texture properties and liquid thickness is seen to facilitate safer swallowing for individuals with dysphagia, by reducing the speed and complexity of oral processing[14]. Given that nutrition and hydration are both compromised in individuals with dysphagia[15,16], research focusing on texture modified foods and liquids has been gathering momentum for more than a decade[17,18]. The term 'thickened fluids' might at first suggest a fairly homogenous product. However, thickened fluids are anything but a uniform commodity. This paper will focus on the scientific nature of thickened fluids, providing information on rheology and material property characteristics. In addition, it will

provide translational information on the clinical impact of thickened fluids for individuals with dysphagia.

THICKENED FLUIDS: RHEOLOGICAL AND MATERIAL PROPERTY CHARACTERISTICS

Rheology is a branch of physics that deals with the deformation and flow of matter. It provides valuable information about the underlying structure of foods and liquids. Rheology is typically the domain of chemical engineering. When it comes to objectively describing liquids we most often think of 'thickness' or 'viscosity'. The unit of measurement for viscosity in the International System of Units (SI) is pascal-seconds, although it is more commonly reported in the dysphagia literature as millipascal-seconds (mPa.s). Viscosity may also be reported in the unit Centipoise (cP), where 1cP=1 mPa. s. Viscosity is the resistance of a substance to flow under an applied force. Liquids like water do not have much resistance to flow and are, therefore, classified as 'low viscosity'. It takes little effort to stir water with a spoon. However, liquids like molasses or tomato sauce (ketchup) have very slow flow rates and consequently a 'high viscosity'. This time the effort to stir is much greater, due to the internal structure of the liquid.

Water is a substance we are all familiar with. We can describe it as a 'fast flowing, transparent, odourless, tasteless liquid'. At a microscopic level it is made up of hydrogen and oxygen molecules. Unseen to our eyes, these molecules move in layers over one another or against other surfaces, such as a glass containing the water.

From a rheological point of view, water at 20℃ has a viscosity of 1.0 mPa.s[19]. In contrast, honey has a viscosity of 10,000 mPa.s, and the tomato sauce mentioned earlier has a viscosity of 50,000 mPa.s. Although water and honey have very different thicknesses, they do share the characteristics of both being Newtonian fluids. Newtonian fluids can be described as fluids where the force required to make the fluid flow is directly proportional to the resulting amount of flow[11]. The internal structure of the molecules makes it easy for them to slide over one another. Not all liquids, however, are Newtonian in nature. The tomato sauce mentioned above, mayonnaise and thickened liquids used in dysphagia management are non-Newtonian fluids. For non-Newtonian fluids the viscosity varies with the force being applied to the fluid (or rate of strain). In practical terms, if one stirs thickened liquids slowly, they appear thick; however, the more vigorously one stirs thickened fluids, the thinner they become. In measurement then, we need to know how much strain is being applied to the fluid, or 'how vigorous the stirring is', to be able to anchor and describe the viscosity in a meaningful way. Non-Newtonian fluids can be further sub-categorized. Thickened liquids used in dysphagia management are 'shear thinning', meaning that the fluid's resistance to flow decreases with increasing rate of shear.

Note that the temperature of the liquid during testing should also be annotated, as viscosity changes as a function of temperature. Toothpaste provides a ready real world example we are familiar with. The toothpaste is far easier to extract from the tube during summer when the temperature is warmer than it is in winter when the temperature is cold. Similarly, cold thickened liquids are likely to be more viscous than their room temperature or hot counterparts.

