Swallowing Rehabilitation Research Lab

www.steeleswallowinglab.ca

Instruction Manual for ASPEKT-C Method using ImageJ

Analysis of Swallowing Physiology:
Events, Kinematics & Timing for Use in Clinical Practice (ASPEKT-C)

Table of Contents

Acronyms

ALS	Amyotrophic Lateral Sclerosis
ASPEKT	Analysis of Swallowing Physiology: Events, Kinematics and Timing
ASPEKT-C	Analysis of Swallowing Physiology: Events, Kinematics and Timing for use in Clinical Practice
COPD	Chronic Obstructive Pulmonary Disease
IDDSI	International Dysphagia Diet Standardisation Initiative
LVC	Laryngeal Vestibule Closure
ms	Milliseconds
PAS	Penetration Aspiration Scale
PD	Parkinson Disease
PhAMPC	Pharyngeal Area at Maximum Pharyngeal Constriction
SCI	Spinal Cord Injury
S-LP	Speech-Language Pathology
SOP	Standard Operating Procedure
SRRL	Swallowing Rehabilitation Research Lab
VFSS	Videofluoroscopic Swallow Study

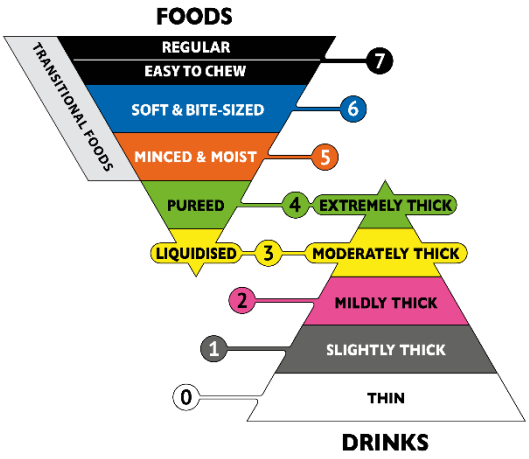
Background and History of the ASPEKT Method

The videofluoroscopic swallow study (VFSS) is an instrumental assessment that is widely considered the gold standard for evaluating swallowing function. At the Swallowing Rehabilitation Research Lab (SRRL), it is our belief that in order to effectively treat dysphagia, clinicians need to understand the underlying mechanisms of impairment. In order to identify the mechanisms of impairment that underlie a person's swallowing difficulties, we first need to know what healthy swallowing looks like.

In April 2019, the article "***Reference Values for Healthy Swallowing Across the Range from Thin to Extremely Thick Liquids***" was published by Professor Catriona Steele and colleagues in the Journal of Speech, Language and Hearing Research. This article established preliminary quantitative reference values for a large number of parameters describing swallowing physiology in healthy adult volunteers from thin liquids to extremely thick liquids (International Dysphagia Diet Standardization Initiative or IDDSI levels 0, 1, 2, 3, 4), as seen on the "drinks" side of the IDDSI pyramid in *Figure 1*. This article also included extensive detail on the methods used for rigorously collecting this data including:

(a) The creation and use of a standardized protocol to collect VFSS data.
(b) The creation and use of a standard operating procedure (SOP) for VFSS rating and analysis, in an attempt to overcome the concern around poor inter-rater reliability (Ekberg et al., 1988; Ott, 1998).

The resultant SOP was entitled the ASPEKT Method, or the *Analysis of Swallowing Physiology: Events, Kinematics and Timing* (Steele, Peladeau-Pigeon et al., 2019). The ASPEKT Method, seen below in *Figure 2,* includes standard definitions for all terminology and quantitative measurements developed with the purpose of conducting VFSS for research. Please note that at this time, the ASPEKT Method does not cover the "foods" side of the IDDSI Framework.



© The International Dysphagia Diet Standardisation Initiative 2016 @https://iddsi.org/framework/

Figure 1: IDDSI Framework (Cichero et al., 2017)

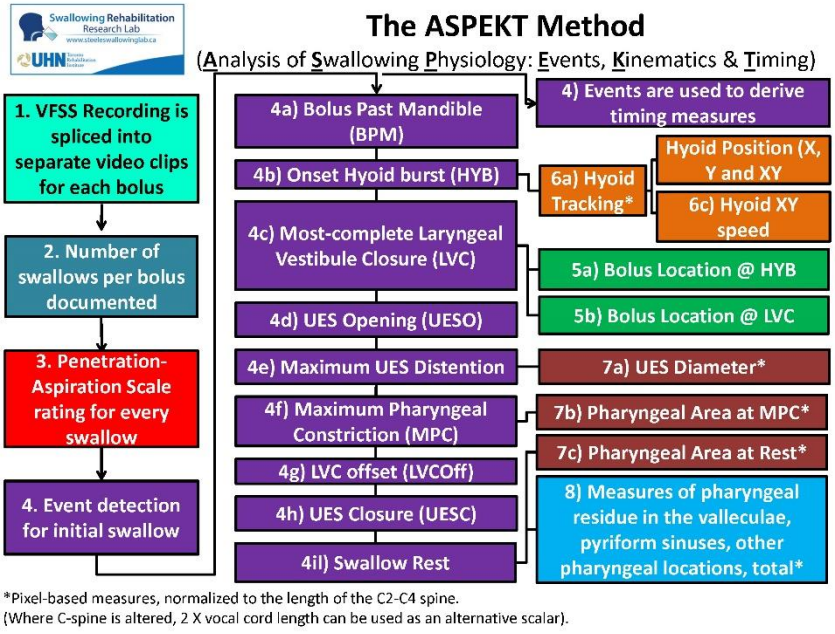


Figure 2: The ASPEKT Method

IMPORTANT NOTE: This instruction manual only provides guidance on post-VFSS analysis. For evidence-based recommendations on VFSS setup and protocol, please see our ***VFSS Best Practice Recommendations*** document at www.steeleswallowinglab.ca.

Introduction to the ASPEKT-C Method

Recognizing that time constraints are likely to make it impractical for a clinician to complete an analysis of every swallow in a videofluoroscopy recording using the full ASPEKT Method, the SRRL undertook to develop a shorter process for regular use by clinicians, called the ASPEKT-C Method (ASPEKT for use in Clinical Practice), shown in *Figure 3*.

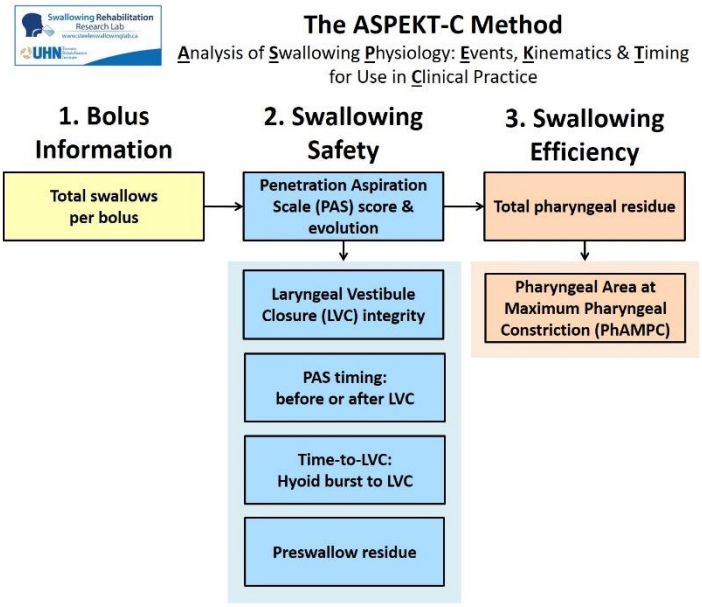


Figure 3: The ASPEKT-C Method

The goal of the ASPEKT-C Method is to assist clinicians in identifying the mechanisms underlying impaired swallowing safety and efficiency on VFSS. Swallowing safety is defined as the ability to protect the airway and swallowing efficiency as the ability to clear material through the pharynx.

The 8 key parameters of swallowing included in the ASPEKT-C Method have been chosen based on data suggesting that they are the parameters that most commonly explain penetration-aspiration and post-swallow residue in people with dysphagia. This conclusion was based on detailed analysis of several clinical datasets using the full ASPEKT Method: 1) a dataset of 305 individuals "at risk" for dysphagia (non-structural, non-congenital, non-oncologic); 2) cross-sectional studies in patient cohorts (Amyotrophic Lateral Sclerosis (ALS), Parkinson Disease (PD), traumatic Spinal Cord Injury (SCI), post-radiation oropharyngeal cancer, Chronic Obstructive Pulmonary Disease (COPD)); and 3) a growing set of other clinical cases.

The 8 key parameters can be compared to normative reference values from healthy volunteers (under age 60) published by Steele, Peladeau-Pigeon and colleagues (2019) and from healthy volunteers over 60 (Gandhi et al 2021). It is important to understand *how* those healthy reference values were collected to determine if they can be applied to your individual clinical setting and patients. Reference values for the ASPEKT-C Method were collected under the conditions described below.

☐ Videofluoroscopy yielding at 30 unique images per second	☐ Protocol to begin with IDDSI Level 0 thin liquids
☐ Low concentration barium (20%w/v)	☐ Stimuli mixed to meet IDDSI levels 0, 1, 2, 3, 4
☐ Xanthan gum thickened liquids	☐ Self-administered comfortable sips of IDDSI levels 0, 1 and 2
☐ Non-cued, spontaneous swallows	☐ Self-administered teaspoons of IDDSI levels 3 and 4

If you collect your data under different conditions, the strict ASPEKT-C Method reference values may not apply. Assessing how modifications of the conditions listed above influence your ability to compare your patient's values to the ASPEKT-C Method reference values is difficult. While there is some information in the literature that can guide how to interpret these changes, in many cases it is simply unknown.

CAUTION: References values may not be generalizable to other situations.

