Dysphagia : 내가 몰랐던 진단 up-to-date

Seung Hak Lee

Department of Rehabilitation Medicine

Asan Medical Center, University of Ulsan College of Medicine

Contents

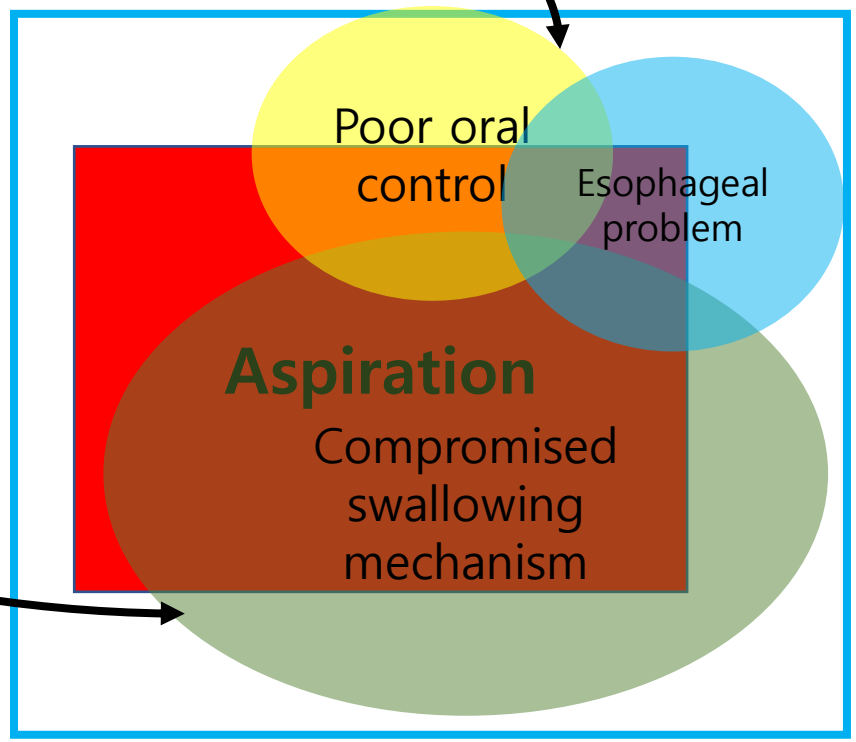
- 연하장애의 개념
- 연하장애의 진단적 접근
- 연하장애의 진단과 평가의 최신 지견
  - Axis 1 : Subjects for diagnosis
  - Axis 2 : New methodology
  - Axis 3 : Digital technology

Concepts related to dysphagia

Conditions prone to peumonia
- Co-morbidities

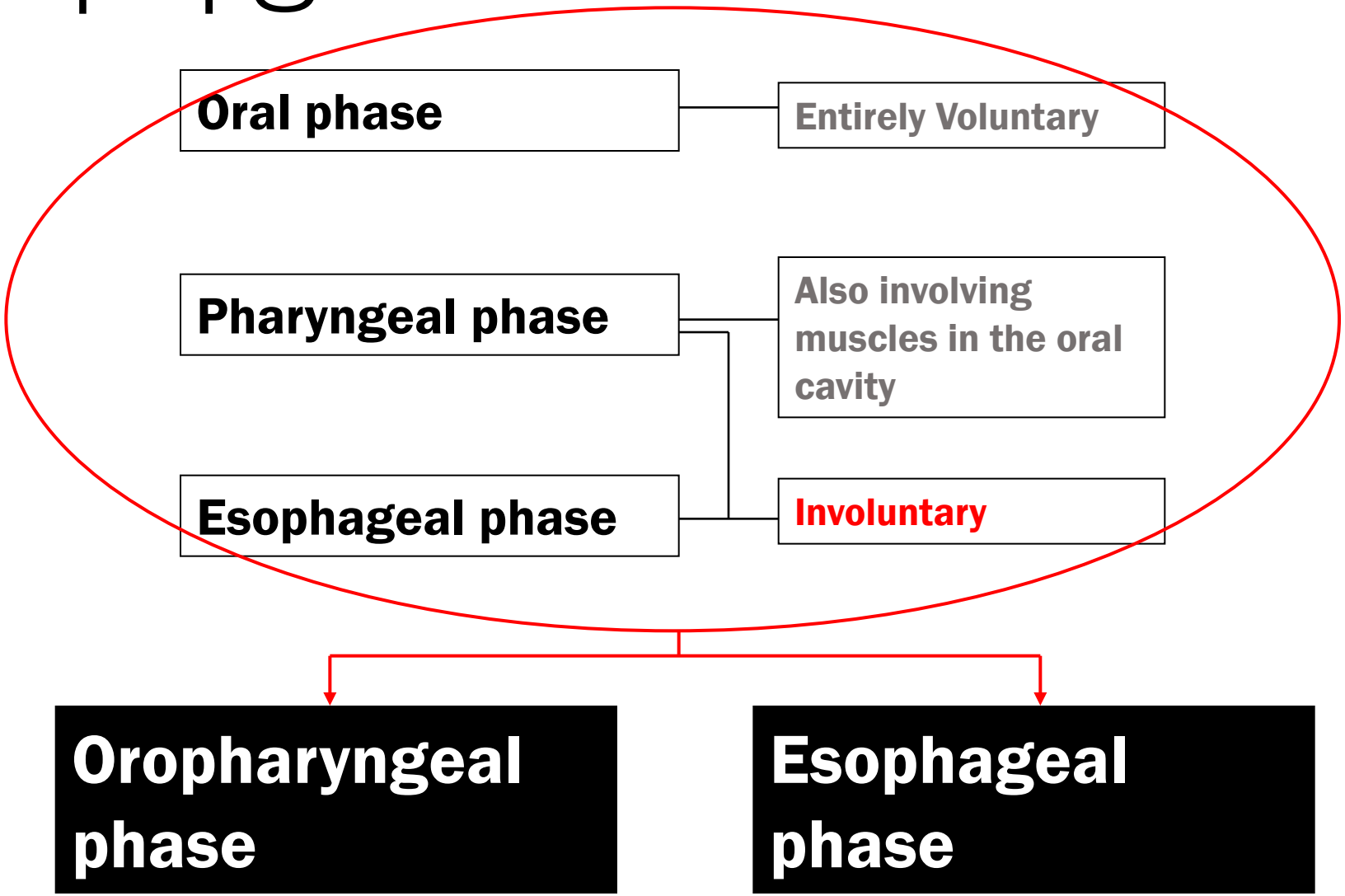
(especially pulmonary disease)
- Immunity
- Eating habits
- …

