Swallowing Rehabilitation Research Lab

www.steeleswallowinglab.ca

ASPEKT Method: Supplemental Material

Analysis of Swallowing Physiology: Events, Kinematics & Timing (ASPEKT)

ASPEKT Method Background

Beginning in April, 2019, the Steele Swallowing Lab of the KITE Research Institute at the Toronto Rehabilitation Institute – University Health Network published a pair of open articles exploring swallowing physiology across the range from thin to extremely thick liquids, in healthy adults (Steele et al., 2019; Smaoui et al., 2021). Both of the articles describe swallowing in healthy adults, collected using a standardized videofluoroscopy protocol and analyzed using a standard operating procedure. The analysis method was entitled the ASPEKT Method (Analysis of Swallowing Physiology: Events, Kinematics and Timing) (see *Figure 1)* and is described in a detailed in Steele and colleagues (2019). In addition to that appendix, this supplementary document contains healthy reference values for the measures that are collected in the ASPEKT Method, and explains how clinicians can use these reference values to determine whether or not values in their patients are impaired.

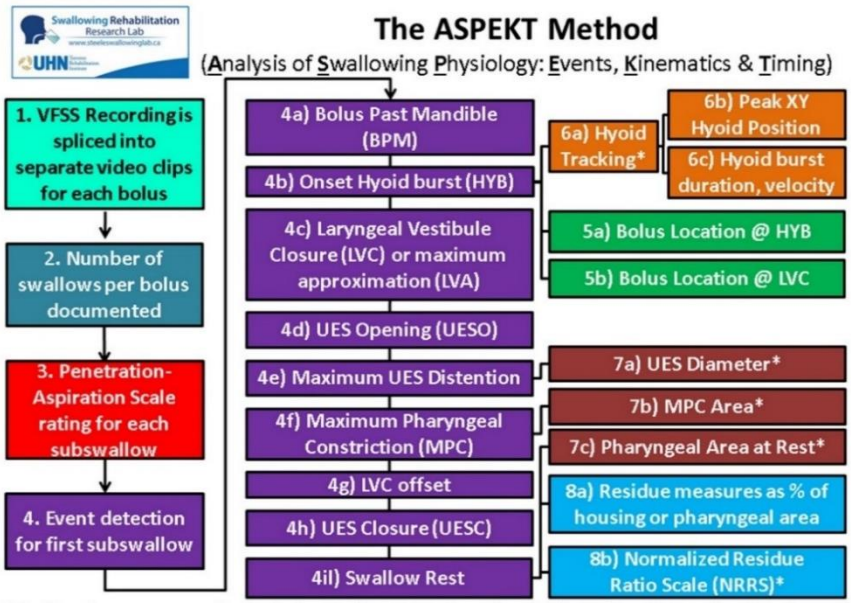

Figure 1: The ASPEKT Method (Steele et al., 2019)

How were the ASPEKT Method healthy reference values collected?

In order to use reference values from healthy volunteers, it is important to understand *how* those healthy reference values were collected to determine if they can be compared to your individual clinical setting and patients. The healthy reference values for the ASPEKT Method were collected under the conditions described below:

- Healthy adult participants aged 21 to 82 years old.
- Videofluoroscopy acquired at 30 unique images (i.e. a videofluoroscopy pulse rate of 30 pulses per second, captured on a synchronized recording system at 30 frames per second).
- Low concentration (20%w/v) barium (Bracco E-Z-Paque) mixed with water (Barbon and Steele, 2019).
- Thickened stimuli prepared with a xanthan-gum based thickening agent (Nestlé ThickenUp Clear).
- Stimuli developed to meet the 5 drink levels of the International Dysphagia Diet Standardisation Initiative framework (www.IDDSI.org): Level 0 thin, Level 1 slightly thick, Level 2 mildly thick, Level 3 moderately thick, and Level 4 extremely thick.
- Participants self-administered comfortable sips of IDDSI level 0 thin, level 1 slightly thick and level 2 mildly thick liquids and self-administered teaspoons of IDDSI level 3 moderately and level 4 extremely thick liquids.
- A non-cued spontaneous swallow paradigm was used. Participants swallowed when they felt ready, without waiting for a cue from the research team.

For clinical data collected under conditions that are different from those listed above, the strict ASPEKT Method reference values may not apply.

Why is it important to compare patient values to healthy reference values?