The reference values were collected using barium prepared to IDDSI levels 0, 1, 2, 3, 4 (*Figure 1*). The ASPEKT-C reference values provided for IDDSI level 3 moderately thick are also generalizable to "liquidised", on the "Foods" side of the framework. Similarly, IDDSI level 4 extremely thick reference values are generalizable to "pureed", on the "Foods" side of the framework. While reference values are included for IDDSI levels 0, 1, 2, 3 and 4, you may not need to test them all as part of your VFSS. Based on the research, thin liquid boluses are the most likely to reveal problems with swallowing safety. Therefore, it makes the most sense, to begin the exam with thin liquids in order to identify penetration-aspiration problems. For swallowing efficiency, the SRRL prefers to use discrete sips of mildly thick liquid. Other consistencies represent interventions that can be explored for their effectiveness in addressing safety and/or efficiency concerns.

Before You Get Started

Please ensure you have the following items available:

- ☐ Print out a copy of the ***VFSS Best Practice Recommendations*** *(*found at www.steeleswallowinglab.ca). This document contains evidence-based recommendations for VFSS. Read and consider each recommendation and how it applies to current VFSS practices within your institution.
- ☐ Print out a copy of the ***ASPEKT-C Method Worksheet*** (found at www.steeleswallowinglab.ca). This worksheet will guide you through the process of calculating quantitative measures based on your patient's VFSS. You will need a new worksheet every time you analyze a new VFSS.
- ☐ Print out a copy of the ***ASPEKT-C Method Scoring Sheet*** (found at www.steeleswallowinglab.ca). This scoring sheet provides instructions on how to carry over values from the ***ASPEKT-C Method Worksheet*** into a chart for comparison against healthy references.
- ☐ Download ImageJ software (found at https://imagej.nih.gov/ij/) or another frame-by-frame and pixel based measurement software. If you are unfamiliar with ImageJ, please find supplemental information under Appendix A of this Instruction Manual.

> ⚠ **CAUTION:** This manual provides step-by-step instructions using the ImageJ software ONLY.

ASPEKT-C Method Worksheet - Overview

Ensure that you have your ***ASPEKT-C Method Worksheet*** in front of you**.** This worksheet is divided into three sections, which have been colour-coded for ease of use and clarity (as shown in *Figure 4*):

Section 1: Bolus Information
Section 2: Swallowing Safety
Section 3: Swallowing Efficiency

1. BOLUS INFORMATION		2. SWALLOWING SAFETY						3. SWALLOWING EFFICIENCY	
1a. IDDSI Level and Bolus #	1b. Total swallows per bolus (e.g., 3)	2a. PAS Score	2b. LVC Integrity	2c. PAS Timing	2d. LVC Timing	2e. Preswallow Residue	2f. PAS Evolution	3a. Total Pharyngeal Residue	3b. PhAMPC
		For the initial swallow of the bolus, what is the PAS score? (1-8) *If PAS 1, 2 or 4, skip to 2f, else continue to 2b.*	For the initial swallow of the bolus, is LVC complete? (Y/N) *Continue 2c.*	Did PAS occur before or after LVC? *If before, continue to 2d. If after, skip to 2f.*	If the answer to 2c. was before LVC, calculate time-to-LVC (frames & milliseconds)[a]. Hyoid burst frame to first frame where laryngeal vestibule is most closed. *Continue to 2e.*	Is there any residue present at the beginning of the clip (before any new bolus enters the oral cavity)? (Y/N) *Continue to 2f.*	Is there evidence of a worse PAS score for later swallows of this bolus? If yes, what is that PAS score (1-8)? If no, enter "N/A". *Continue to 3a.*	Is there pharyngeal residue[b] at the end of the initial swallow of the bolus? If no, move to next bolus (1a). If yes, measure. Total pharyngeal residue = (V res. area + PS res. area + Other res. area) / (C2-4 length)² x 100% *Compare to scoring sheet. If atypical, continue to 3b.*	For the initial swallow, measure Pharyngeal Area at Maximum Pharyngeal Constriction (PhAMPC). PhAMPC = pharyngeal area / (C2-4 length)² x 100% *Move to next bolus (1a).*
					frames / milliseconds			V res. area; PS res. area; Other res. area; C2-4 length; calculation	pharyngeal area; C2-4 length; calculation

Figure 4: ***ASPEKT-C Method Worksheet***

As you move through the process, you will complete 1 row of the ***ASPEKT-C Method Worksheet*** for each bolus administered. If you have 6 boluses, you'll go through the ASPEKT-C Method 6 times, 1 bolus per row. It is important to analyze each bolus, and not collapse boluses of the same volume or consistency together, because we know that they may present differently within a single VFSS exam. For instance, patients who have impaired swallowing safety do not show penetration-aspiration on every swallow (Steele, Mukherjee, et al., 2019). It can be helpful to think of the ASPEKT-C Method as a "choose your own adventure" critical thinking pathway that we apply to each bolus. Not all 8 parameters of the ASPEKT-C Method may need to be completed for every bolus. This will be dictated by the patient's performance with that individual bolus and determined through a series of questions.

We will now explain each section of the ***ASPEKT-C Method Worksheet*** in detail with step-by-step instructions. You may wish to print out a hard copy of this instruction manual in colour so that you can quickly flip to sections of interest, particularly as you become more familiar with this document's content.

The information on each column or parameter of the ***ASPEKT-C Method Worksheet*** will be presented in the following format. Symbols have been incorporated to allow you to quickly locate information of interest.

"Not Applicable": Indicates if and/or when a parameter does NOT need to be completed. This information has intentionally been placed at the beginning of each section to prevent you from assessing a parameter, only to realize later that it is not required. Please note, this information is also available in the columns describing each parameter in the ***ASPEKT-C Method Worksheet***.

"Background": Explains the history behind a given ASPEKT-C Method parameter, its purpose, and why it was included in the ASPEKT-C Method. It may also include standardized definitions.

"How To": Describes how to analyze the parameter in question for the field and generate quantitative values where applicable.

"Next Step": Based on the results of the parameter you have just analyzed, this lets you know your next step.

"Example": This includes the ***ASPEKT-C Method Worksheet*** with sample values. This information will be surrounded by a black box.

ASPEKT-C Method Worksheet - Section 1: Bolus Information

1a. IDDSI Level and Bolus

Always complete this column for every bolus.

Background: The purpose of this column is to help keep track of exactly which bolus you are measuring, particularly since there can be multiple boluses of the same consistency and volume, each with unique ASPEKT-C Method measurement outcomes.

How to: Use this column to record the IDDSI level/consistency information and the bolus sequence or repetition number.

Next Step: Continue to the next column "*1b. Total Swallows per Bolus*" on the ***ASPEKT-C Method Worksheet***.

Example: If you administered 2 boluses of IDDSI level 0 thin, you would fill out *thin 1* and *thin 2* down the length of this column.

1. BOLUS INFORMATION		2. SWALLOWING SAFETY					
1a. IDDSI Level and Bolus #	1b. Total swallows per bolus (e.g., 3)	2a. PAS Score For the initial swallow of the bolus, what is the PAS score? (1-8) *If PAS 1, 2 or 4, skip to 2f, else continue to 2b.*	2b. LVC Integrity For the initial swallow of the bolus, is LVC complete? (Y/N) *Continue 2c.*	2c. PAS Timing Did PAS occur before or after LVC? *If before, continue to 2d. If after, skip to 2f.*	2d. LVC Timing If the answer to 2c. was before LVC, calculate time-to-LVC (frames & milliseconds)[a]. Hyoid burst frame to first frame where laryngeal vestibule is most closed. *Continue to 2e.*	2e. Preswallow Residue Is there any residue present at the beginning of the clip (before any new bolus enters the oral cavity)? (Y/N) *Continue to 2f.*	2f. PAS Evolution Is there evidence of a worse PAS score for later swallows of this bolus? If yes, what is that PAS score (1-8)? If no, enter "N/A". *Continue to 3a.*
Thin 1					frames / milliseconds		
Thin 2					frames / milliseconds		

Figure 5: ***ASPEKT-C Method Worksheet*** with column "*1a. IDDSI Level and Bolus #*" completed

1b. Total Swallows Per Bolus

Always complete this column for every bolus.

Background: One indicator of swallowing efficiency is the total number of swallows taken to clear the bolus. The purpose of this column is to tally the number of swallows taken. A swallow is defined as UES opening plus at least one of the following:

1. pharyngeal constriction,
2. laryngeal elevation and/or
3. hyoid excursion.

Two points of caution:

1) Do NOT include swallow attempts (e.g., hyoid and laryngeal excursion in the absence of UES opening) in the total number of swallows per bolus. For example, if on a given bolus there are 3 swallows and 1 swallow attempt, the total number of swallows is 3. On boluses where there is never any UES opening on any of the associated subswallows, and the patient is required to expectorate or suction out the entire bolus, do not use the ASPEKT-C Method to score this trial. The comments section on the ***ASPEKT-C Method Scoring Sheet*** may be used to document this important finding.
1) You may wish to differentiate between spontaneous and clinician-cued subswallows (e.g., did you ask the patient to swallow again or did they swallow/spontaneously/un-cued) in your notes here as it may provide information about the patient's sensation or awareness of residue.

How To: Indicate the total number of swallows taken to clear the bolus that were captured before the fluoroscopy was turned off.

Next Step: Continue to the blue section entitled "*2. Swallowing Safety*", more specifically the next column "*2a. PAS Score*" on the ***ASPEKT-C Method Worksheet***.

Example: If you witness a patient swallow 4 times to clear their first single cup sip of thin liquids, enter the number *4* in the first row of this column.