Etiology
- Neurologic condition (stroke)
- Structural problem (H&N cancer)
- Deconditioning
- Aging
- miscellaneous
- ……



Consequences
- **Aspiration pneumonia**
- Dehydration
- Malnutrition
- Poor QOL
- …

연하의 과정

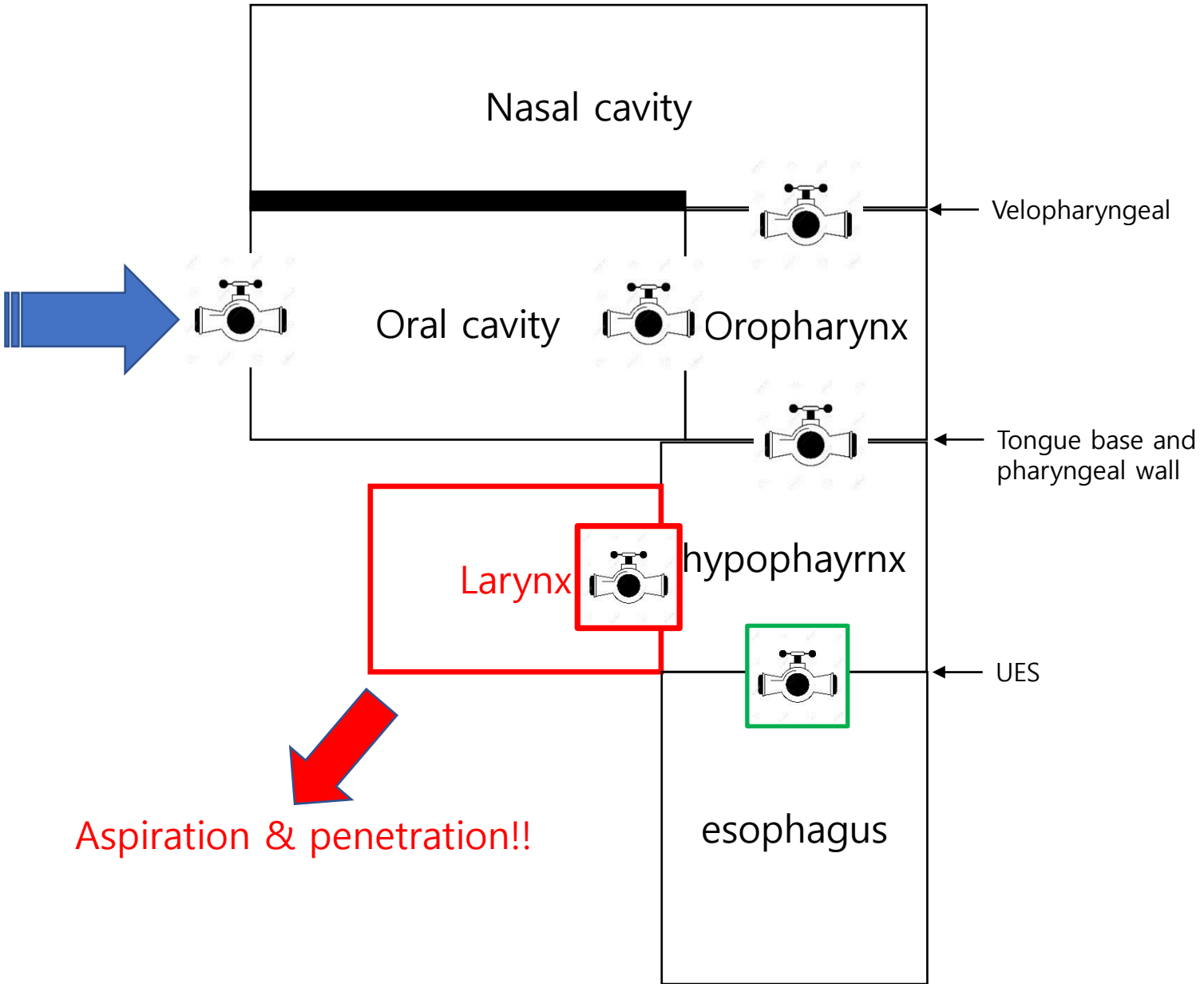

Oral phase
Entirely Voluntary
Pharyngeal phase
Also involving muscles in the oral cavity
Esophageal phase
Involuntary