To most accurately appreciate the viscosity of thickened liquids, it is critical that the shear rate being applied to the liquid is known. This is particularly important for understanding the viscosity of non-Newtonian liquids. As noted above, apply a vigorous or fast rate of strain, and the liquid becomes thinner; apply a slower rate of strain and the liquid maintains its thickness level. In the oral cavity as we savour a spoonful of chocolate pudding there is little lingual movement, however, a pudding that has a less pleasant flavor may be moved very quickly through the oral cavity and into the pharynx. Thus the tongue plays a critical role in changing the shear rate, or how vigorously the bolus moves in the mouth, and in ejection from the oral cavity into the pharynx. The pharyngeal constrictors also play a role in sweeping the tail of the bolus through the pharynx, applying a further shear rate. Dating back to the early 1990's shear rates were reported for swallowing in the range of 1-100/sec with an average value of 50/sec[17, 20]. By way of example 50/sec refers to a change in velocity from 0 to 50mm/sec over a distance of 1mm[21]. Although a Newtonian fluid such as water may have a viscosity of 1 mPa.s regardless of whether it is sheared at 50 sec-1 or 100/sec, those values are very different for non-Newtonian liquids. For example, thickened infant formula measured at its serving temperature of 37℃ and a very low shear rate of 1/sec has a viscosity of 1,350 mPa.s, but when measured at a faster shear rate of 50/sec it drops to 320 mPas and when rate of strain is increased to 100/sec, the viscosity value drops again to 240 mPa.s[22].

Stokes *et al*[23] challenge that although it may be possible to create thickened liquids that have a similar viscosity at 50sec-1 the viscosity above and below this shear rate is far more difficult to control due to properties such as elasticity. In fact, Popa Nita *et al*[21] clearly demonstrate this point showing that for shear rates at and above 50 sec-1 that there is little difference in the apparent viscosity of Varibar® Honey and Pudding liquids. Note also, that although for healthy people a shear rate of 50-100/sec has been put forward for industry standard testing, that the oral shear rates of individuals with dysphagia are unknown. With poor tongue strength and coordination a common feature of oral dysphagia, it would not be unreasonable to suggest that the oral shear rate for individuals with dysphagia would be far less than 50/sec.

Whilst the viscosity of a liquid provides us with useful information, it does not provide us with a complete understanding of the structure of the fluid. As an analogy, imagine that we know the weight of an individual. For argument's sake the adult person weighs 55 kg. However, we need much more information before we can determine whether this person's weight should be cause for concern. If the person were male, 55 kg and 190 cm in height, then we would have grave concerns for his physical health, compared to the same weight of a female of 159 cm height. A similar situation occurs with thickened fluids. To have just the viscosity information alone is insufficient. To truly understand the behavior of thickened fluids we need to consider the material properties of density of the fluid and its yield stress to complete our understanding. Density is the mass per unit volume. Liquids such as barium are more dense than ordinary fluids. For example, thickened infant formula has a density of 0.91 g/cm^3 whereas liquid barium has a density of 1.62 g/cm^3, despite both liquids having a comparable viscosity[22]. A fluid that is more dense will require more force to generate movement.

The final element for consideration is yield stress. This is the force required to break down the internal structure of the fluid in order for it to flow. Think of a billiard table with balls arranged ready for the break. Considerable force is required from the pool cue to cause the momentum of one ball to push another, that then pushes another, and so on. Within thickened fluids those microscopic particles, must also be pushed to a point where they are set in motion to the point where flow will occur. Steele and Van Lieshout[24] reported the yield stress of honey-thick apple juice at 1.42 Pa, whilst its barium counterpart showed a yield stress of 2.1 Pa, not quite double the magnitude. In this instance, more tongue force could be anticipated in order to make

the honey thick barium flow as compared with the effort required to make the honey-thick apple juice without barium flow.

The internal structure of a fluid will also provide clues as to whether it is likely to have a yield stress. Some fluids have a more complex particle structure than others. For example, milk contains milk solids, and orange juice contains fibrous solids particles[25]. These differ to water, as water does not contain any solids. The addition of a thickener powder also introduces tiny solid particles. Therefore, all thickened liquids can be anticipated to have a yield stress that must be overcome to allow the liquid to flow. There are clinical implications that come from this understanding of internal liquid structure. It may seem logical that the thicker liquid, the safer the swallow. However, the amplitude of maximum muscle activity increases with increasing viscosity, as does total swallow duration[26]. As a result, those with weakened oropharyngeal musculature will in fact have more difficulty moving a very thick bolus, with an increased likelihood of post swallow residue[27]. Individuals who aspirate very thick liquids have worse outcomes, including fatal ones[28]. Thus the prescription of liquid thickness needs to be carefully chosen to be of most benefit to the patient.