There are many situations in clinical medicine where patient values are compared to healthy reference values. Two common examples are described below:

a) Height and weight charts for children

It is routine to assess growth and nutritional status in infancy, childhood and adolescence (up to 19 years of age) by comparing individual growth measurements against growth data or growth charts from a reference ("normal") population (a "growth reference" or "growth standard"). *Figure 2*, below, is a reference chart published by the World Health Organization for weight and height in girls up to age 5 years. By comparing the height and weight of a girl to this chart, a clinician or parent can understand whether the child is relatively tall or of typical weight for their age.

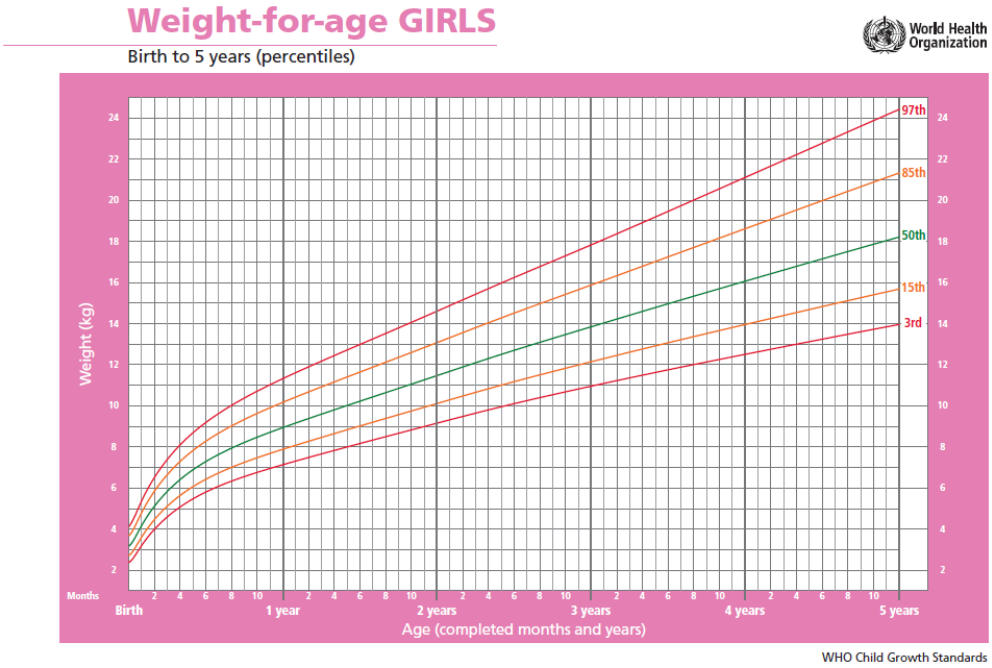

Figure 2. WHO Child Growth Standards Weight-for-age: Birth to 5 years percentiles chart for girls. Source: http://www.who.int/childgrowth/standards/chts_wfa_girls_p/en/

b) Interpreting blood test results

When a blood sample is sent to a lab, the goal is to compare the values of various components of the blood sample to healthy reference values, to understand whether or not there is a problem. For example, a test might determine whether a person has sufficient iron or is anemic, whether they have high or low sodium or potassium, whether they have an adequate number of red blood cells, hemoglobin or platelets, or whether they have higher-than-usual numbers of white blood cells suggesting infection. Reference tables that are used for interpreting blood tests and other laboratory tests in Canada can be found at: https://mcc.ca/objectives/normal-values/?cn-reloaded=1.

The goal of the ASPEKT Method is to provide clinicians with reference values for healthy swallowing, which will enable them to determine which components of swallowing fall outside the norms.

The Statistical Definition of Reference Ranges

If you think back to the grades you received on examinations in university, you will be familiar with the concept of a "bell curve". A bell curve (*Figure 3)* is the usual (or expected) shape of the distribution of grades on an exam, organized by their frequency of occurrence. The measure of central tendency on a bell curve is the average score, or mean, and it is common to describe how far a value is from the mean using standard deviations.

For data that are normally distributed, there are a few rules:

- the shape of the curve is symmetrical
- the mean and the median have the same value
- 68% of the data will fall within 1 standard deviation of the mean
- 95% of the data will fall within 2 standard deviations of the mean

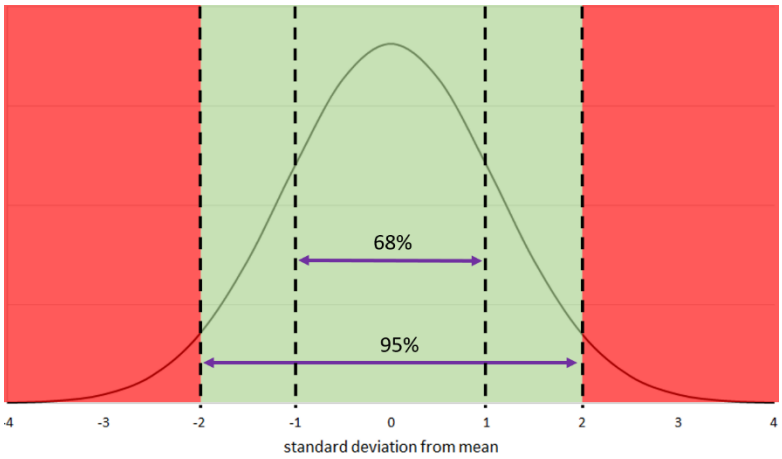

Figure 3: Example of normally distributed data.