Oropharyngeal phase
Esophageal phase

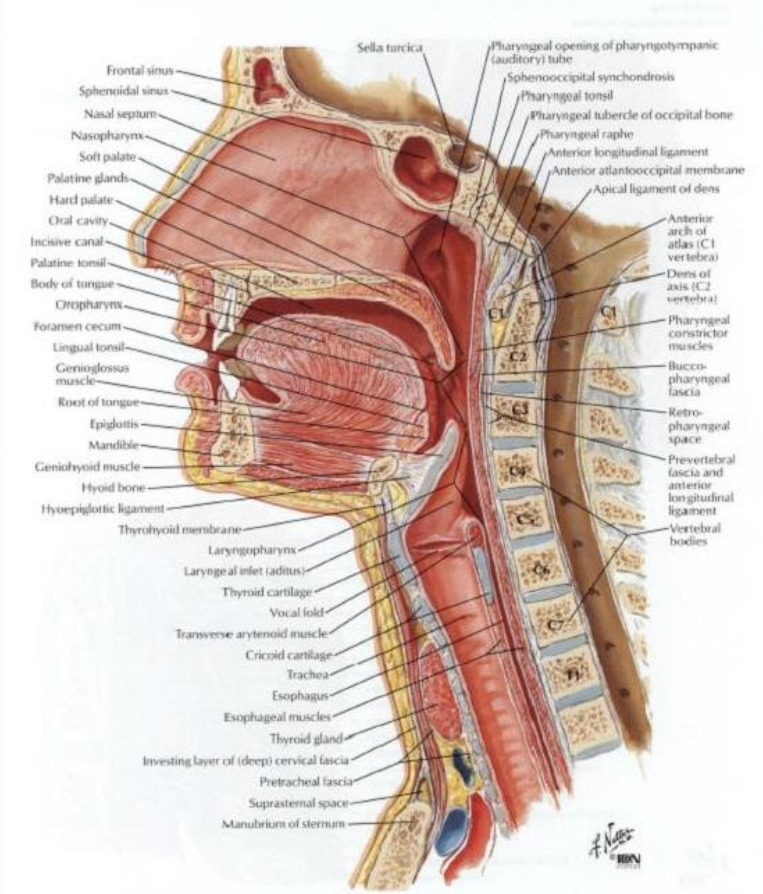
Mechanism of swallowing, Chambers and valves

- **6 Chambers**
  - Oral cavity
  - Nasal cavity
  - Oropharynx
  - Hypopharynx
  - Larynx
  - Esophagus

- **6 valves**
  - Lips
  - Oral tongue
  - velopharyngeal
  - Laryngeal
    - Epiglottis
    - VF adduction
  - Tongue base and pharyngeal wall
  - UES