CONTRAST AGENTS USED FOR VIDEOFLUOROSCOPIC SWALLOW STUDIES

Two types of liquids are now commonly used in radiological assessment of swallowing function (videofluoroscopy or modified barium swallow). These are barium sulphate mixtures (powders or ready mixed solutions) and iodine solutions. Iodine based products such as Gastrograffin® have typically not been used in radiological assessment of swallowing where aspiration was a likely outcome due to the potential for pulmonary oedema[29]. Gastrograffin is of the older class of 'hypertonic or hyperosmolar water-soluble, non-absorbable contrast agents'. The toxicity of contrast agents decreases with lower osmolarity. With advances in the development of contrast agents, low-osmolar or even iso-osmolar nonionic, water-soluble contrast agents can safely be used for radiological assessment of swallowing[21,29,30,31]. The benefit of iodine solutions is that their viscosity is very low and more closely aligned to that of regular thin liquids (<10 m.Pas)[32]. In contrast, standard undiluted barium sulphate liquids can vary from 133 mPa.s (E-Z-Paque 60% w/v)[33] to 390 mPa.s[22], whilst the Varibar® range is specifically formulated to attempt to meet the USA National Dysphagia Diet viscosity levels for nectar, honey and spoon-thick fluids[34].

Barium is a suspension with large insoluble particles. It is this unique characteristic that means that liquids with barium added to them have a higher density than those without[17]. This feature allows for structures such as the mucosa to be coated by barium, making them easier to see radiologically. The challenge comes though in determining at what point a 'coating' becomes 'residue'[33]. Popa Nita[21] note that the density of food liquids and contrast materials falls within the narrow range of 1-2 g/mL, whilst viscosity variations can be in order of magnitudes of difference. Although this is true, this does not mean that density should be ignored. Dantas *et al*[35] investigated the effects of low density barium (1.4 g/cm^3) and high density barium (2.5 g/cm^3) on the oral and pharyngeal phases of swallowing. The viscosities of the two fluids were 200 mPa.s and 300 mPa.s respectively. For 5 and 10 mL bolus swallows oral transit time and pharyngeal clearance times were longer for high density barium than low density barium. The upper oesohpgaeal sphincter was open for longer for the high density preparation. Intrabolus pressure and the magnitude of anterior hyoid movement was greater for high density preparations. The pharyngeal pressure wave was not affected by barium density. These findings suggest that small differences in density do indeed have an effect on swallowing physiology. They point to a need to standardize or provide specifications for barium used in studies of oropharyngeal swallowing[21,33,36]. Published research from Europe suggests the benefits of dual use of iodine solutions and barium sulphate solutions during dysphagia examinations. The iodine solutions are used to determine safety swallowing regular liquids, whilst high density barium solutions are used to examine safety swallowing 'thick' liquids[30,31].

A number of studies have shown that barium impregnated fluids have both higher density and higher yield stress values than their non-barium counterparts. It takes more effort to enable these fluids to flow. From a practical point of view this has implications for dysphagia assessment. If the test fluids (X-ray barium-impregnated fluids) require more effort to initiate flow, how reliable are these fluids for predicting flow behavior for ordinary fluids used at meal-times[17,22,36]? Can we be certain that the swallowing patterns we see under X-ray conditions are comparable to those seen at the bed-side? Research has shown that healthy individuals modulate their sip mass and sip volume when comparisons are made between their behavior for barium-containing and non-barium-containing liquids. Specifically, small sips and less sip mass is taken when consuming barium-impregnated liquids[24]. For individuals with oropharyngeal sensory impairments, it is possible that the heavier barium solutions actually help with swallowing safety by providing intra-oral information via mechanoreceptors that is not usually present? It is possible then, that an individual may safely swallow a barium-impregnated liquid, but struggle with the same consistency in its non barium-impregnated form? Clinicians need to be aware of this complication when interpreting modified barium swallow results.