In statistical terms, it is common to describe the bottom 2.5% and the top 2.5% of the data (i.e. in the tails of the distribution, accounting for 5% of the observed values when combined), more than 2 standard deviations from the mean, as "abnormal".

Values in the central 95% of the distribution on a bell-shaped distribution can be described as falling "Within the Reference Interval", whereas values in the 2.5% tails on either side can be described as "Extreme" values.

Shifting from Means and Standard Deviations to Percentiles

The original ASPEKT Method manuscript and its supplement contain reference value tables reporting means and standard deviations (SD) for measures of swallowing physiology. However, over the course of developing the ASPEKT Method and ASPEKT Reference Values, we have come to appreciate that means and standard deviations are not, in fact, the most appropriate values to use to define reference values for measures of swallowing. There are two reasons for this:

1) Most of the swallowing data that we have collected from healthy adults does not, in fact, display a symmetrical bell-curved normal distribution. Instead, many of the parameters that we are interested in display what is called a "positive skew", where the most common values are either a value of zero or a value close to zero. A good example of this would be measures of residue. In healthy people, we expect to see either no pharyngeal residue or very little pharyngeal residue. Some parameters may also display a "negative skew", where small values would potentially be of clinical concern. The diameter of UES distension is an example of a negatively skewed parameter where small values associated with limited opening would be unusual in healthy people.

2) When we think about measures of swallowing in a clinical context, most of the parameters that we are interested in are uni-directional (rather than bi-directional). Residue is a good example here, as well. As clinicians, we are interested in whether our patients display MORE residue than normal and it is of little clinical interest to know if a patient displays LESS residue than normal. Conversely, narrow UES diameter would be of clinical interest but we would probably not be clinically concerned about a situation where someone displays wider UES diameter than usual.

Figure 4, below, illustrates a positively skewed data distribution. A few quick facts about skewed distributions:

- The median (or 50th percentile) is the measure of central tendency; half of the observed values fall below this value, while the other half fall above this value.
- The 75th percentile (p75) is analogous to 1 standard deviation above the mean on a normal distribution; in the opposite direction, the 25th percentile (p25) is analogous to 1 standard deviation below the mean on a normal distribution.
- The range between p25 and p75 is known as the interquartile range. Half of the observed values fall within the interquartile range, while 25% of the observed values fall below this range (below p25) and the remaining 25% fall above this range (above p75).
- The 97.5th percentile (p97.5) identifies the 2.5% of values at the very top of the distribution. However, for positively skewed distributions, it is probably more appropriate to consider the 5% of values at the top of the distribution (above p95) as "Extreme" values. Similarly, for a negatively skewed distribution, the 5% of values at the bottom of the distribution (below p5) would be considered extreme.

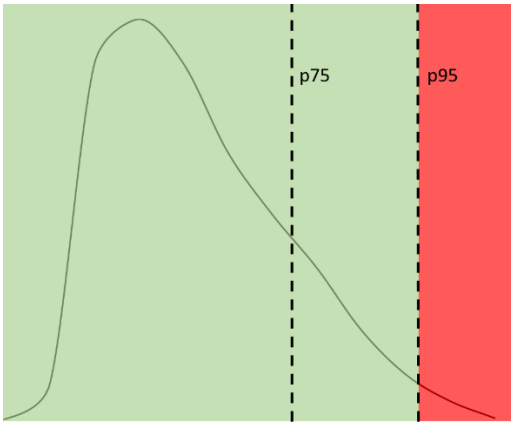

Figure 4: Example of positively skewed data distribution.