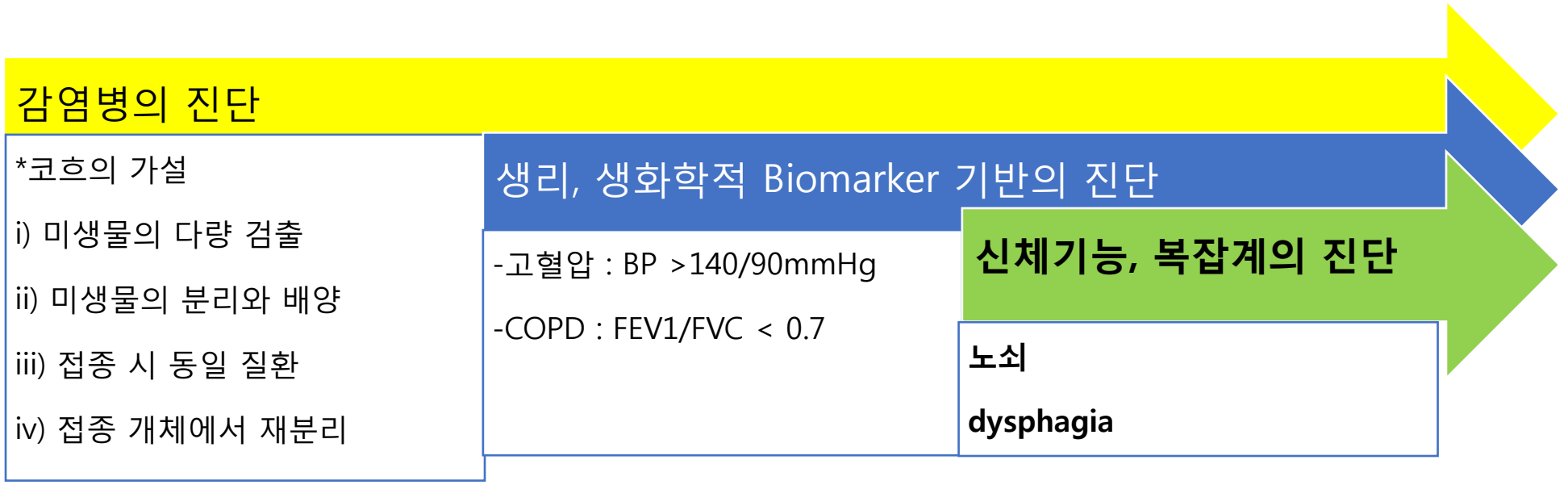
Two key concepts : pressure & leak





연하장애 진단의 문제점

- 불명확한 정의, Biomarker의 부재
- Dysphagia = aspiration?
  - Aspiration & penetration의 정도 (PAS) 가 dysphagia의 조작적 정의가 될 수는 있음
  - 그러나 dysphagia의 의미를 PAS만으로 제한하는 것은 무리



연하장애의 평가 틀

- 증상과 병력청취

- 임상척도, 설문
  - Clinical dysphagia scale (CDS)
  - Mann Assessment if swallowing ability (MASA)
  - EAT-10
  - MD Anderson dysphagia inventory (MDADI)
  - Dysphagia short questionnaire

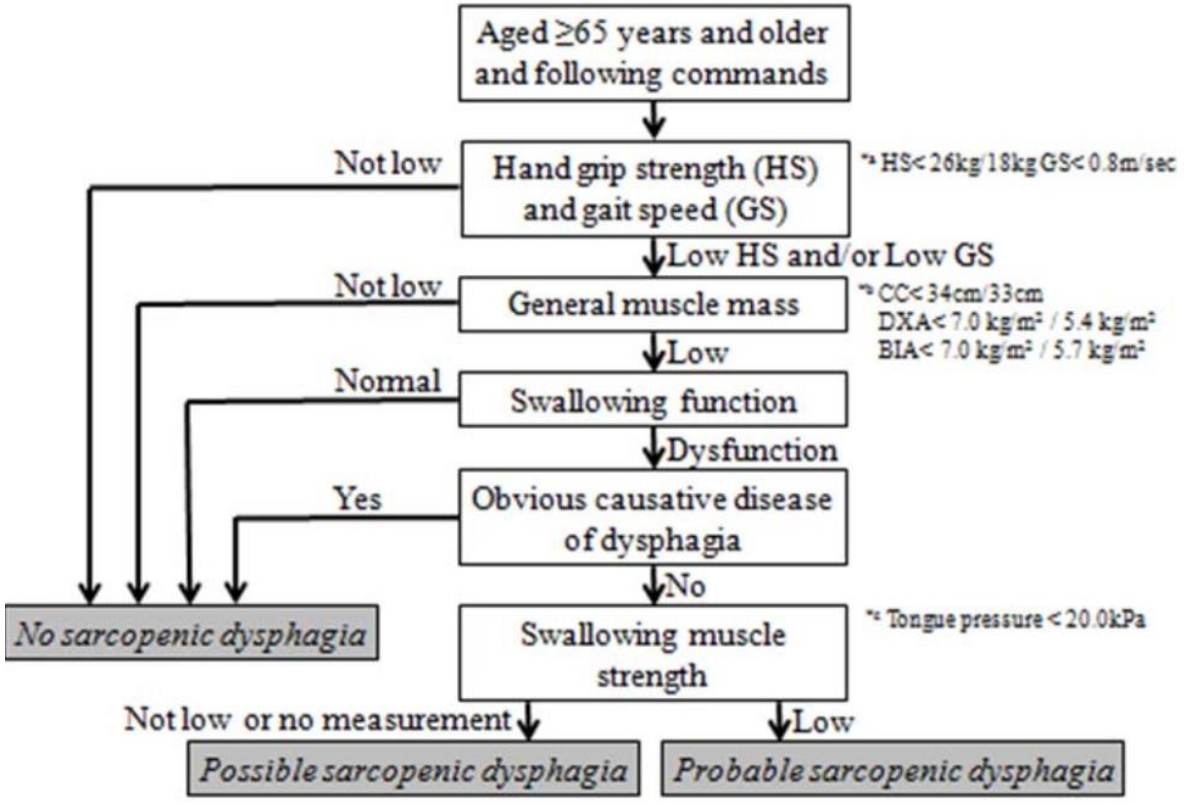
- 침상선별검사 (Bedside Screening test)
  - Water swallow test
  - Gugging swallow screen (GUSS)
  - Modified Evans blue dye test
  - Bronchial auscultation
  - Burke dysphagia screening test (BDST)
  - Toronto bedside swallow screening test