1. BOLUS INFORMATION		2. SWALLOWING SAFETY					
1a. IDDSI Level and Bolus #	1b. Total swallows per bolus (e.g., 3)	2a. PAS Score	2b. LVC Integrity	2c. PAS Timing	2d. LVC Timing	2e. Preswallow Residue	2f. PAS Evolution
		For the initial swallow of the bolus, what is the PAS score? (1-8) *If PAS 1, 2 or 4, skip to 2f, else continue to 2b.*	For the initial swallow of the bolus, is LVC complete? (Y/N) *Continue 2c.*	Did PAS occur before or after LVC? *If before, continue to 2d. If after, skip to 2f.*	If the answer to 2c. was before LVC, calculate time-to-LVC (frames & milliseconds)[a]. Hyoid burst frame to first frame where laryngeal vestibule is most closed. *Continue to 2e.*	Is there any residue present at the beginning of the clip (before any new bolus enters the oral cavity)? (Y/N) *Continue to 2f.*	Is there evidence of a worse PAS score for later swallows of this bolus? If yes, what is that PAS score (1-8)? If no, enter "N/A". *Continue to 3a.*
Thin 1	4				frames / milliseconds		

Figure 6: ***ASPEKT-C Method Worksheet*** with column "*2a. Total Swallows per Bolus*" completed

ASPEKT-C Method Worksheet - Section 2: Swallowing Safety

2a. Penetration-Aspiration Scale Score

Always complete this column for every bolus.

Background: The 8-point Penetration Aspiration Scale (PAS) (Rosenbek et al., 1996) (*Figure 7 A*) has become the standard way of describing the severity of airway invasion. The scale can be broken down into different levels. Steele and Grace-Martin slightly adapted this scale in 2017. They proposed a modified scale where a PAS score of 4, describing material that contacts the vocal fold but is ejected from the airway, reflects normal function. For our purpose in ASPEKT-C, the scale can be broken down into two categories (*Figure 7 B*). PAS scores of 1, 2 and 4 are considered "typical" as no material is left within the airway. PAS scores of 3, 5 and higher fall into the "atypical" range, as whenever material enters the supraglottic space and stays there, it is at risk for eventual aspiration.

A

8-Point Penetration-Aspiration Scale
(Rosenbek et al., 1996)

1	Material does not enter the airway
2	Material enters the airway, remains above the vocal folds, and is ejected from the airway
3	Material enters the airway, remains above the vocal folds, and is NOT ejected from the airway
4	Material enters the airway, contacts the vocal folds, and is ejected from the airway
5	Material enters the airway, contacts the vocal folds, and is NOT ejected from the airway
6	Material enters the airway, passes below the vocal folds, and is ejected into the larynx or out of the airway
7	Material enters the airway, passes below the vocal folds, and is NOT ejected from the trachea despite effort
8	Material enters the airway, passes below the vocal folds, and no effort is made to eject

B

Dichotomized Penetration-Aspiration Scale
(for use in ASPEKT-C)

1	Material does not enter the airway	Typical
2	Material enters the airway, remains above the vocal folds, and is ejected from the airway	
4	Material enters the airway, contacts the vocal folds, and is ejected from the airway	
3	Material enters the airway, remains above the vocal folds, and is NOT ejected from the airway	Atypical
5	Material enters the airway, contacts the vocal folds, and is NOT ejected from the airway	
6	Material enters the airway, passes below the vocal folds and is ejected into the larynx or out of the airway	
7	Material enters the airway, passes below the vocal folds, and is NOT ejected from the trachea despite effort	
8	Material enters the airway, passes below the vocal folds, and no effort is made to eject	

Figure 7: A) Penetration Aspiration Scale (Rosenbek et al, 1996);
B) Dichotomized Penetration-Aspiration Scale for use in the ASPEKT-C Method

How To: For the initial swallow of the bolus, identify the PAS score.

Next Step:

What is your PAS score on the first swallow of this bolus?	
PAS of 1, 2, 4	**PAS of 3, 5, 6, 7, 8**
These scores are considered "typical".	These scores are considered "atypical".
Skip ahead to "*2f. PAS Evolution*" on the ***ASPEKT-C Method Worksheet*.**	Continue to "*2b. LVC Integrity*" on the ***ASPEKT-C Method Worksheet*** to investigate possible contributors.

2b. Laryngeal Vestibule Closure (LVC) Integrity

Not Applicable: Do not complete this column if the *"2a. PAS score"* was "typical" (i.e., 1, 2, or 4).

Background: If the PAS score is "atypical" (i.e., scores of 3, 5, 6, 7 or 8), examine Laryngeal Vestibule Closure (LVC) integrity. LVC is one of the most critical parameters associated with airway protection. Complete LVC is defined as a complete seal between epiglottis and arytenoids leaving no visible airspace or contrast in the laryngeal vestibule (see *Figure 8 A*). Incomplete closure includes any amount of air or contrast in the laryngeal vestibule. This can include a wide gap with minimal to no closure (see *Figure 8 B*) or partial tissue contact between the arytenoids and laryngeal surface of the epiglottis (see *Figure 8 C*).

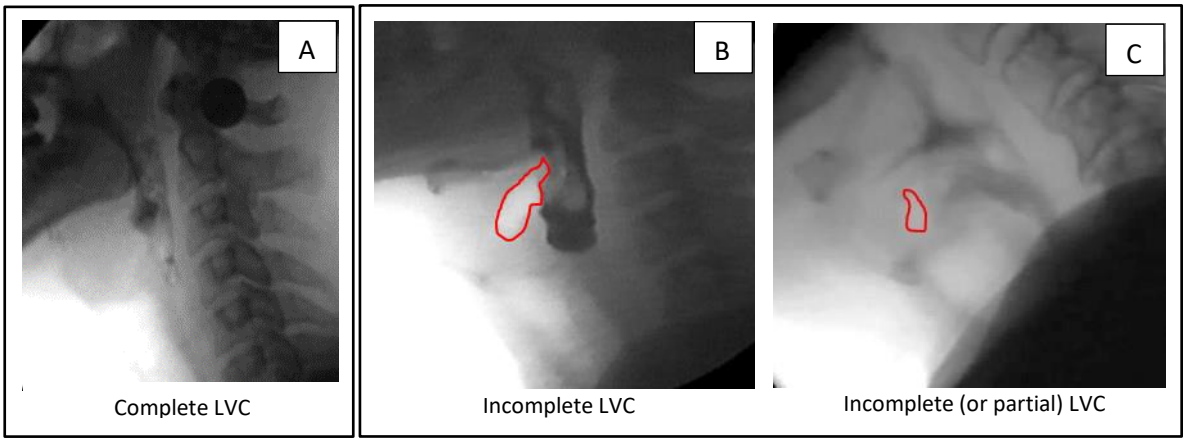


Figure 8: Sample images showing complete LVC (A) and incomplete closure (B) & (C).

How To: For the initial swallow of the bolus, determine if complete LVC occurred. "Yes" indicates complete closure and "No" indicates incomplete or partial closure.

Next Step:

Did complete LVC occur?	
Yes – Complete LVC	**No – Incomplete or Partial LVC**
This is considered "typical". It suggests that it is not the integrity of LVC but rather the timing that may be impaired, leading to a PAS event.	This is considered "atypical". The PAS event may be occurring due to inability to achieve complete airway closure during the swallow. However, this may not be the only factor leading to the PAS event.
Continue to the next column "*2c. PAS Timing*" on the ***ASPEKT-C Method Worksheet.***	

Example: This sample figure below demonstrates that you must have an "atypical" PAS score in order to move on to *"2b. LVC Integrity".* It also demonstrates that there are two potential responses to column *"2b. LVC Integrity"*, yes ("Y") or no ("N").

1. BOLUS INFORMATION		2. SWALLOWING SAFETY					
1a. IDDSI Level and Bolus #	1b. Total swallows per bolus (e.g., 3)	2a. PAS Score	2b. LVC Integrity	2c. PAS Timing	2d. LVC Timing	2e. Preswallow Residue	2f. PAS Evolution
		For the initial swallow of the bolus, what is the PAS score? (1-8) *If PAS 1, 2 or 4, skip to 2f, else continue to 2b.*	For the initial swallow of the bolus, is LVC complete? (Y/N) *Continue 2c.*	Did PAS occur before or after LVC? *If before, continue to 2d. If after, skip to 2f.*	If the answer to 2c. was before LVC, calculate time-to-LVC (frames & milliseconds)[a]. Hyoid burst frame to first frame where laryngeal vestibule is most closed. *Continue to 2e.*	Is there any residue present at the beginning of the clip (before any new bolus enters the oral cavity)? (Y/N) *Continue to 2f.*	Is there evidence of a worse PAS score for later swallows of this bolus? If yes, what is that PAS score (1-8)? If no, enter "N/A". *Continue to 3a.*
		MUST be: 3, 5, 6, 7, 8	Y		frames / milliseconds		
		MUST be: 3, 5, 6, 7, 8	N		frames / milliseconds		

Figure 9: ***ASPEKT-C Method Worksheet*** with column "2b. *LVC Integrity"* completed for two separate boluses

2c. PAS Timing

Not Applicable: Do not complete this column if *"2a. PAS Score"* was "typical" (i.e., 1, 2, or 4).

Background: Regardless of whether the LVC closure was achieved under "*2b. LVC Integrity*", we want to know more about why the PAS event occurred. The first step is to look at timing and ask when the PAS event occurred.

How To: For the PAS event observed on the initial swallow of the bolus, determine if it occurred before or after LVC.

Next Step:

Did PAS occur before or after LVC?	
Before	**After**
When the PAS event occurs before LVC, it is possible the system did not react quickly enough to the incoming bolus.	When the PAS event occurs after LVC, it is possible that the patient is penetrating or aspirating residue on which they displayed impaired swallowing efficiency.
Continue to "*2d. LVC Timing*" on the ***ASPEKT-C Method Worksheet*.**	Skip ahead to "*2f. PAS Evolution*" on the ***ASPEKT-C Method Worksheet***.

Example: This demonstrates that there are two potential responses to column *"2c. PAS Timing"*.