Determining Clinical Decision Points

Although it is statistically accurate to consider the 5% of data in the tail(s) of the distribution as "abnormal", or "extreme", we need to consider whether or not the boundaries of the reference interval, are good boundaries for deciding whether or not somebody has a value of clinical concern. The answer here is "not necessarily". In fact, using the boundaries (or limits) of the reference interval for this purpose is probably too stringent because values in healthy people and values in people who genuinely have a clinical condition of concern are likely to overlap to some degree. In laboratory medicine, the thresholds used to identify values of potential clinical concern are called "Clinical Decision Points" and they are often set at values that fall towards the boundaries of the reference interval rather than at the reference interval limits. For example, the upper boundary of the reference interval for measures of fasting blood glucose in healthy adults is ≥ 6 mmol/L (with some variations in exactly where this line falls due to age, sex and body mass index). However, the clinical decision point that is used as the clinically accepted value for triggering concern and diagnosing a patient with "prediabetes" is ≥ 5.6 mmol/L.

When it comes to swallowing, we don't yet have enough data to set clinical decision points with confidence, but we believe that there is probably value in proposing clinical decision points at points along the distribution that are less extreme than the boundaries of the reference interval. Therefore, we propose using the term "typical" to describe values that fall in the central 50% of the healthy data distribution, and "atypical" for all values that fall outside that range, either below the 25th or above the 75th percentile. "Atypical" values include values that are truly extreme, in the tails of the distribution, and also values that are approaching those tails. If we are looking at a skewed parameter, would be clinically interested in only one side of the distribution rather than "atypical" values on both sides. In *Figure 5* below, we use traffic light colour coding to represent typical values on a bell-shaped normal distribution in green-shaded areas and to divide the atypical ranges into red-coloured extreme values and amber-coloured values outside the typical range, but approaching the boundaries of the reference interval. *Figure 6* shows an analogous image for a positively skewed distribution.

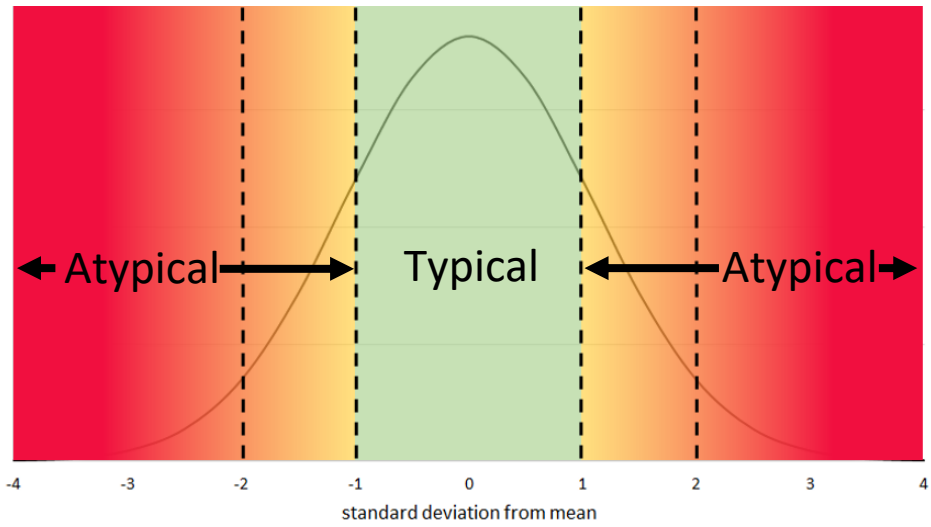

Figure 5: Example of normally distributed data. Green shaded area showing "typical" values. Gradient yellow to red showing "atypical" values with red being more extreme.

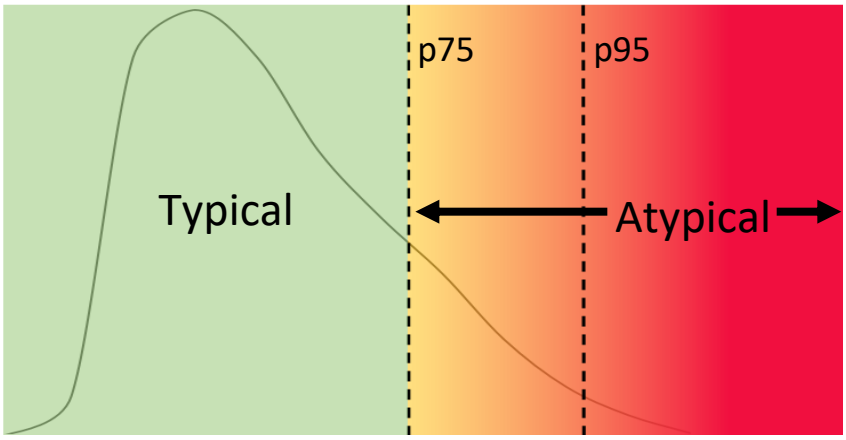

Figure 6: Example of positively skewed data distribution. Green shaded area showing "typical" values. Gradient yellow to red showing "atypical" values with red being more extreme.