- **Instrumental test**
  - **Videofluoroscopic Swallowing Study (VFSS) : Gold-standard**
  - Fiberoptic Endoscopic Evaluation of Swallowing (FEES)
  - Swallow scintigraphy
  - High Resolution Manometry

- Aspiration 여부의 확인에 대한 기구적 접근
- VFSS는 swallowing의 시간에 따른 동적 (motion) 정보를 제공한다는 점에서 특별한 이득을 제공
- Manometry는 pressure profile을 제공한다는 점에서 타 검사와 차별점

Axis 1 : Subjects for diagnosis

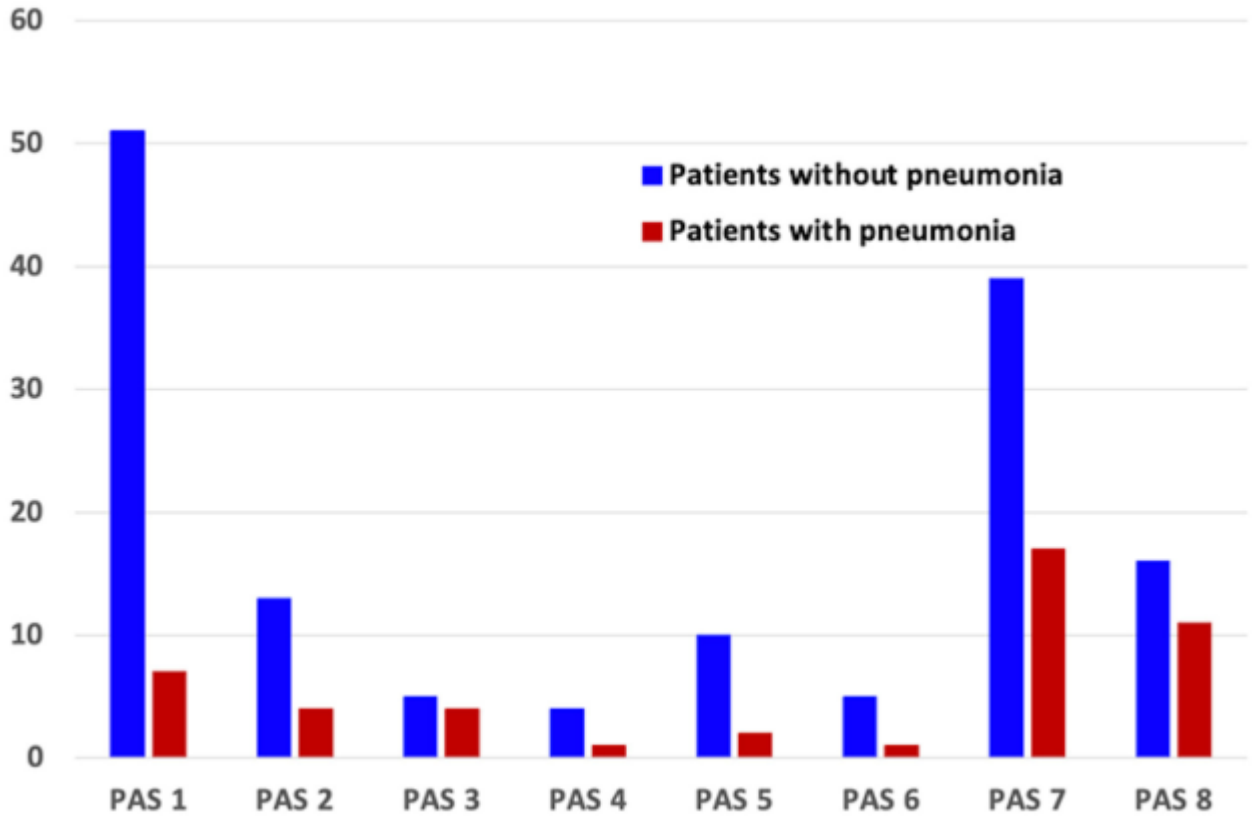
Sarcopenic dysphagia, presbyphagia



Diagnostic algorithm for sarcopenic dysphagia. Mori, Takashi, et al. JCSM Clinical Reports 2.2 (2017): 1-10.

Tongue pressure measurement for evaluation of sarcopenic dysphagia. Maeda, Keisuke, and Junji Akagi. Dysphagia 30.1 (2015): 80-87

Axis 1 : diagnostic range



PAS score	OR	95% Confidence interval		*p*-value†
		Lower bound	Upper bound	
1	1.0			
2	2.242	0.569	8.832	0.249