1. BOLUS INFORMATION		2. SWALLOWING SAFETY					
1a. IDDSI Level and Bolus #	1b. Total swallows per bolus (e.g., 3)	2a. PAS Score For the initial swallow of the bolus, what is the PAS score? (1-8) *If PAS 1, 2 or 4, skip to 2f, else continue to 2b.*	2b. LVC Integrity For the initial swallow of the bolus, is LVC complete? (Y/N) *Continue 2c.*	2c. PAS Timing Did PAS occur before or after LVC? *If before, continue to 2d. If after, skip to 2f.*	2d. LVC Timing If the answer to 2c. was before LVC, calculate time-to-LVC (frames & milliseconds)[a]. Hyoid burst frame to first frame where laryngeal vestibule is most closed. *Continue to 2e.*	2e. Preswallow Residue Is there any residue present at the beginning of the clip (before any new bolus enters the oral cavity)? (Y/N) *Continue to 2f.*	2f. PAS Evolution Is there evidence of a worse PAS score for later swallows of this bolus? If yes, what is that PAS score (1-8)? If no, enter "N/A". *Continue to 3a.*
				before	frames / milliseconds		
				after	frames / milliseconds		

Figure 10: ***ASPEKT-C Analysis Worksheet*** with column "2c. *PAS Timing"* completed for 2 separate boluses

2d. LVC Timing

Not Applicable:
Do not complete this column if *"2a. PAS score"* was WNL (i.e., 1, 2, or 4).
Do not complete this column if PAS event in "*2c. PAS Timing*" occurred "after" the swallow.

Background: Once we have established that the PAS event occurred before LVC, we need to look at how quickly the system responded to the incoming bolus. The system's response is called *"time-to-LVC"* which represents the time from the "hyoid burst frame" to "LVC frame". This parameter is sometimes referred to as Laryngeal Vestibule Closure reaction time (LVCrt) in the literature.

Hyoid burst frame: The first frame of the rapid anterior-superior movement of the hyoid associated with the first swallow. The moment where the hyoid appears to "take off" or "burst".

LVC frame: The frame of maximum approximation of the arytenoids to the epiglottis during the first swallow. In other words, the first frame when the laryngeal vestibule is the most closed.

NOTE: 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.

How To: For the initial swallow of the bolus, calculate time-to-LVC.

The first step is to calculate the difference between the hyoid burst frame number and the LVC frame number. Example: hyoid burst frame=20, LVC frame=40, time-to-LVC value= 20 frames

The second step is to convert the value into milliseconds. To do this, divide your value in frames by the recording frame rate (i.e., number of images captured per second) then multiply by **1000**. If you are unsure about your recording frame rate, speak with your radiology department.
Example: 20 frames / (30 frames per second) x 1000 = 667 ms

Next Step: Once *"2d. LVC Timing"* is calculated, continue to "*2e. Preswallow Residue"* on the ***ASPEKT-C Method Worksheet***.

Example: If the hyoid burst occurs at frame 1125 and LVC at frame 1150, this means time-to-LVC is 25 frames.

1. BOLUS INFORMATION		2. SWALLOWING SAFETY					
1a. IDDSI Level and Bolus #	1b. Total swallows per bolus (e.g., 3)	2a. PAS Score For the initial swallow of the bolus, what is the PAS score? (1-8) *If PAS 1, 2 or 4, skip to 2f, else continue to 2b.*	2b. LVC Integrity For the initial swallow of the bolus, is LVC complete? (Y/N) *Continue 2c.*	2c. PAS Timing Did PAS occur before or after LVC? *If before, continue to 2d. If after, skip to 2f.*	2d. LVC Timing If the answer to 2c. was before LVC, calculate time-to-LVC (frames & milliseconds)[a]. Hyoid burst frame to first frame where laryngeal vestibule is most closed. *Continue to 2e.*	2e. Preswallow Residue Is there any residue present at the beginning of the clip (before any new bolus enters the oral cavity)? (Y/N) *Continue to 2f.*	2f. PAS Evolution Is there evidence of a worse PAS score for later swallows of this bolus? If yes, what is that PAS score (1-8)? If no, enter "N/A". *Continue to 3a.*
				MUST be: before	20 frames / 667 ms (frames / milliseconds)		

Figure 11: ***ASPEKT-C Method Worksheet*** with column "2d. *LVC Timing"* completed

2e. Preswallow residue

Always complete this column for every bolus.

Background: One indicator of swallowing safety is the presence of residue before any new bolus is administered. When compared to clean baseline swallows, swallows with pre-existing or preswallow residue exceeding a consistency specific threshold had double the odds of an atypical PAS score of ≥3 (Steele et. al., 2020). The purpose of this column is to identify whether or not there is any residue present in the pharynx before any new bolus is administered.

How To: Indicate whether or not there is any residue present in the pharynx at the beginning of the video clip (before any new bolus enters the oral cavity). More specifically, before any new bolus enters the pharynx

Note: You may not be able to assess this parameter if the fluoro was turned on after the bolus entered the oral cavity or pharynx.

Next Step: Continue to *"2f. PAS Evolution"* on the ***ASPEKT-C Method Worksheet***.

Example: This demonstrates that there are two potential responses to column *"2e. Preswallow Residue"*.

1. BOLUS INFORMATION		2. SWALLOWING SAFETY					
1a. IDDSI Level and Bolus #	1b. Total swallows per bolus (e.g., 3)	2a. PAS Score For the initial swallow of the bolus, what is the PAS score? (1-8) *If PAS 1, 2 or 4, skip to 2f, else continue to 2b.*	2b. LVC Integrity For the initial swallow of the bolus, is LVC complete? (Y/N) *Continue 2c.*	2c. PAS Timing Did PAS occur before or after LVC? *If before, continue to 2d. If after, skip to 2f.*	2d. LVC Timing If the answer to 2c. was before LVC, calculate time-to-LVC (frames & milliseconds)[a]. Hyoid burst frame to first frame where laryngeal vestibule is most closed. *Continue to 2e.*	2e. Preswallow Residue Is there any residue present at the beginning of the clip (before any new bolus enters the oral cavity)? (Y/N) *Continue to 2f.*	2f. PAS Evolution Is there evidence of a worse PAS score for later swallows of this bolus? If yes, what is that PAS score (1-8)? If no, enter "N/A". *Continue to 3a.*
					frames / milliseconds	Y	
					frames / milliseconds	N	

Figure 12: ***ASPEKT-C Method Worksheet*** with column "2e. *Preswallow Residue*" completed for 2 separate boluses

2f. PAS Evolution

Always complete this column for every bolus.

Background: Now we want to take a step back and look at all the swallows of this particular bolus; is there evidence of a worse PAS score on any of the swallows involving this bolus? For instance, a patient may perform 4 swallows for a single bolus and over that time, the PAS score may worsen (e.g., penetration becomes aspiration or new material is aspirated on a later swallow of the same bolus). If the PAS score does not worsen across later swallows for the bolus and remains consistent with the initial value from "*2a. PAS score*", enter "N/A".

How To: Is there evidence of a worse PAS score for this bolus compared to the initial value in "*2a. PAS Score*"? If yes, include that PAS score. If no, enter "N/A".

Next Step: Continue to section *"3. Swallowing Efficiency"* on the ***ASPEKT-C Method Worksheet***.

Example: You already completed column *"2a. PAS Score"* and indicated a PAS score of *2* on the first swallow of the bolus. However, with the second or third swallows of this same bolus, material falls below the true vocal folds and there is no cough response. This evolution to a score of *8*, should be captured under column "*2f. PAS Evolution*". As a second example, if you completed column *"2a. PAS Score"* and indicated a PAS score of *4* on the first and only swallow of the bolus, we would enter "N/A" under column "*2f. PAS Evolution*".

1. BOLUS INFORMATION		2. SWALLOWING SAFETY					
1a. IDDSI Level and Bolus #	1b. Total swallows per bolus (e.g., 3)	2a. PAS Score For the initial swallow of the bolus, what is the PAS score? (1-8) *If PAS 1, 2 or 4, skip to 2f, else continue to 2b.*	2b. LVC Integrity For the initial swallow of the bolus, is LVC complete? (Y/N) *Continue 2c.*	2c. PAS Timing Did PAS occur before or after LVC? *If before, continue to 2d. If after, skip to 2f.*	2d. LVC Timing If the answer to 2c. was before LVC, calculate time-to-LVC (frames & milliseconds)[a]. Hyoid burst frame to first frame where laryngeal vestibule is most closed. *Continue to 2e.*	2e. Preswallow Residue Is there any residue present at the beginning of the clip (before any new bolus enters the oral cavity)? (Y/N) *Continue to 2f.*	2f. PAS Evolution Is there evidence of a worse PAS score for later swallows of this bolus? If yes, what is that PAS score (1-8)? If no, enter "N/A". *Continue to 3a.*
		2			frames / milliseconds		8
		4			frames / milliseconds		N/A

Figure 13: ***ASPEKT-C Method Worksheet*** with column "2f. *PAS Evolution"* completed for two separate boluses

ASPEKT-C Method Worksheet – Section 3: Swallowing Efficiency

3a. Total Pharyngeal Residue

Not Applicable: If there is no pharyngeal residue at the end of the initial swallow of the bolus, you do not need to measure *"3a. Total Pharyngeal Residue"* or "3b. PhAMPC". Move on to the next bolus in the VFSS by returning to "*1a. IDDSI Level and Bolus #*".

Background: A second criterion to consider when determining whether swallowing impairments are present is swallowing efficiency. Efficiency is defined as the ability to clear material through the pharynx. The total pharyngeal residue includes any remaining bolus material in the valleculae, pyriform sinuses, and/or elsewhere in the pharynx. Note that in the ASPEKT-C Method, oral residue is not quantitatively calculated.

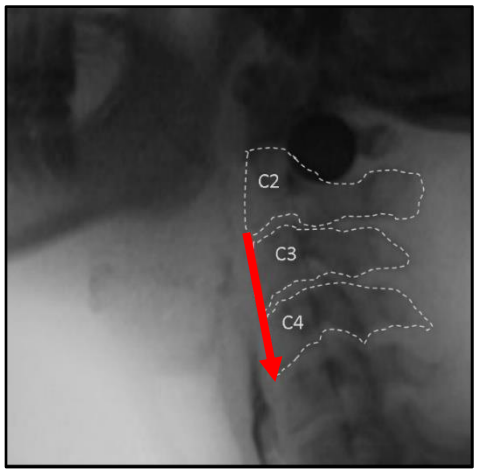


Figure 14: Sample image of cervical spine

As part of the ASPEKT-C Method, residue severity is measured at the end of the initial swallow for the bolus. If there are 4 swallows associated with a single bolus, measure the residue remaining after the first swallow only. This is important, as subsequent swallows may be a compensatory measure that reduce residue and underestimate a patient's level of impairment.