Using the Reference Tables with Your Patient's Values

On the pages that follow, you will find reference tables by consistency for timing measures and pixel-based measures of healthy swallowing. Each table includes columns for the "Healthy Reference Interval" which in statistical terms would define values falling outside the p2.5 and p97.5 as "Extreme" values. Each table also include columns for the "Proposed Clinical Decision Point(s)" based on the p25 and/or p75. The direction of clinical concern for most parameters is in a single direction, such that atypical high values may warrant concern whereas atypical low values are of no concern (or vice versa).

We recommend that clinicians use these "Proposed Clinical Decision Point(s)" for interpreting values seen in their patients. If your patient's value falls outside the "Proposed Clinical Decision Point(s)" threshold, it is "atypical". If your patient's value does not fall outside the "Proposed Clinical Decision Point(s)" threshold, it is "typical".

Example: Your patient's Laryngeal Vestibule Closure (LVC) duration was 333ms with a thin liquid. The "Proposed Clinical Decision Point(s)" for IDDSI Level 0 Thin is based on p25 with a threshold of < 400 ms. Your patient's value would fall outside this threshold and would be "atypical".

Given that healthy individuals typically swallow a bolus in a single swallow, these **reference values were calculated for the initial swallow of the bolus only.**

What about ASPEKT Method parameters that are categorical?

Some parameters in the ASPEKT Method are not continuous but behave in a categorical fashion. These include the number of swallows per bolus (most commonly one), Penetration-Aspiration Scale Scores, and Laryngeal Vestibule Closure (LVC) integrity. Here, we base the classification of values into typical, atypical and extreme values on the observed frequencies of occurrence in the ASPEKT Method healthy reference value dataset, as summarized below:

Parameter Name	Consistency	Typical	Atypical High	Atypical Extreme
Number of Swallows per Bolus	Thin	1	2	3 or more
	Slightly thick			
	Mildly thick			
	Moderately thick			
	Extremely thick			
Penetration-Aspiration Scale Scores	Thin	1	2	3 or worse
	Slightly thick			
	Mildly thick			
	Moderately thick			
	Extremely thick			
Laryngeal Vestibule Closure (LVC) Integrity	Thin	Complete	Partial	Incomplete
	Slightly thick			
	Mildly thick			
	Moderately thick			
	Extremely thick			

ASPEKT Method: IDDSI Level 0 Thin Reference Values

	Parameter Name (Unit)	Healthy Reference Interval			Proposed Clinical Decision Point(s)	
		2.5%ile (p2.5)	50%ile (p50)	97.5%ile (p97.5)	Percentile	Threshold
Timing [ϕ]	Swallow Reaction Time (bolus passing mandible to hyoid burst) (ms)	-33	133	967	p75	> 400
	Hyoid-Burst-to-UES-Opening Interval (ms)	33	100	200	p75	> 133
	Upper Esophageal Sphincter (UES) Opening Duration (ms)	400	467	634	p25	< 434
	Time-to-LVC (time from hyoid burst to LVC) (ms)	33	133	267	p75	> 167
	Laryngeal Vestibule Closure (LVC) Duration (ms)	300	467	934	p25	< 400
Pixel-Based	Vallecular Residue %(C2-4)^2	0.0	0.1	1.8	p75	> 0.7
	Pyriform Sinus Residue %(C2-4)^2	0.0	0.0	1.9	p75	> 0.0[§]
	Other Pharyngeal Residue %(C2-4)^2	0.0	0.1	0.8	p75	> 1.0
	Total Pharyngeal Residue %(C2-4)^2	0.0	0.2	4.5	p75	> 1.7
	Pharyngeal Area at Maximum Constriction (PhAMPC) %(C2-4)^2	0.0	1.0	6.2	p75	> 2.7
	UES Diameter %(C2-4)^2	9	21	32	p25	< 17
	Pharyngeal Area at Rest %(C2-4)^2	37	59	92	p25	< 51
					p75	> 70
	Hyoid Peak Position: X coordinate %(C2-4) *	122	142	182	p25	< 134
	Hyoid Peak Position: Y coordinate %(C2-4) *	40	88	136	p25	< 73
	Hyoid Peak Position: XY coordinate %(C2-4) *	148	172	197	p25	< 163
	Hyoid Speed: XY %(C2-4)/second [ϒ]	71	122	180	p25	< 103

[ϕ] Timing parameters are derived from frame based measurement and converted into milliseconds.

* We selected the frame showing the furthest hyoid XY position relative to the anterior-inferior corner of C4 as the hyoid peak position. Values reported are showing the X, Y and XY coordinates of hyoid on that frame.