THICKENING AGENTS

The past twenty years have seen the rapid development of thickening agents used in dysphagia management. Initially food based thickeners such as potato starch, corn flour and rice cereal were used. Modified maize starch then gained popularity, but most recently gum based thickeners are most popular due to their stability over time. Starch based thickeners cause a liquid to become thicker as the starch molecules swell. Gum based thickeners on the other hand, cause entangled meshes that water molecules become trapped in[37]. A number of studies have demonstrated that beverages thickened with starch are unstable. These liquids typically continue to thicken over time[39,40,41]. As noted above, very thick liquids can be just as challenging to individuals with dysphagia as very thin liquids. In contrast, gum based thickened liquids show superior stability over time[39,42].

There is one notable exception to liquids thickened with starch continuing to thicken over time. Human breast milk thickened with starch becomes thinner rather than thicker over time. De Almeida[43] concluded that the presence of amylase in human milk causes a partial breakdown of the starch in the thickener, resulting in a thin liquid the longer that starch is exposed to the amylase. Although gums have better stability, their use with infants is currently not recommended. The infant digestive tract is not mature enough to cope with degrading gums. Some premature infants who have ingested milk thickened with gum based products died as a result of necrotizing enterocolitis[44].

Amylase is also found in human saliva. In infants, salivary amylase is negligible for the first three months and does not reach adult levels

until 1-2 years of age[45]. Salivary amylase plays an important role in helping to breakdown starch molecules into simple carbohydrates and water, as an initial part of the digestion process. In clinical practice, starch based thickening agents have the potential to be broken down if, during spoon feeding, saliva is transferred from the oral cavity to the feeding cup. In a sobering study, Hanson *et al*[46] demonstrated that within 10-15 minutes of adding just 0.5 mL of saliva to 100 mL of fluid, the result was a reduction of liquid thickness from custard-thick consistency to a liquid akin to the thickness of normal water. Hanson *et al*[46] also noted that salivary amylase is affected by pH. Liquids of low pH (e.g. Coca Cola) reduce the effect of amylase on starch breakdown. Low pH liquids such as fruit juice, white wine and acidic soft drinks that are thickened with starch are, therefore, more likely to retain their desired thickness level. However, liquids of high pH (e.g. coffee pH 6.8) show a rapid and significant decrease in viscosity due to the effects of salivary amylase.

Mouthfeel and flavour

Stokes *et al*[23] correctly point out that texture and mouthfeel of food and liquids play an important role in product acceptability. Not only the feel of the product during swallowing, but any oral sensation after the swallow, such as astringency or mouth coating can affect the person's desire to consume that food or beverage. For individuals with dysphagia, thickened liquids are not a diet of choice, but one of necessity. However, poor mouthfeel and flavor of thickened liquids will affect compliance, and this has a direct effect on hydration.

Mucoadhesion is one of the properties of gum thickeners that make them useful for pharmaceutical applications. The bioadhesive qualities of xanthan, guar and locust bean gum are used to good effect when medication needs to be administered through buccal or nasal absorption sites[47,48]. Unfortunately these same qualities that are useful for mucosal drug delivery, affect the physiological sensation associated with reduction in thirst[49]. Anecdotally, individuals with dysphagia complain that thickened liquids do not quench their thirst. Mouth wetness, such as that occurring with an influx of saliva or wet liquid conveys signals to the brain that thirst has been quenched[50]. Thickened liquids do not possess this property, further reducing patient compliance. Consider also that 'thickened water' does not meet the definition of mouth quenching 'water' provided earlier. Even in healthy individuals, it has been demonstrated that thirst sensation progressively increases with increasing liquid viscosity[51].

In addition to a sticky after-feel of thickened liquids within the mouth, there is a critical point at which increasing liquid thickness dulls flavor release[52]. Both flavor suppression and 'off flavours' have been associated with thickened liquids[53]. Whilst the entangled polymer networks suppress flavor, the ability of saliva to act as a solute for the thickened liquid also likely adversely affects flavor perception. Furthermore, a reduction in tongue movement has adverse effects on sensory ratings for mouth-feel and flavor[54]. Flavor suppression due to the polymer binding in thickened liquids, coupled with impaired tongue strength in individuals with oropharyngeal dysphagia amplifies an impaired ability to perceive flavor. These issues will adversely effect patient compliance with an impact on the ability to maintain adequate hydration.