Scaling measurements to the length of the C2-C4 cervical spine controls for differences in the size of the system including sex-based or height based differences (Molfenter and Steele, 2014). By tailoring the residue measures to an individual's anatomy, comparisons can be made between anatomically normalized measures within or across exams. It is important to identify C2-C4 correctly. C1-C3 cannot be substituted as it is significantly longer (Nagy et al., 2015). See *Figure 14* for a sample tracing from the anterior inferior corner of C2 to the anterior inferior corner of C4.

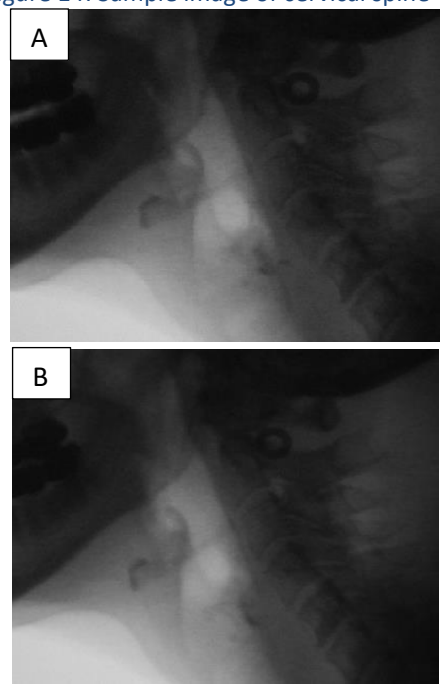


Figure 15: Sample images of (A) a positioning frame prior to administration of any boluses taken at the beginning of the VFSS showing darkness overlying the pyriform sinuses and (B) a frame after the patient swallowed a bolus of barium.

Caution: When assessing the presence or absence of pharyngeal residue, there may be darker structures overlying the pharynx, particularly the pyriform sinuses, which can act as confounding factors, potentially inflating residue severity. In these cases, comparing a clean positioning frame taken from the very beginning of the VFSS (see example in *Figure 15A*) to your frame of interest (see example in *Figure 15B*) may be helpful to minimize the risk of overestimating residue.

Note: Larger volume boluses are likely to leave greater residue. Higher barium concentrations (i.e. ≥ 60% w/v) are more likely to leave a coating on the walls of the pharynx, which may be difficult to distinguish from residue.

How To: Is there pharyngeal residue at the end of the initial swallow of the bolus? If yes, measure the pharyngeal residue using the step-by-step instructions below.

Step 1: Identify the frame on which to measure residue

For the first swallow of the bolus, select the first frame showing the pyriform sinuses at their lowest position (relative to the spine) at the end of the swallow, prior to any hyoid burst or laryngeal elevation related to an ensuing sub-swallow (if any). The frame on which you want to measure may look very similar to the image of the pharynx taken at the beginning of the VFSS, in that the pharynx should be rested or relaxed. Use the forward and backwards arrow keys on your keyboard to move frame by frame, to locate the frame that meets this definition. Avoid frames that are "blurred" due to additional patient movement.

Figure 16: Frame selected for total pharyngeal residue measurement showing rested or relaxed pharynx

Step 2: Measure residue in the pharynx

Trace the residue remaining in each of the spaces (valleculae, pyriform sinuses and other), one at a time, using the following steps. If a particular space does not contain any residue, there is no need to trace – simply write '0' in the designated field on the ***ASPEKT-C Method Worksheet***.

i. Select the *Freehand* tool (*Figure 17*).

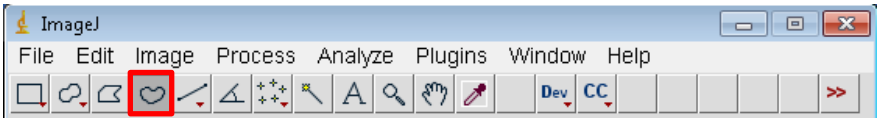


Figure 17: ImageJ *Freehand* tool

ii. Click and hold to trace a contour line around the area of interest. See sample images in *Figure 18* for tracings of each space (valleculae in yellow, pyriform sinuses in green and other in blue). The boundaries of the pharynx are defined to include all space:

- above the UES
- below the top of C2
- posterior to the arytenoids, base of tongue, and pharyngeal surface of the epiglottis
- anterior to the posterior pharyngeal wall

NOTE: Do not include penetrated or aspirated material in the laryngeal vestibule.

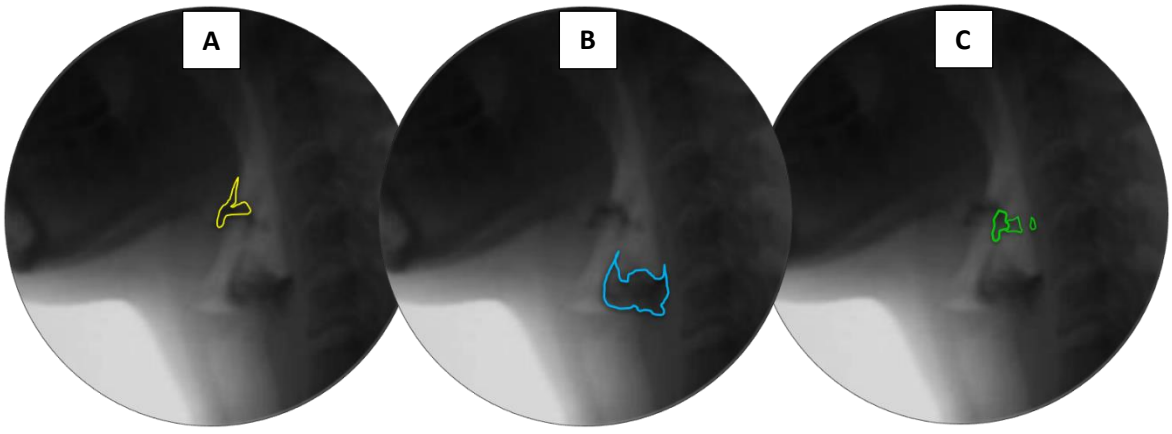


Figure 18: Sample tracings of remaining residue in A) valleculae, B) pyriform sinuses, C) other

QUICK TIP: To refine or adjust the residue area tracing, follow these steps:

- Right-click on the *Oval* tool and choose *Selection Brush* tool (*Figure 19 left*).
- Click and hold down to adjust the area tracing.
  - Double click on the *Oval* tool to change the size of the brush (*Figure 19 right*).
- Use this tool to nudge the contour line already created around the residue.

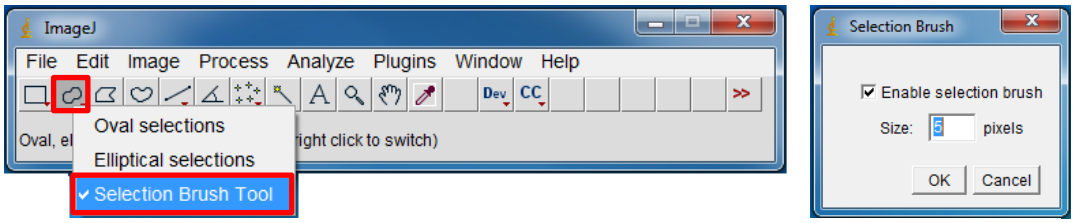


Figure 19: Selection Brush tool in ImageJ

iii. Press Ctrl + M when you have completed the area tracing.
   - If this is your first measurement, a *Results* box will open automatically. Leave the *Results* box open as it will continue to add measurements taken.

iv. Enter the *Area* value in the designated field on the ***ASPEKT-C Method Worksheet.***

v. Repeat these steps for each of these three spaces (valleculae, pyriform sinuses and other).

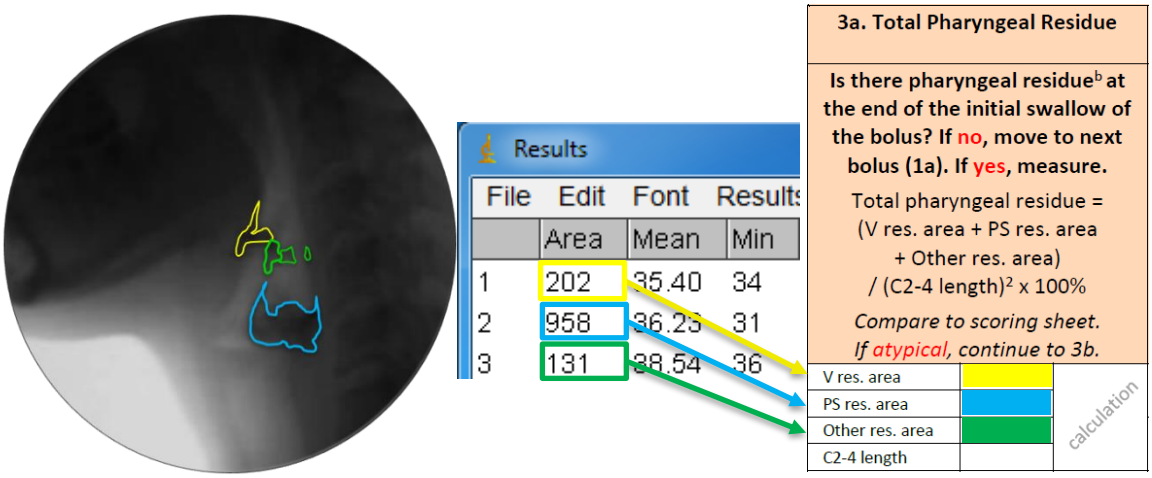


Figure 20: Sample total pharyngeal residue area measurement

Step 3: Measure the C2-C4 cervical spine length scalar

i. Select the *line* tool (see *Figure 21*).