[ϒ] Rate of change in hyoid position from burst onset to hyoid peak XY position divided by duration of the hyoid burst movement from burst onset to peak position.

[§] There were insufficient examples of pyriform sinus residue on thin liquid swallows in the healthy reference dataset to identify the 75th percentile with confidence. For the time-being, any pyriform sinus residue should be considered as information of potential clinical concern.

ASPEKT Method: IDDSI Level 1 Slightly Thick Reference Values

		Healthy Reference Interval			Proposed Clinical Decision Point(s)	
	Parameter Name (Unit)	2.5%ile (p2.5)	50%ile (p50)	97.5%ile (p97.5)	Percentile	Threshold
Timing ϕ	Swallow Reaction Time (bolus passing mandible to hyoid burst) (ms)	- 67	133	934	p75	> 400
	Hyoid-Burst-to-UES-Opening Interval (ms)	33	133	200	p75	> 167
	Upper Esophageal Sphincter (UES) Opening Duration (ms)	334	467	634	p25	< 400
	Time-to-LVC (time from hyoid burst to LVC) (ms)	- 100	133	367	p75	> 234
	Laryngeal Vestibule Closure (LVC) Duration (ms)	300	467	767	p25	< 400
Pixel-Based	Vallecular Residue %(C2-4)^2	0.0	0.1	2.8	p75	> 1.0
	Pyriform Sinus Residue %(C2-4)^2	0.0	0.0	1.9	p75	> 0.6
	Other Pharyngeal Residue %(C2-4)^2	0.0	0.2	0.4	p75	> 0.3
	Total Pharyngeal Residue %(C2-4)^2	0.0	0.3	5.1	p75	> 1.9
	Pharyngeal Area at Maximum Constriction (PhAMPC) %(C2-4)^2	0.0	1.2	5.0	p75	> 2.5
	UES Diameter %(C2-4)^2	9	19	31	p25	< 15
	Pharyngeal Area at Rest %(C2-4)^2	37	59	92	p25	< 51
					p75	> 70
	Hyoid Peak Position: X coordinate %(C2-4) *	119	141	181	p25	< 132
	Hyoid Peak Position: Y coordinate %(C2-4) *	39	88	143	p25	< 70
	Hyoid Peak Position: XY coordinate %(C2-4) *	144	168	206	p25	< 159
	Hyoid Speed: XY %(C2-4)/second ϒ	67	113	209	p25	< 94

ϕ Timing parameters are derived from frame based measurement and converted into milliseconds.

* We selected the frame showing the furthest hyoid XY position relative to the anterior-inferior corner of C4 as the hyoid peak position. Values reported are showing the X, Y and XY coordinates of hyoid on that frame.

ϒ Rate of change in hyoid position from burst onset to hyoid peak XY position divided by duration of the hyoid burst movement from burst onset to peak position.

ASPEKT Method: IDDSI Level 2 Mildly Thick Reference Values

		Healthy Reference Interval			Proposed Clinical Decision Point(s)	
	Parameter Name (Unit)	2.5%ile (p2.5)	50%ile (p50)	97.5%ile (p97.5)	Percentile	Threshold
Timing ϕ	Swallow Reaction Time (bolus passing mandible to hyoid burst) (ms)	- 33	167	1301	p75	> 534
	Hyoid-Burst-to-UES-Opening Interval (ms)	33	133	234	p75	> 167
	Upper Esophageal Sphincter (UES) Opening Duration (ms)	334	467	634	p25	< 400
	Time-to-LVC (time from hyoid burst to LVC) (ms)	- 33	133	367	p75	> 200
	Laryngeal Vestibule Closure (LVC) Duration (ms)	300	467	734	p25	< 400
Pixel-Based	Vallecular Residue %(C2-4)^2	0.0	0.1	3.0	p75	> 1.1
	Pyriform Sinus Residue %(C2-4)^2	0.0	0.1	1.1	p75	> 0.4
	Other Pharyngeal Residue %(C2-4)^2	0.0	0.4	1.2	p75	> 0.7
	Total Pharyngeal Residue %(C2-4)^2	0.0	0.6	5.3	p75	> 2.2
	Pharyngeal Area at Maximum Constriction (PhAMPC) %(C2-4)^2	0.0	1.2	7.5	p75	> 3.3
	UES Diameter %(C2-4)^2	9	19	30	p25	< 15
	Pharyngeal Area at Rest %(C2-4)^2	37	59	92	p25	< 51
					p75	> 70
	Hyoid Peak Position: X coordinate %(C2-4) *	121	143	179	p25	< 134
	Hyoid Peak Position: Y coordinate %(C2-4) *	52	90	140	p25	< 77
	Hyoid Peak Position: XY coordinate %(C2-4) *	143	173	201	p25	< 161
	Hyoid Speed: XY %(C2-4)/second ϒ	73	114	189	p25	< 96

ϕ Timing parameters are derived from frame based measurement and converted into milliseconds.