3	5.829	1.257-	27.022	**0.024**
4	1.821	0.177	18.709	0.614
5	1.457	0.263	8.068	0.666
6	1.457	0.148	14.357	0.747
7	3.176	1.199	8.411	**0.020**
8	5.009	1.665	15.071	**0.004**

Distribution of PAS scores from VFSS in patients with dysphagia due to frailty. Chang, Min Cheol, and Soyoung Kwak. Frontiers in medicine 8 (2021): 1049.

Pediatric population

- 성인과 다른 anatomy, physiology
- 발달의 issue
- Radiation hazard
  - pediatric VFSS performed with **15 frames per second (fps)** vs standard 30 fps -> **no difference**

    Layly, Julie, et al. Dysphagia 35.2 (2020): 296-300.
- Standardized assessment tool
  - BaByVFSS Impairment Profile, (BaByVFSSImP©)
  - quantification of swallowing observations made from VFSS in bottle-fed babies

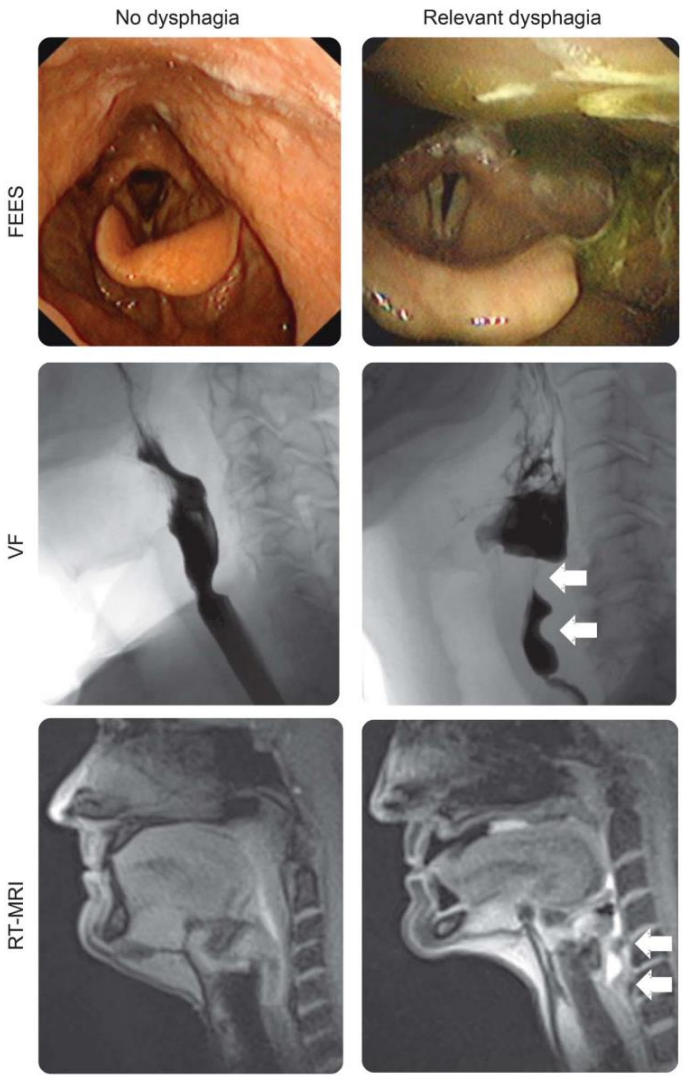
    Martin-Harris, Bonnie, et al. Dysphagia 35.1 (2020): 90-98.