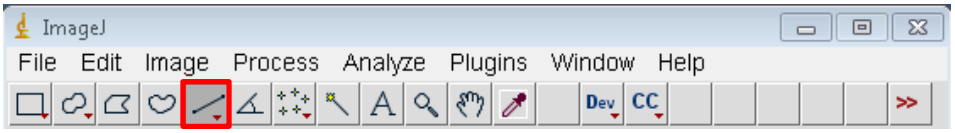


Figure 21: ImageJ *line* tool

ii. Click (and hold) on the anterior inferior edge of C2 vertebral body.

iii. Hold the mouse button down and drag to draw a line to the anterior inferior edge of C4.
   - If you make a mistake, click anywhere on the image and the line will disappear.

iv. Press Ctrl + M. ImageJ will append this measurement to the *Results* table.

v. Enter the *length* value in the designated field on the ***ASPEKT-C Method Worksheet***.

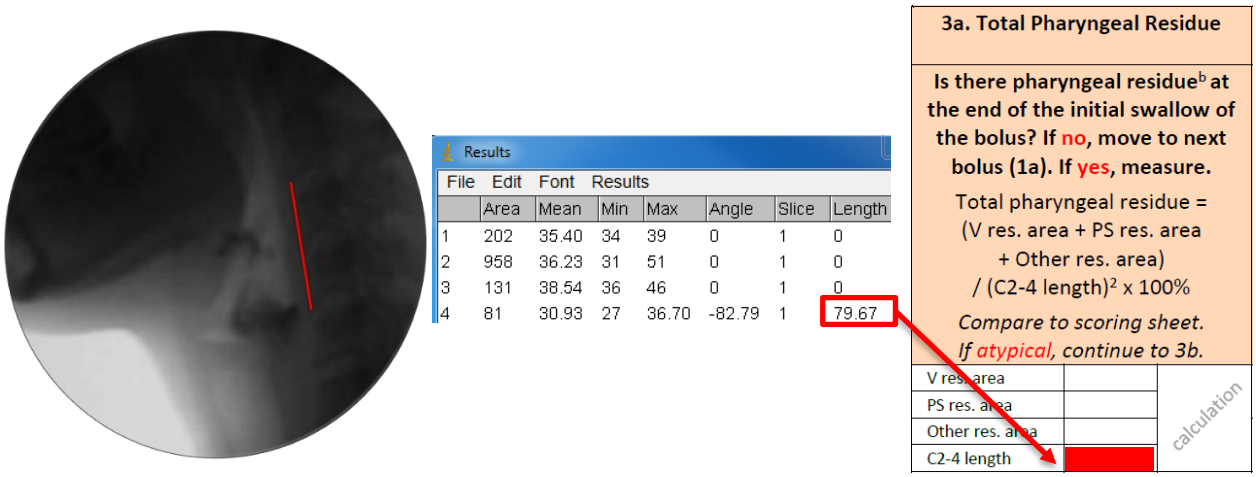


Figure 22: Sample cervical spine C2-C4 length measurement

Step 4: Calculate total pharyngeal residue

Calculate the total pharyngeal residue as a percent of the C2-C4 squared space using the formula included in the "*3a. Total Pharyngeal Residue*" column on the ***ASPEKT-C Method Worksheet.*** The residue shown in *Figure 23* can be calculated as follows. The red dashed square in *Figure 23* shows the $(C2\text{-}C4)^2$ reference area (i.e., C2-C4 length squared) to which residue area(s) is compared. In this example, the total pharyngeal residue is equivalent to 20.1% of the red-dashed square.

$$Total\ Pharyngeal\ residue$$

$$= \frac{V\ res.area + PS\ res.\ area + Other\ res.area}{(C2 - C4\ length)^2} x\ 100\%$$

$$= \frac{202 + 958 + 131}{(79.67)^2} x\ 100\% = \ 20.1\%$$

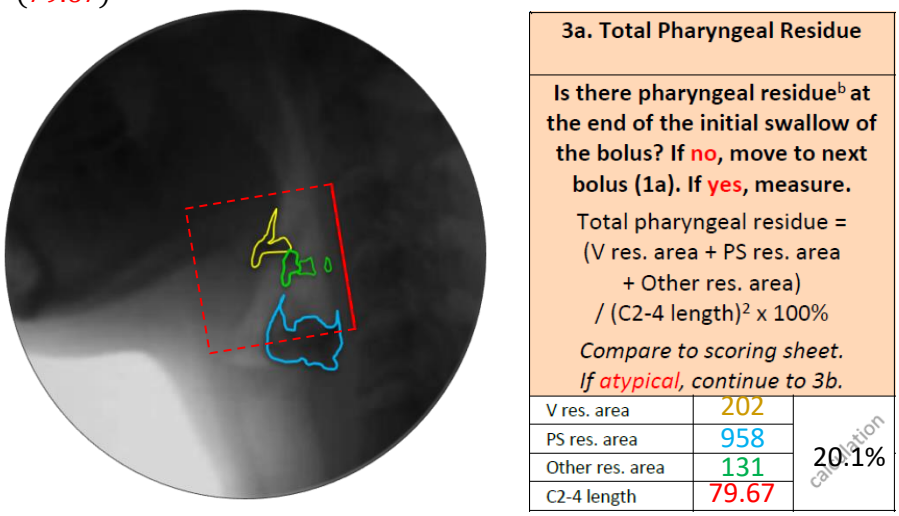


Figure 23: Sample total pharyngeal residue tracing and completed ***ASPEKT-C Method Worksheet***

Next Step:

Compare the total pharyngeal residue value to the *ASPEKT-C Method Scoring Sheet* to determine if it is "typical" or "atypical".	
Typical	**Atypical**
Move on to score the next bolus in your VFSS by returning to "*1a. IDDSI Level and Bolus #*".	Continue to "*3b. PhAMPC*" on the ***ASPEKT-C Method Worksheet***.

3b. Pharyngeal Area at Maximum Pharyngeal Constriction (PhAMPC)

Not Applicable: If there is no pharyngeal residue or "typical" residue identified in column "*3a. Total Pharyngeal Residue"*, there is no need to complete this section. Move on to score the next bolus in the VFSS by returning to "*1a. IDDSI Level and Bolus #*".

Background: Once it has been determined that "atypical" pharyngeal residue is present at the end of the first swallow, we want to examine the underlying mechanism leading to the efficiency impairment. In the ASPEKT-C Method, the next step is to look at Pharyngeal Area at Maximum Pharyngeal Constriction (PhAMPC). This is defined as the area of unobliterated visible airspace and/or bolus at maximum constriction during the first swallow of the bolus.

As mentioned in column "*3a. Total Pharyngeal Residue*", the ASPEKT-C Method scales quantitative measurements such as total pharyngeal residue and PhAMPC to the length of the C2-C4 cervical spine to control for differences in the size of the system.

NOTE: Older adults are likely to display larger PhAMPC.

How To: For the initial swallow, measure pharyngeal area at maximum pharyngeal constriction (PhAMPC). You can measure PhAMPC using the step-by-step instructions below.

Step 1: Identify the frame on which to measure PhAMPC
For the first swallow of the bolus, select the earliest frame showing maximum obliteration or squeeze of the pharynx. This frame must occur before the upper pharynx begins to relax and before the tracheal air column begins to descend.

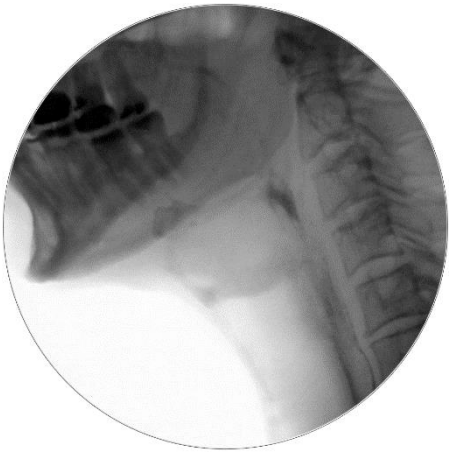


Figure 24: Frame selected for PhAMPC measurement

IMPORTANT NOTE: Upper boundary of the Pharynx

When tracing residue in the pharynx do not go higher than the top of the C2 vertebral body shown in *Figure 25*. While it is not necessary to draw a line as shown in *Figure 25,* it may be helpful to visualize a right angle tool that cuts across the top of the pharynx visually. While it is rare for bolus to appear at that level on your PhAMPC frame, it may be possible particularly in cases when patients have escape of the bolus into the nasopharynx.

Figure 25: Image showing upper boundary of pharynx

Step 2: Measure the remaining visible airspace or bolus in the pharyngeal area

i. Select the *Freehand* tool.

ii. Click and hold to trace a contour line around the area of visible air space and residue in the pharynx.

- If there is no visible air space and/or residue, there is no need to trace. In this case, simply write "0" in the designated field on the ***ASPEKT-C Method Worksheet***.

NOTE: The boundaries of the pharynx are defined to include all space:

- above the UES
- below the top of C2 - see "Important Note" from Step 1 *Figure 25*Figure
- posterior to the arytenoids, base of the tongue, and pharyngeal surface of the epiglottis
- anterior to the posterior pharyngeal wall

QUICK TIP: To refine or adjust the residue area tracing, follow these steps:

- Right-click on the *Oval* tool and choose *Selection Brush* tool (*Figure 26 left*).
- Click and hold down to adjust the area tracing.
  - Double click on the *Oval* tool to change the size of the brush (*Figure 26 right*).
- Use this tool to nudge the contour line already created around the residue.

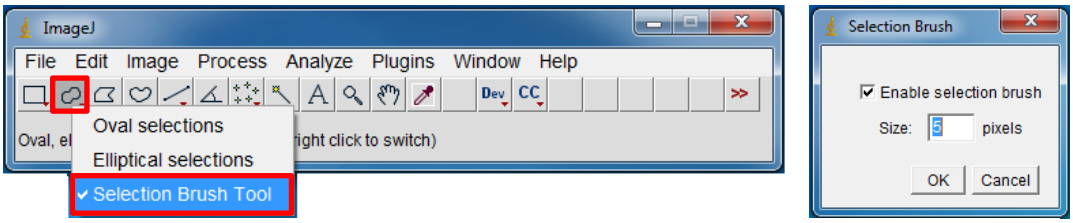


Figure 26: Selection Brush tool in ImageJ

iii. Press Ctrl + M when you have completed the area tracing, a *Results* box will open automatically.

iv. Enter the *Area* value in the designated field in the ***ASPEKT-C Method Worksheet***.