* We selected the frame showing the furthest hyoid XY position relative to the anterior-inferior corner of C4 as the hyoid peak position. Values reported are showing the X, Y and XY coordinates of hyoid on that frame.

ϒ Rate of change in hyoid position from burst onset to hyoid peak XY position divided by duration of the hyoid burst movement from burst onset to peak position.

ASPEKT Method: IDDSI Level 3 Moderately Thick / Liquidised Reference Values

		Healthy Reference Interval			Proposed Clinical Decision Point(s)	
	Parameter Name (Unit)	2.5%ile (p2.5)	50%ile (p50)	97.5%ile (p97.5)	Percentile	Threshold
Timing[ϕ]	Swallow Reaction Time (bolus passing mandible to hyoid burst) (ms)	- 67	267	1468	p75	> 667
	Hyoid-Burst-to-UES-Opening Interval (ms)	67	167	267	p75	> 200
	Upper Esophageal Sphincter (UES) Opening Duration (ms)	300	400	534	p25	< 367
	Time-to-LVC (time from hyoid burst to LVC) (ms)	0	167	300	p75	> 200
	Laryngeal Vestibule Closure (LVC) Duration (ms)	300	434	734	p25	< 400
Pixel-Based	Vallecular Residue %(C2-4)^2	0.0	0.0	1.8	p75	> 0.6
	Pyriform Sinus Residue %(C2-4)^2	0.0	0.0	1.4	p75	> 0.5
	Other Pharyngeal Residue %(C2-4)^2	0.0	0.2	1.1	p75	> 0.5
	Total Pharyngeal Residue %(C2-4)^2	0.0	0.2	4.3	p75	> 1.6
	Pharyngeal Area at Maximum Constriction (PhAMPC) %(C2-4)^2	0.0	0.7	4.9	p75	> 2.1
	UES Diameter %(C2-4)^2	8	15	26	p25	< 12
	Pharyngeal Area at Rest %(C2-4)^2	37	59	92	p25	< 51
					p75	> 70
	Hyoid Peak Position: X coordinate %(C2-4) *	120	140	176	p25	< 132
	Hyoid Peak Position: Y coordinate %(C2-4) *	47	88	130	p25	< 72
	Hyoid Peak Position: XY coordinate %(C2-4) *	139	170	200	p25	< 158
	Hyoid Speed: XY %(C2-4)/second [r]	61	104	157	p25	< 89

[ϕ] Timing parameters are derived from frame based measurement and converted into milliseconds.

* We selected the frame showing the furthest hyoid XY position relative to the anterior-inferior corner of C4 as the hyoid peak position. Values reported are showing the X, Y and XY coordinates of hyoid on that frame.

[r] Rate of change in hyoid position from burst onset to hyoid peak XY position divided by duration of the hyoid burst movement from burst onset to peak position.

ASPEKT Method: IDDSI Level 4 Extremely Thick / Pureed Reference Values

		Healthy Reference Interval			Proposed Clinical Decision Point(s)	
	Parameter Name (Unit)	2.5%ile (p2.5)	50%ile (p50)	97.5%ile (p97.5)	Percentile	Threshold
Timing [ϕ]	Swallow Reaction Time (bolus passing mandible to hyoid burst) (ms)	- 67	367	1701	p75	> 801
	Hyoid-Burst-to-UES-Opening Interval (ms)	67	167	267	p75	> 200
	Upper Esophageal Sphincter (UES) Opening Duration (ms)	300	400	534	p25	< 367
	Time-to-LVC (time from hyoid burst to LVC) (ms)	33	133	267	p75	> 167
	Laryngeal Vestibule Closure (LVC) Duration (ms)	334	434	634	p25	< 400
Pixel-Based	Vallecular Residue %(C2-4)^2	0.0	0.0	1.5	p75	> 0.5
	Pyriform Sinus Residue %(C2-4)^2	0.0	0.0	1.4[§]	p75	> 0.5[§]
	Other Pharyngeal Residue %(C2-4)^2	0.0	0.1	1.1[§]	p75	> 0.5[§]
	Total Pharyngeal Residue %(C2-4)^2	0.0	0.1	4.2	p75	> 1.5
	Pharyngeal Area at Maximum Constriction (PhAMPC) %(C2-4)^2	0.0	0.2	3.8	p75	> 1.4
	UES Diameter %(C2-4)^2	9	16	26	p25	< 14
	Pharyngeal Area at Rest %(C2-4)^2	37	59	92	p25	< 51
					p75	> 70
	Hyoid Peak Position: X coordinate %(C2-4) *	120	143	177	p25	< 134
	Hyoid Peak Position: Y coordinate %(C2-4) *	42	87	133	p25	< 72
	Hyoid Peak Position: XY coordinate %(C2-4) *	144	168	202	p25	< 160
	Hyoid Speed: XY %(C2-4)/second [ɾ]	67	105	203	p25	< 89

