

# Developing a protocol for objective quantitative analysis of swallowing in children:

## A videofluoroscopic study

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### Introduction

- Objective videofluoroscopic swallow study (VFSS) measures can quantify swallow biomechanics
- A vast range of measures reported in literature but rarely used in clinical practice
- There is a need for a VFSS protocol that is feasible, time effective and clinically relevant

### Research Aim

- To establish a standard protocol for objective quantitative VFSS analysis in children.

### Methodology

Table 1: Steps of developing the protocol

1	Literature review
2	Database collection
3	Rater-reliability
4	Construct & content validity
5	Criterion validity
6	External validity
7	Internal consistency reliability
8	Revised protocol

### 1: Literature review

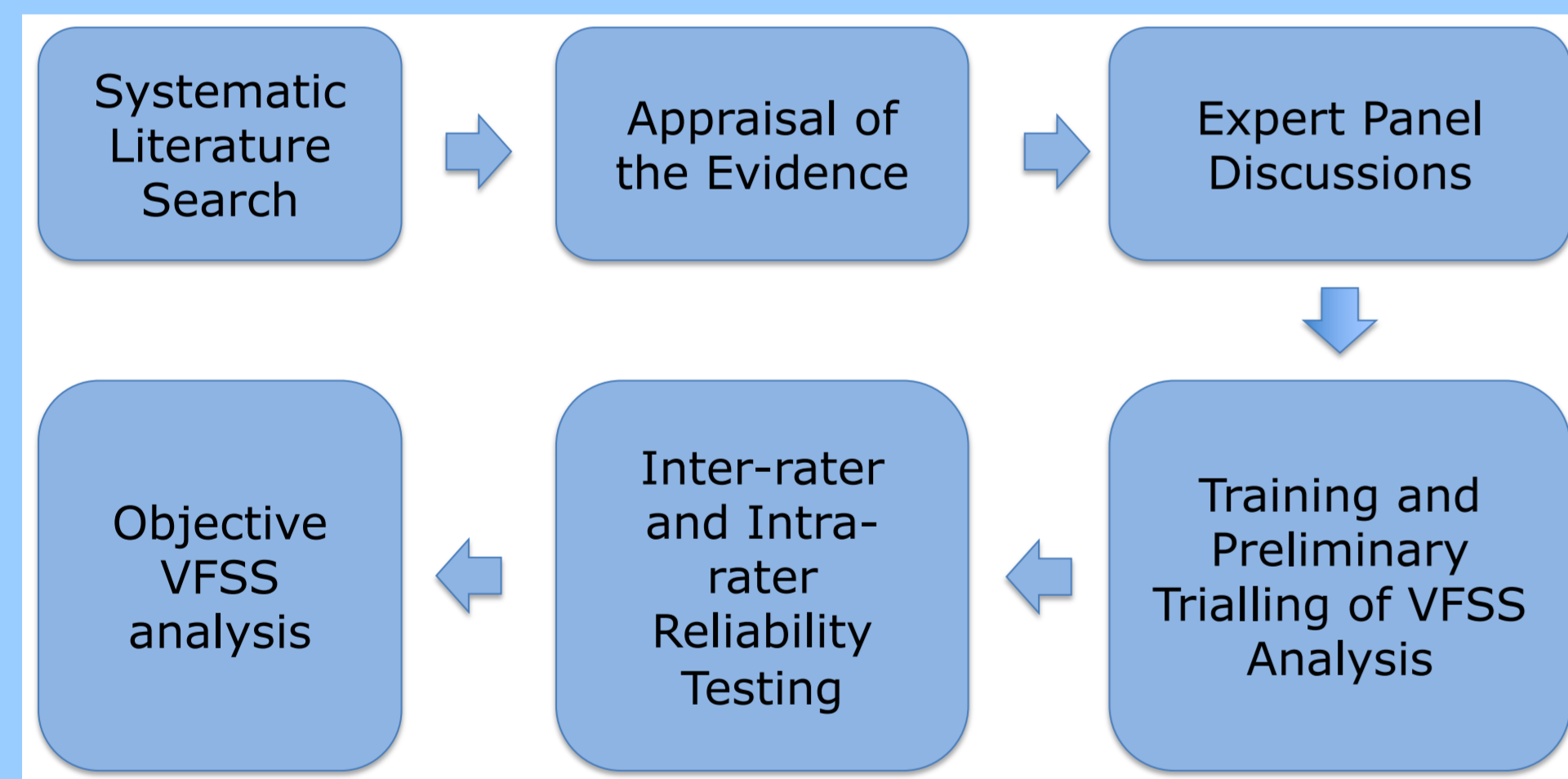


Figure 1: The process of developing the VFSS protocol

### Objective quantitative VFSS measures

Table 2: VFSS measures studied in children 0-21 years (n=553)