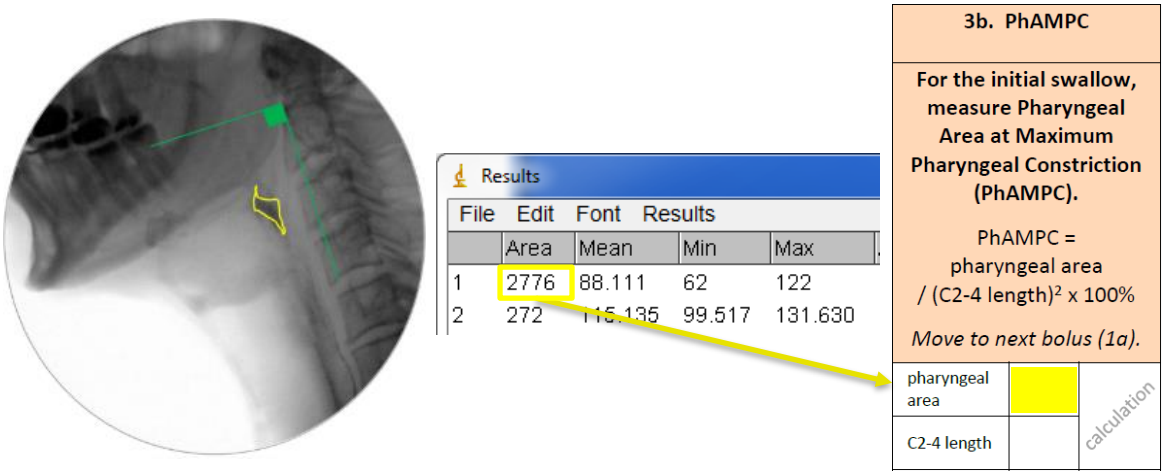


Figure 27: Sample pharyngeal area measurement

Step 3: Measure the C2-C4 cervical spine length scalar

i. Select the *line* tool (*Figure 28*).

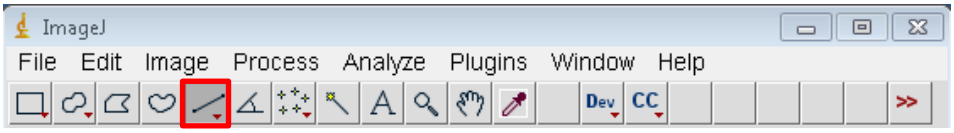


Figure 28: ImageJ *line* tool

ii. Click (and hold) on the anterior inferior edge of C2 vertebrae.

iii. Hold the mouse button down and drag to draw a line to the anterior inferior edge of C4.
- If you make a mistake, click anywhere on the image and the line will disappear.

iv. Press Ctrl + M. ImageJ will append this measurement to the *Results* table.

v. Enter the *length* value in the designated field on the ***ASPEKT-C Method Worksheet***.

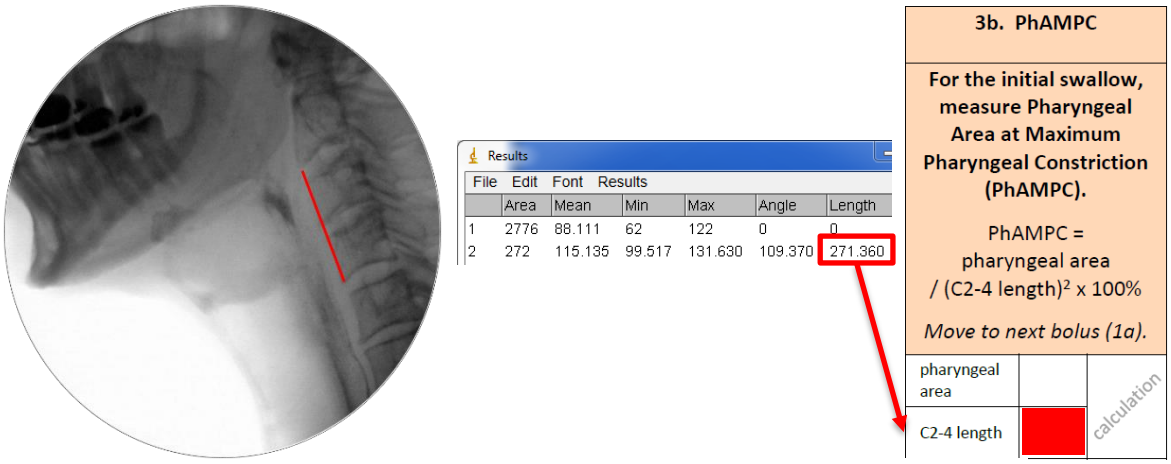


Figure 29: Sample cervical spine length measurement

Step 4: Calculate PhAMPC

Calculate the PhAMPC as a percent of the C2-C4 squared space using the formula included in the "*3b. PhAMPC*" column on the ***ASPEKT-C Method Worksheet.*** The unobliterated area of the pharynx shown in *Figure 30* can be calculated as follows. The red dashed square in *Figure 30* shows the $(C2\text{-}C4)^2$ reference area (i.e., C2-C4 length squared) to which the measured area is compared. In this example, PhAMPC is 3.8% of the red-dashed square.

$$PhAMPC = \frac{pharyngeal\ area}{(C2 - C4\ length)^2} x\ 100\% = \frac{2776}{(271.36)^2} x\ 100\% = 3.8\%$$

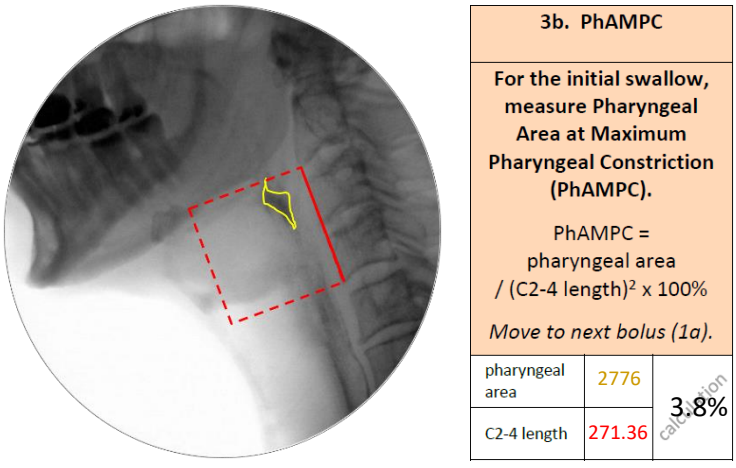


Figure 30: Sample image showing PhAMPC

Next Step: Move on to score the next bolus in your VFSS, returning to "*1a. IDDSI Level and Bolus #s*".

ASPEKT-C Method Scoring Sheet

1. On the ***ASPEKT-C Method Scoring Sheet***, complete the "*My Patient Values*" table (*Figure 31* by transferring the worst value per parameter per consistency from your ***ASPEKT-C Method Worksheet*** into the blue and peach columns. The worst value is defined as the most impaired value (e.g, highest PAS score, longest time-to-LVC, largest total pharyngeal residue, largest PhAMPC).
   - These values may come from different boluses of the same consistency. This is ok because the point of the ***ASPEKT-C Method Scoring Sheet*** is to make clear to the clinician *all* the mechanisms at play contributing to the patient's swallowing safety and efficiency profile so that they can be considered in treatment planning.

2. It is ok to have blank fields. This may indicate:
   - Consistencies were not tested (e.g., I did not test my patient with "slightly thick" in VFSS) **OR**
   - Parameters did not require calculation according to the ASPEKT-C Method pathway (e.g., if PAS is "typical" for all thin liquid boluses, you would have no "*2d. LVC Timing*" value under IDDSI Level 0 thin).

3. The frequency of how often an unsafe PAS event occurs is clinically relevant. Whether a patient aspirates on 1 of 4 trials versus 4 of 4 trials of thin liquids may portray a different profile of risk and should be included as part of documentation in the "My Patient Values" table.

My Patient Values			Mechanism							Mechanism	
IDDSI Level		2a. & f. PAS Score & Evolution	2b. LVC Integrity	2d. Time-to-LVC	2e. Preswallow Residue	Safety (typical, atypical)	Frequency of Atypical PAS Events	1b. # of swallows	3a. Total Pharyngeal Residue %(C2-4)[2]	3b. PhAMPC %(C2-4)[2]	Efficiency (typical, atypical)
0	Thin										
1	Slightly Thick										
2	Mildly Thick										
3	Moderately Thick/Liquidised										
4	Extremely Thick/Pureed										

Figure 31: "My Patient Values" table from the ***ASPEKT-C Method Scoring Sheet***

4. Use the "*ASPEKT-C Typical Reference Values*" table (*Figure 32*) to compare your patient values. If any of the safety values fall outside the typical reference range, their safety is "atypical". If any of the efficiency values fall outside the typical reference values, their efficiency is "atypical".

ASPEKT-C Typical Reference Values[a]		2a. & f. PAS Score & Evolution[b]	2b. LVC Integrity	2d. Time-to-LVC	2e. Preswallow Residue[c]	If any of the safety values fall outside the typical reference values, enter atypical.	Comment on the frequency of atypical PAS events (e.g.,1 of 4 trials)	1b. # of swallows	3a. Total Pharyngeal Residue %(C2-4)[2]	3b. PhAMPC %(C2-4)[2]	If any of the efficiency values fall outside the typical reference values, enter atypical.
IDDSI Level											
0	Thin	1, 2, 4	Complete	< 167 ms	N			1	< 1.7 %	< 2.7 %	
1	Slightly Thick	1, 2, 4	Complete	< 234 ms	N			1	< 1.9 %	< 2.5 %	
2	Mildly Thick	1, 2, 4	Complete	< 200 ms	N			1	< 2.2 %	< 3.3 %	
3	Moderately Thick/Liquidised	1, 2, 4	Complete	< 200 ms	N			1	< 1.6 %	< 2.1 %	
4	Extremely Thick/Pureed	1, 2, 4	Complete	< 167 ms	N			1	< 1.5 %	< 1.4 %	

Figure 32: "ASPEKT-C Typical Reference Values" table form the ***ASPEKT-C Method Scoring Sheet***

Other Observations

The ***ASPEKT-C Method Scoring Sheet*** includes a section for Other Observations (as shown in *Figure 33*). While there are no ASPEKT-C Method typical reference values available for other views (e.g., AP), consistencies (e.g., minced and moist), or with the use of interventions (e.g., effortful swallow), you may wish to note those other observations under this section.