The effects of thickener concentration

Many commercial food thickener companies recommend a single recipe for a particular thickness level, regardless of the beverage being thickened. Research has demonstrated, however, that the type of liquid being thickened interacts with the thickener. As noted above, the pH of the liquid will affect how quickly salivary amylase will degrade the thickener. In a different study Mertz-Garcia[39] showed that thickeners mixed with orange juice or 2% milk typically produced thicker liquids than when mixed at the same concentrations with water or coffee. In addition, it has recently been demonstrated that doubling or tripling the concentration of thickener results in a logarithmic increase rather than a linear increase in both viscosity and yield stress[55]. For example, at 1% concentration of a xanthan+dextrin solution, the viscosity is reported at 180 mPa.s, however, at 2% concentration this figure nearly triples to 510 mPa.s, whilst at 3% concentration, the figure is quadruple the initial viscosity at 790 mPa.s A similar pattern can be seen with yield stress rising from 2.06 Pa at 1% concentration, to 10.5 Pa at 2% concentration and 18.5 Pa at 3% concentration. This has important implications when recipes are being developed for patients returning home with powdered thickeners. The idea of doubling the dose of powder to double the liquid thickness is a flawed concept.

HOW THICK IS THICK?

As noted above, liquids should only be thickened to the level required to improve swallowing safety. In this regard, thickened liquids are like a drug prescription; the dose must be correctly prescribed for each individual. Liquids that are too thick can be just as detrimental as those that are too thin. The international literature suggests that dysphagia clinicians might recommend liquids thickened to one of four different thicknesses. Thin, or regular liquids are those that healthy people most commonly consume (water, tea, coffee etc.). Nectar-like or Mildly thick liquids are thicker than naturally thick liquids and run fast through the tines of a fork, leaving a mild coating. Honey-like or Moderately thick liquids are similar to the thickness of room temperature honey or a thickshake; these liquids drip slowly in dollops through the tines of a fork. Spoon-thick or Extremely thick liquids are similar to the thickness of pudding or mousse; these liquids sit on and do not flow through fork tines. Viscosity levels prescribed by some countries are shown in the table below. Table 1 shows some of the most common thickness levels reported in the liter ature[34,39,55,56,57,58,59,60,61].

If the correct dose, or thickness, is deemed to be important, then the ability to accurately measure thickness is a logical assumption. Accurate measurement of liquid thickness requires the use of rheometers and the technical expertise of specialists such as chemical engineers[17,23,24,46,55]. Unfortunately, hospitals and aged care facilities do not have the funds or resources to measure liquid thickness in

Table1 Common levels of liquid thickness reported in the literature for dysphagia management.

Country	Thinnest				Thickest
USA[34]	Thin		Nectar-like (51-350cP[1])	Honey-like (351-1700cP)	Spoon-thick (>1700cP)
UK[55]			Stage 1	Stage 2	Stage 3
Japan[56]	Less Mildly Thick (< 50mPa.s[1])		Mildly thick (50-150mPa.s[1])	Moderately thick (150-300mPa.s)	Extremely thick (300-500 mPa.s)
Ireland[57]	Regular	Grade 1- Slightly Thick	Grade 2- Mildly Thick	Grade 3- Moderately Thick	Grade 4- Extremely Thick
Australia[58], New Zealand[59]	Regular		Level 150- Mildly thick	Level 400- Moderately thick	Level 900- Extremely thick
Denmark[60]	Normal	Chocolate Milk	Syrup	Jelly	
Sweden[61]	Liquids		Thickened liquids		

[1] 1cP=1 mPa.s.

this fashion. Low technology options such as the line spread test or Bostwick consistometer provide clinicians with some very general information about the flowability of thickened liquids; however, by analogy, these tools could be likened to using bathroom weight scales to measure ingredients required for fine cooking. These tools assess the way the fluid reacts to gravity. However, we do not swallow by gravity, hence it is not surprising to find that the results gained from a consistometer are different to those using rheological tools where shear rate such as that which occurs during swallowing, is factored into the measurement. Germain *et al*[64] have demonstrated that with thickened liquids have similar flow behavior and consistency indices, on rheological measurements appear to be very different. The effect is magnified as the liquids become thicker. The consistometer readings also showed very wide standard deviations, demonstrating that the samples tested even within the same thickness level (nectar, honey or pudding) showed very different textural properties. The consistometer readings do, however, provide an objective measure that is likely superior to subjective assessments made using stirring or observing flow as thickened liquids are drawn through fork tines.