Objective quantitative swallow measures		Descriptive swallow measures
Timing/ coordination measures	Displacement measures	
Total pharyngeal transit time (TPT) <sup>1</sup>	Pharyngeal constriction ratio (PCR) <sup>1</sup>	Penetration-Aspiration Scale (PAS) <sup>5</sup>
Time to airway closure (Airwaycl) <sup>1</sup>	Maximum opening of PES during a swallow (PESmax) <sup>1</sup>	Airway violation (PAS≥3) (+/-) <sup>6,7</sup>
Airway closure duration (ACD) <sup>1</sup>	Bolus clearance ratio (BCR) <sup>4</sup>	Frequency of penetration- aspiration <sup>10**</sup>
PES opening duration (PESdur) <sup>1</sup>	Maximal hyoid elevation** (Hmax) <sup>1</sup>	Time of airway violation <sup>9</sup>
Coordination of airway closure with bolus transit (BP1AEcl) <sup>1</sup>	Maximum approximation of hyoid bone and larynx** (HL) <sup>1</sup>	Post-swallow residue <sup>2</sup>
Stage transition duration** (STD) <sup>9</sup>	Oro-pharyngeal swallow efficiency (OPSE) <sup>11</sup>	Bolus residue scale (BRS) <sup>8</sup>
Laryngeal elevation** (LE) <sup>1</sup>		Naso-Pharyngeal Reflux (NPR) <sup>3</sup>
Duration to hyoid maximum elevation ** (Hdur) <sup>1</sup>		Esophago-Pharyngeal Reflux (EPR) <sup>9</sup>
Duration of maximum hyoid displacement ** (Hm) <sup>1</sup>		Suck/swallow bolus control <sup>2*</sup>
Duration of velopharyngeal closure (VCD) <sup>3</sup>		Frequency of penetration- aspiration <sup>10**</sup>
Suck time <sup>2*</sup>		Time of airway violation <sup>9</sup>
Tongue- soft palate cycle (T-SP) <sup>6*</sup>		Post-swallow residue <sup>2</sup>
Suck: swallow ratio <sup>2*</sup>		Bolus residue scale (BRS) <sup>8</sup>
Number of swallows in 20-s loop <sup>10*</sup>		Naso-Pharyngeal Reflux (NPR) <sup>3</sup>