Other Observations

While there are no ASPEKT-C Method typical reference values available for other views (e.g., AP), consistencies (e.g., minced and moist), or with the use of interventions (e.g., effortful swallow), you may wish to note those other observations below.

IDDSI Level	Swallowing Safety	Swallowing Efficiency

Anterior/Posterior view? Yes/No Vallecular Sinus Residue Asymmetry? _____ Pyriform Sinus Residue Asymmetry? _____

Figure 33: "Other Observations" section of the ***ASPEKT-C Method Scoring Sheet***

ASPEKT-C Documentation Considerations

- As previously mentioned the ***ASPEKT-C Method Worksheet*** was created as a "rough worksheet" to guide clinicians through process of VFSS analysis. This document is not meant to be included as is into a patient's paper chart or electronic patient record. The ***ASPEKT-C Method Scoring Sheet*** contains a table of "*My Patient Values*" where you may wish to use colour coding of red and green to quickly see which values were typical and atypical. The ASPEKT-C "*My Patient Values*" table can be copied/pasted into a report and accompanied by an impression statement.
- The ASPEKT-C "*My Patient Values*" table only captures the patient's worst performance, not the frequency with which that impairment occurs. If a particular parameter did not show impairment on all trials, it may be salient to capture this in the text of your report (e.g., a PAS of 5, resulting from incomplete LVC integrity only occurred on 1 out of 4 thin liquid bolus trials).
- While the ASPEKT-C Method focuses solely swallowing physiology, it is important to still consider any structural impairments identified by radiology that could be co-occurring and contributing to your patient's profile as part of your report.

How Healthy Reference Values are Defined in the ASPEKT-C Method

The ASPEKT-C Method typical reference values were established based on the 75% percentile values as shown in *Figure 34.* 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** (except for "*2e. PAS evolution*")

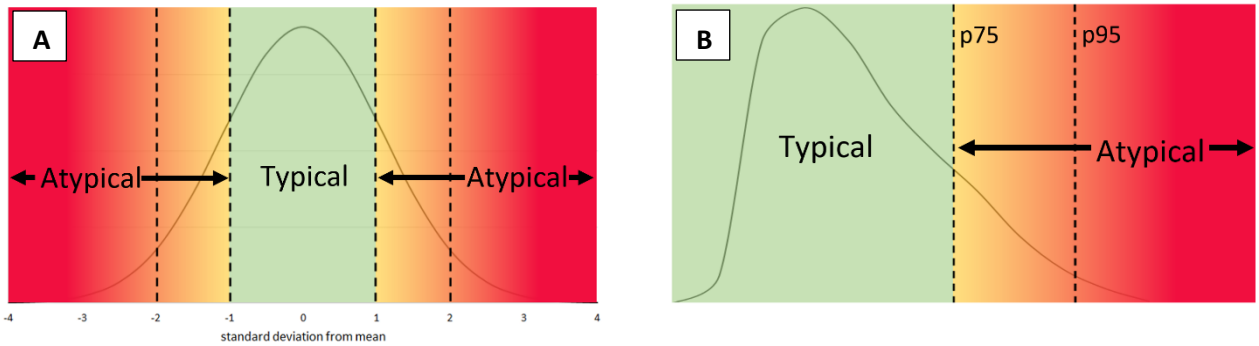


Figure 34: Examples of A) normally distributed data, and B) positively skewed data

Next Step(s) if ASPEKT-C Method Did Not Identify Underlying Mechanism of Impairment

The ASPEKT-C Method is a critical decision-making pathway made up of 8 parameters that the SRRL believes are the most common underlying mechanisms for dysphagia. However, dysphagia is a complex phenomenon and it is possible that the reason for your patient's swallowing safety or efficiency impairment is not explained by the 8 parameters in the ASPEKT-C Method. If these parameters do not explain the impairments observed in your patient, then this would be a situation where other parameters might need to be explored using the full ASPEKT Method described by Steele, Peladeau-Pigeon et al. (2019).

It may be helpful to narrow down the list of additional parameters of interest by looking at the research associated your patient's suspected dysphagia etiology. Our team has published results of the ASPEKT Method in the following cohorts:

- Healthy aging (Mancopes et al., 2021)
- Amyotrophic Lateral Sclerosis (ALS) (Waito et al., 2020)
- Parkinson Disease (PD) (Gandhi et al., 2021)
- post-radiation oropharyngeal cancer (Barbon et al., 2020)
- Chronic Obstructive Pulmonary Disease (COPD) (Mancopes et al., 2020)

It should be noted that patients are complex and can often have multiple comorbidities e.g., a patient with COPD that just had a stroke. In these cases, it is important to understand the profiles associated with each of these diagnoses as we determine the primary contributors to our patient's individual situation.

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Appendix A: Introduction to ImageJ Software

Frame-by-frame and pixel based measurement tools are required to apply the ASPEKT-C Method. The SRRL uses ImageJ software which is as image analysis program created at the National Institutes of Health (https://imagej.nih.gov/ij). It is public domain, available free of charge, and runs on a variety of operating systems. You may wish to speak with an in-house IT department before downloading it.

Opening a Video using ImageJ

Drag and drop your file into the ImageJ toolbar. If your video is not compatible, you will need to either convert your video into an appropriate format or use another frame-by-frame viewing software at your own risk. See ImageJ online documentation for more information about compatible video formats (https://imagej.nih.gov/ij/docs/menus/file.html).

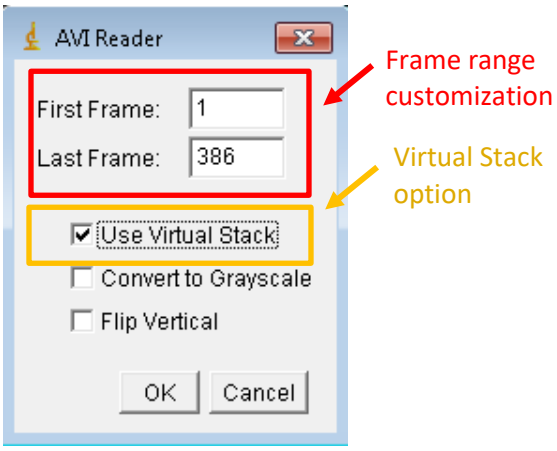

Figure 35: ImageJ's *AVI Reader* menu.

Many AVI video files can be large and may be too large for your computer's memory capacity. When opening an AVI file, you may wish to reduce the number of frames opened (*Figure 35*, red box) or select *virtual stack* option (*Figure 35*, orange box) when you open your video for ease of use. These memory options are unfortunately not available if you are opening a DICOM file.

The ASPEKT-C Method requires careful frame-by-frame viewing to identify penetration aspiration events, LVC integrity and PAS timing. Advance the video frame-by-frame by pressing the forward or backward arrow keys on your keyboard or using the arrows at the bottom of the video window (*Figure 36*, orange arrows). Frame numbers are located on the top left-hand corner of the video window (*Figure 36*, red box).

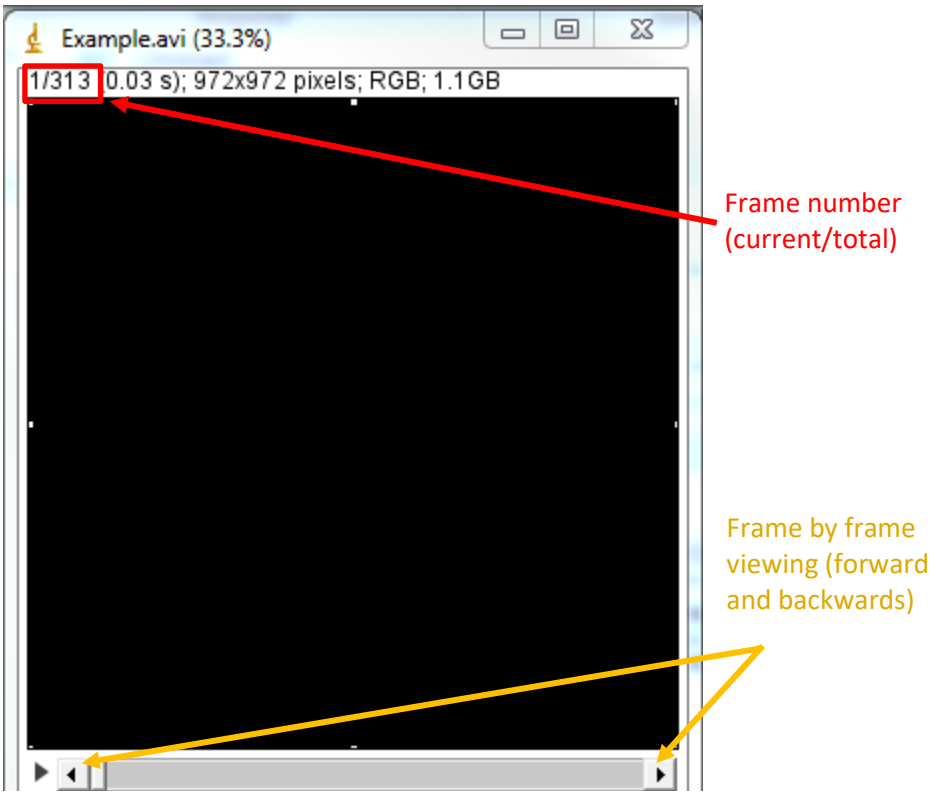

Figure 36: Sample video windows in ImageJ