Table 1 Domains with components and score variants

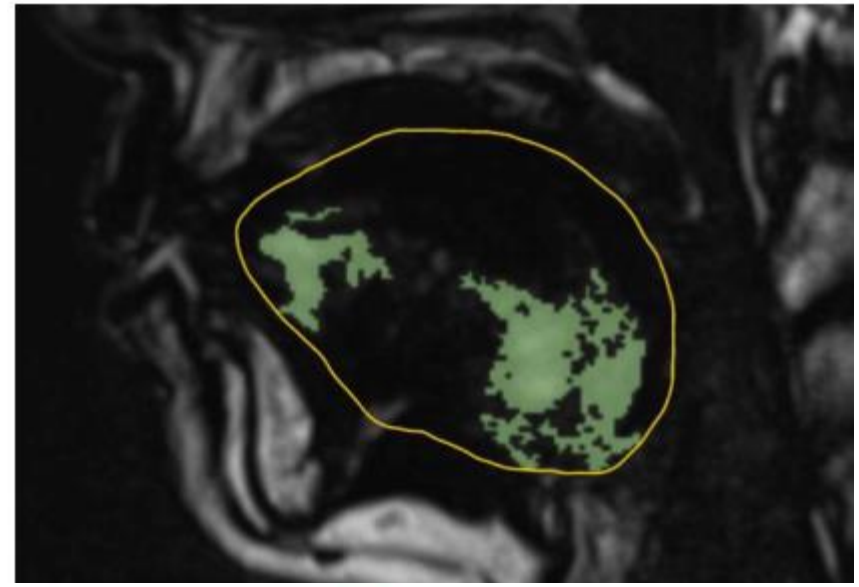
Domain	Component	Range of possible scores
Lingual motion/pharyngeal swallow initiation	Initiation of nutritive sucks	0–2
	Number of sucks to form bolus	1–7
	Nutritive suck rhythmicity/organization	0–2
	Suck/swallow bolus control	0–2
	Bolus location at initiation of pharyngeal swallow	0–3
	Timing of initiation of pharyngeal swallow	0–2
Palatal-pharyngeal approximation	Palatal-pharyngeal approximation/palatal integrity	0–3
	Location of bolus at time of palatal-pharyngeal approximation	0–2
Airway invasion/laryngeal closure	Early laryngeal vestibular closure	0–3
	Late laryngeal vestibular closure	0–3
	Timing of airway entry	0–4
	Amount of penetration	0–2
	Frequency of penetration	0–3
Aspiration	Amount of aspiration	0–2
	Frequency of aspiration	0–3
Pharyngeal transport and clearance	Epiglottic movement	0–2
	Tongue base retraction	0–4
	Pharyngeal stripping wave	0–2
	Valleculae residue	0–4
	Pyriform residue	0–4
	Pharyngoesophageal segment (Upper esophageal sphincter)	0–3