Henderson et al., 2016; Dharmarathna et al., in revision, AJSLP

### 2: Database collection

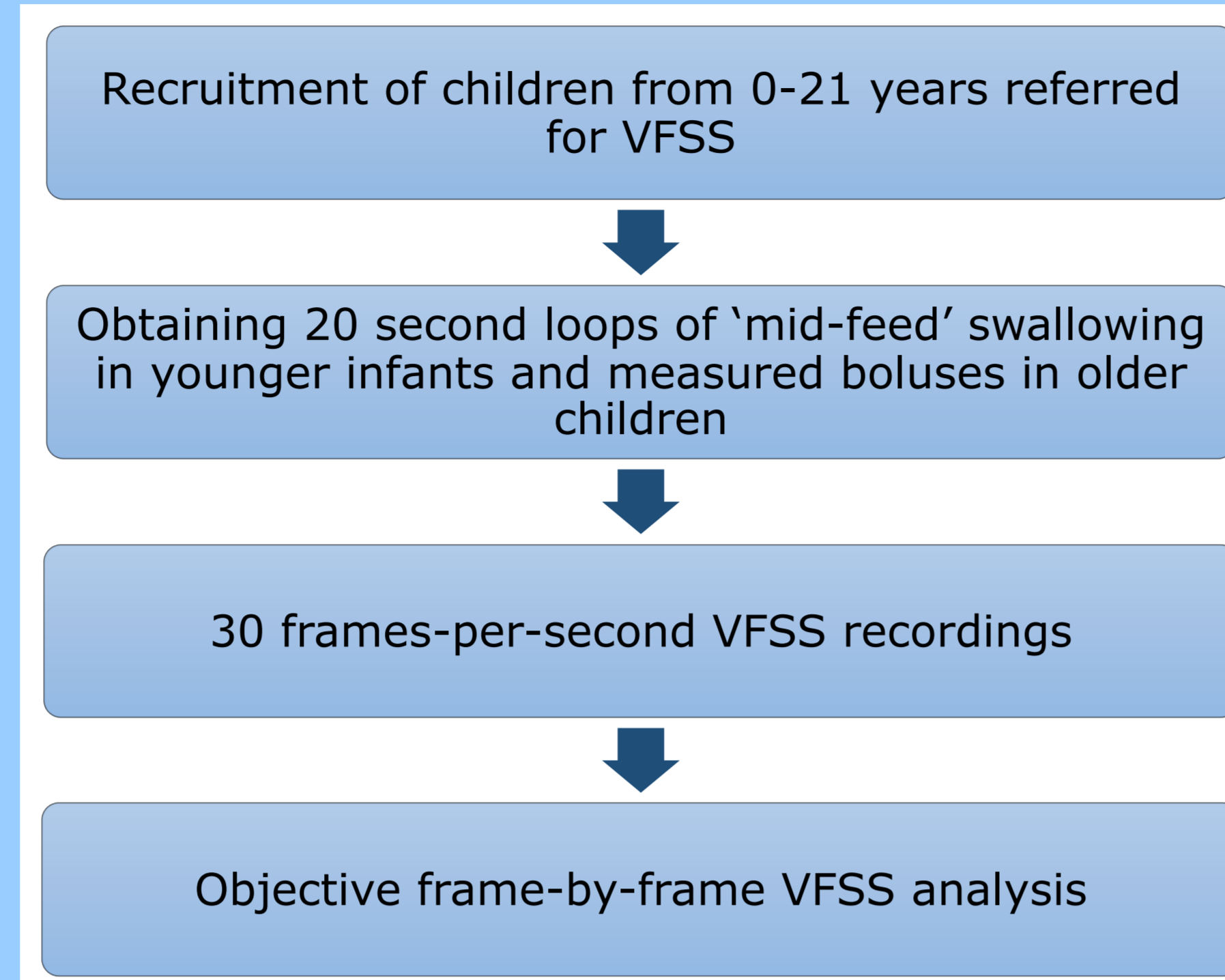


Figure 2: Process of administering VFSS and obtaining data

Table 3: Cohort demographics (n=553)

Demographic	Frequency (n)	Percentage (%)	
Age of the child	0-12 months	184	33.3
	1-3 years	183	33.1
	3.1-5 years	74	13.4
	5.1-12 years	82	14.8
	12.1-18 years	29	5.2
	18-21 years	1	0.2
Swallow act studied	Midfeed sucking	210	38.0
	Midfeed drinking	214	38.7
	Thin liquid-5ml	99	17.9
	Thin liquid-10ml	30	5.4

### 3: Inter-rater & intra-rater reliability

- Large sample (n=174)
- Random sample of 50 infants (0-9 months) and 124 older children (1-21 years)
- Blinded clinicians
- Good - excellent intra-rater reliability across measures (ICC = .75-.98)

### 4: Construct & content validity

- Selected VFSS measures represent the domains of swallowing
- Valid in young infants (Dharmarathna et al, 2020a)
- Can quantify residue in children (Dharmarathna et al, 2021b)

### 5: Criterion validity

- Correlations with penetration-aspiration scale scores and predictive of aspiration in children (Dharmarathna et al, 2021c)

### 6: External validity

- Generalizable findings
- 'Trends' across etiologies

### 7: Internal consistency reliability:

- Inter-item correlations across VFSS measures
- Cronbach's alpha- for item reduction (led to reduction to 6 objective and 3 descriptive measures)