[ϕ] Timing parameters are derived from frame based measurement and converted into milliseconds.

* We selected the frame showing the furthest hyoid XY position relative to the anterior-inferior corner of C4 as the hyoid peak position. Values reported are showing the X, Y and XY coordinates of hyoid on that frame.

[ɾ] Rate of change in hyoid position from burst onset to hyoid peak XY position divided by duration of the hyoid burst movement from burst onset to peak position.

[§] There were insufficient examples of pyriform sinus residue or other pharyngeal residue on extremely thick liquid swallows in the healthy reference dataset to identify the 75th percentiles for these parameters with confidence. For the time-being, we recommend using the values obtained for moderately thick liquids to guide interpretation and clinical decision making regarding residue with extremely thick liquids.

How are variations in data collection methods, sex and age likely to impact these measures?

For clinical data collected under conditions that are different from those listed on page 2 of this document, the strict ASPEKT Method reference values may not apply. Assessing how modifications of those conditions influence the ability to compare clinical values to the ASPEKT Method reference values is something that we continue to study in our research. Additionally, we have preliminary evidence to suggest that some trends in measures may be expected in healthy individuals as a function of sex and age. For the time being, we have summarized our expectations regarding the impact of differences in sip volume, cueing, barium concentration, sex and age on ASPEKT Method measures, based on the literature.

	Parameter Name (Unit)	Expected Changes
Timing	Sip Volume (ml)	• Sip volume is likely to vary as a function of administration method (cup sip vs spoon delivery), the volume available in the cup and instructions. • Men take larger sips on average than women.
	Number of swallows per bolus (#)	• Although healthy adults typically swallow a bolus in a single swallow, larger bolus volumes may lead to more than one swallow.
	Swallow Reaction Time (bolus passing mandible to hyoid burst) (ms)	• Cued swallows are likely to display a shorter swallow reaction time. • Older adults are likely to display longer swallow reaction times.
	Hyoid-Burst-to-UES-Opening Interval (ms)	• Larger volume boluses are likely to travel faster through the pharynx, resulting in a shorter Hyoid-Burst-to-UES-Opening interval.
	Upper Esophageal Sphincter (UES) Opening Duration (ms)	• Larger volume boluses are likely to display longer UES opening duration. • Older adults are likely to display longer UES Opening duration, which suggests a spontaneous compensation.
	Time-to-LVC (time from hyoid burst to LVC) (ms)	• We are not aware of any data showing trends in time-to-LVC as a function of sex, age, sip-volume, cueing, or barium concentration.
	Laryngeal Vestibule Closure (LVC) Duration (ms)	• Older adults display longer LVC duration, which suggests a spontaneous compensation.
Pixel Based	Vallecular Residue %(C2-4)^2	• Larger volume boluses are likely to leave greater residue. • Higher barium concentrations are more likely to leave a coating on the walls of the pharynx, which may be difficult to distinguish from residue.
	Pyriform Sinus Residue %(C2-4)^2	
	Other Pharyngeal Residue %(C2-4)^2	
	Total Pharyngeal Residue %(C2-4)^2	
	Pharyngeal Area at Maximum Constriction (PhAMPC) %(C2-4)^2	• Older adults are likely to display larger PhAMPC.
	UES Diameter %(C2-4)^2	• Larger volume boluses are likely to display wider UES diameter.
	Pharyngeal Area at Rest %(C2-4)^2	• Older adults are likely to display larger pharyngeal area at rest. • Men are likely to display larger pharyngeal area at rest than women.
	Hyoid Peak Position X %(C2-4)	• The cervical spine is likely to compress with age in healthy adults, meaning that the cervical spine reference scalar will be smaller, contributing to larger values of hyoid peak position in older adults.
	Hyoid Peak Position Y %(C2-4)	
	Hyoid Peak Position XY %(C2-4)	

What if I have questions?

Questions regarding the ASPEKT Method can be sent by email to tri-swallowinglab@uhn.ca.

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