WHAT'S IN A NAME?

A recent publication has demonstrated the varying names and descriptions that exist around the world for the different levels of liquid thickness used in dysphagia management. Table 1 shows an abbreviated list of published national terminologies for thickened liquids[56]. Even this abbreviated list shows the potential for confusion and for medical errors to occur when the names for thickened liquids are not standardized. Nectar and honey are liquids that exist in their own right, and whilst the intention is that their thickness properties be mimicked when making thickened liquids, anecdotally some patients have been confused thinking that only fruit nectar can be consumed. Table 1 also clearly demonstrates another conundrum in this field. Are thickened liquids a food, or are they in fact more like a medicine or medical device? Names such as nectar and honey are comforting and familiar and fall more towards a food-based classification. Terms such as mildly thick or extremely thick, Level 150, Level 900 and even stage 1 or stage 2 suggest that the characteristic of viscosity is the one that needs to be focused on. Given that a liquid that is too thick can be just a dangerous to a person with dysphagia as one that is too thin, it is important that clinicians, carers and patients appreciate that correct dose or viscosity is vital for their safety. Pre-packaged thickened drinks are being manufactured to provide consistency of thickened liquids, with the result of (a) fewer errors such as those associated with manual mixing; (b) less wastage and (c) cost benefits[65].

Note also the different viscosity ranges reported in table 1. The American Dietetic Association[34] denoted by values in cenitpoise (cP), shows quite different viscosity recommendations to the Japanese[43] viscosity ranges, denoted by values in milliPascal seconds (mPa.s). Looking at these values, is it logical to say that a liquid of viscosity 350 cP is so vastly different to a liquid of 351 cP? Is it more likely that distinct bands of thickness that fall within an approved range, with a cross-over zone showing transition from one thickness level to another would be more akin to what happens in clinical practice? At what point does a liquid cease to be a liquid, and become a semi-solid that might be better suited to the texture modified foods side of the table? Standardisation of names and preferably objective measurement values would do much to enhance patient safety and advance research into the therapeutic use of thickened liqudis in dysphagia management. An internationally recognized terminology would provide a single point of reference that would allow patients, clinicians, researchers and industry to all communicate about the same substance. The International Dysphagia Diet Standardisation Initiative is a global initiative that is currently working to this end for both texture modified foods and liquids[56].

SUMMARY AND CONCLUSIONS

Dysphagia clinicians use thickened liquids therapeutically to enhance swallowing safety. Thickened liquids are not a beverage of choice, but one of necessity. For infants the correct thickness level is essential as infants derive both nutrition and hydration requirements from milk feeds. A feed that is too thick may increase the physiologic load to extract the thickened milk, causing more energy to be expended than what is gained during the feed. For the elderly, a natural decline in thirst, coupled with compliance problems increases the risk of dehydration. The consequences of dehydration include risks associated with renal failure, falls, impaired mental status, urinary tract infection, and decreased muscle strength, amongst others. Making thickened liquids to a consistent level of thickness is a challenge as the amount of thickener needed to reach the desired viscosity changes depending on the liquid being thickened. The addition of thickening agents changes the flavor of liquids and the mouthfeel after swallowing. The test materials used radiologically must be specified at the very least. Consideration should be given to the dual use of iodine and barium sulphate solutions in radiographic swallowing studies. Measures of viscosity, density and yield stress are required to accurately describe thickened liquids. Accurate measurement of these rheological and material properties is the domain of chemical engineering. Varying names for thickened liquids nationally and internationally adversely affect patient safety. Efforts are under way to better understand the therapeutic levels of thickness that assist individuals with dysphagia and standardized names and definitions of these liquids.

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CONFLICT OF INTERESTS

There are no conflicts of interest with regard to the present study.

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