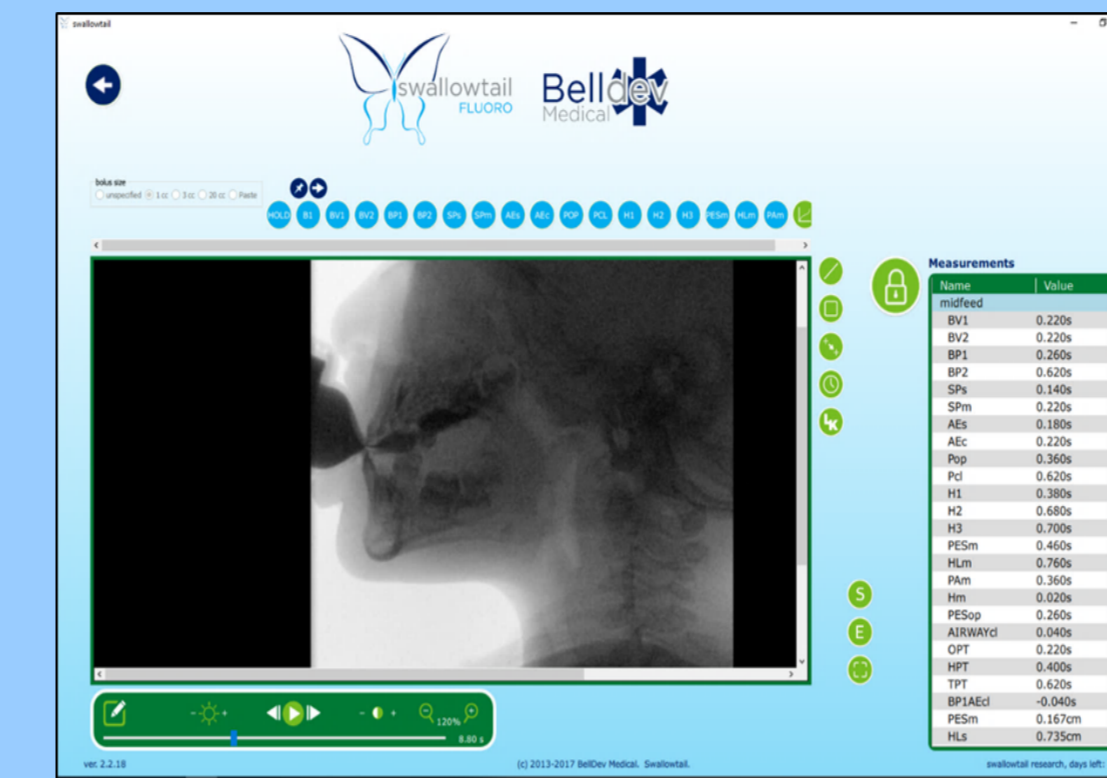


Figure 3: Frame-by-frame viewing pane of Swallowtail™ to record timing and displacement measures

### 8: Revised protocol

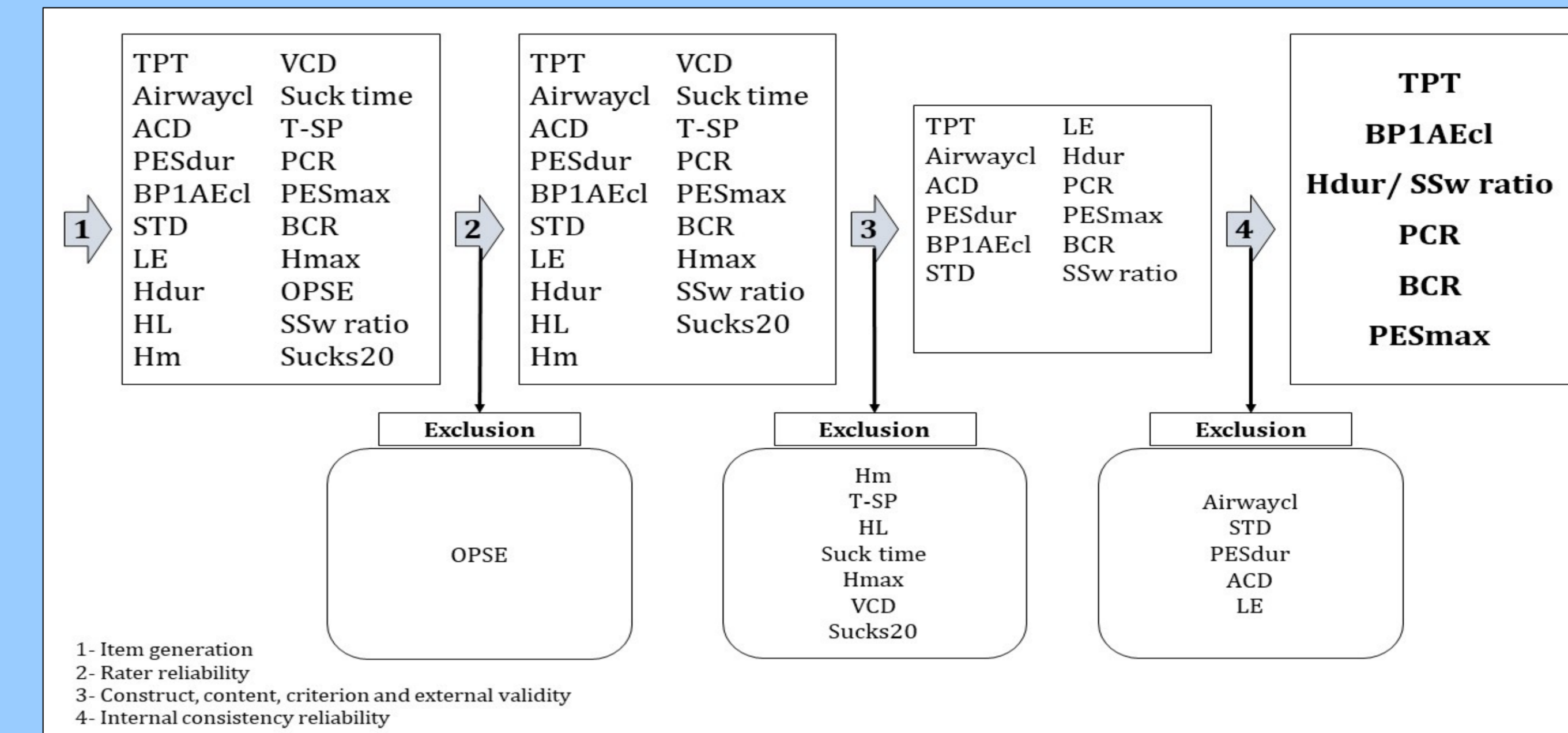


Figure 4: Developing a protocol of objective quantitative measures of VFSS for children

### Final Protocol

Infants (0-9 months)	In all children (0-21 years)
Recording at 30 frames per second	
Mid-feed sucking of bottle-fed infants for 20 seconds	10ml Mid-feed sequential drinking (100ml)
TPT, Coordination of airway closure with bolus transit (BP1AEcl), PCR, PESMax, BCR, PenAsp, Nasopharyngeal reflux (NPR) (+/-), BRS	
Number of sucks per swallow (SSw ratio)	Hdur

### Threshold scores- Heightened risk of aspiration

Infants (0-9 months)	In all children (0-21 years)
If more than 3 sucks per swallow are present	If TPT is ≥ 2s
If TPT is > .5s	If BCR is ≥ .1
	If PCR is ≥ .2

### Discussion

- Established a clinically validated standard protocol
- Distinguished measures for milk sucking infants & older children
- Larger cohort of children- diversity (age, etiology, swallow act)
- Provides objective interpretation of swallow biomechanics in children
- Allows meaningful comparisons across time and for testing therapeutic strategies for children
- Directing for more individualized intervention for children with swallowing disorders

### References

Dharmarathna, I., Miles, A., & Allen, J. (2021a). Predicting penetration-aspiration through quantitative swallow measures of children: A videofluoroscopic study. *European Archives of Otorhinolaryngology*.  
 Dharmarathna, I., Miles, A., & Allen, J. (2021b). Quantifying bolus residue and its risks in children: A videofluoroscopic study. *American Journal of Speech-Language Pathology* (in press).  
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 Henderson, M., Miles, A., Holgate, V., Peryman, S., & Allen, J. (2016). Application and verification of quantitative objective videofluoroscopic swallowing measures in a pediatric population with dysphagia. *Journal of Pediatrics*, 178, 200-205.e1. <https://doi.org/10.1016/j.jpeds.2016.07.050>