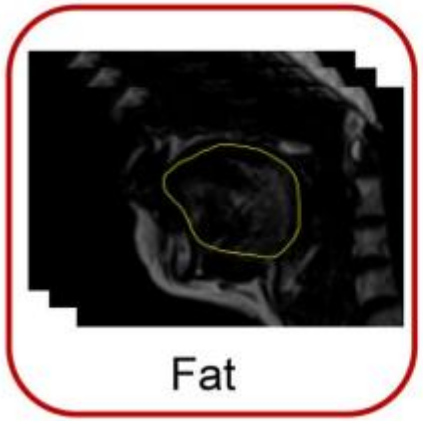
Axis 2 : new methodology

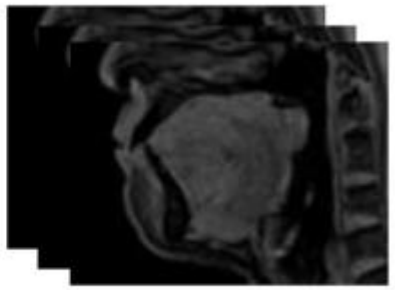
MRI

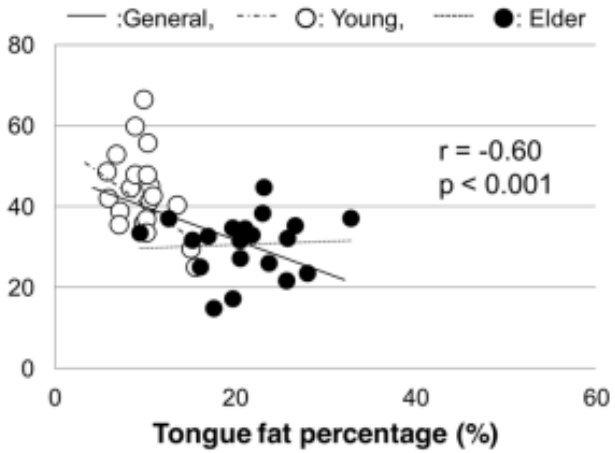


Real-time MR in patient with inclusion body myositis. Olthoff, Arno, et al. Neurology 87.20 (2016): 2132-2138..





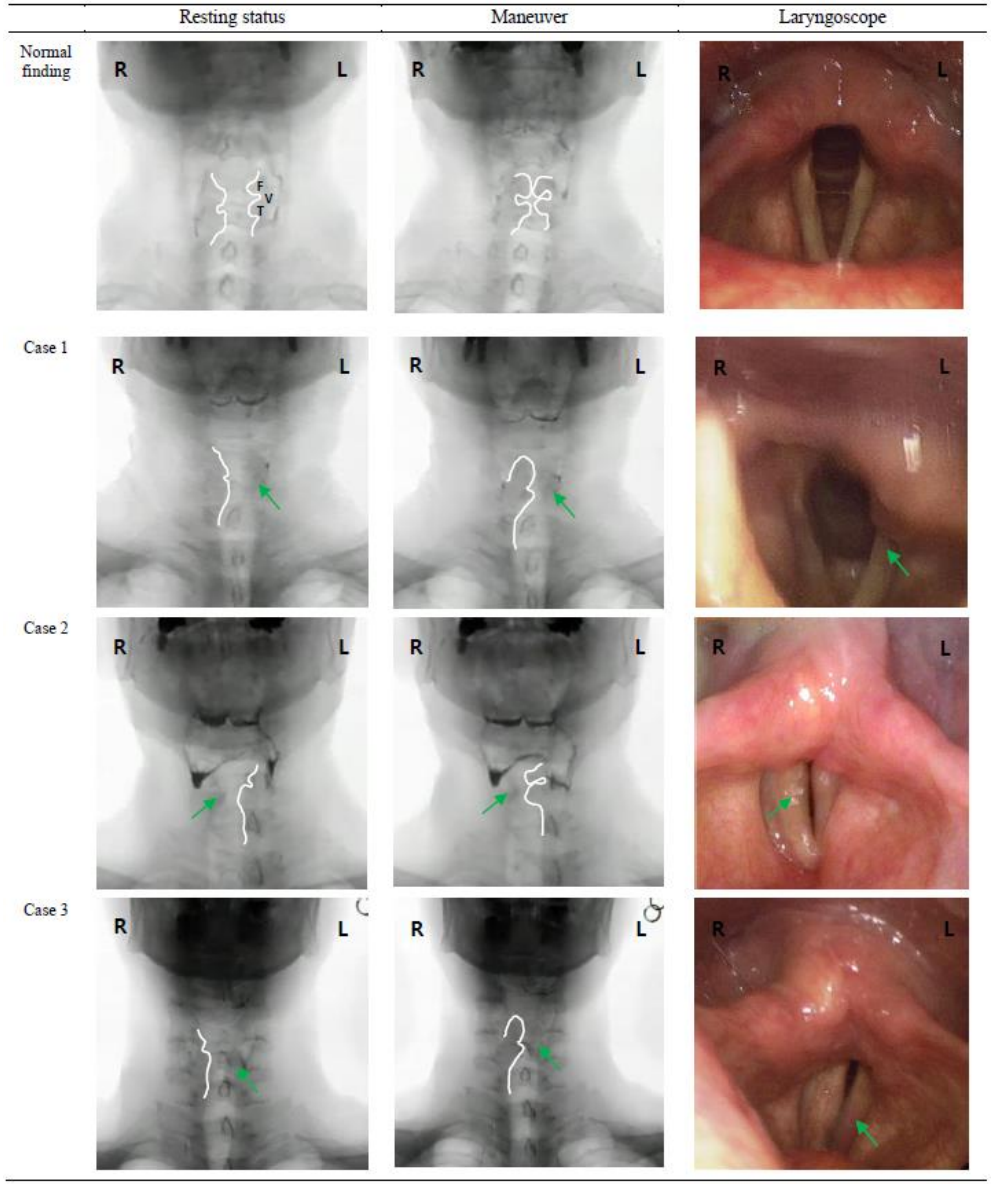


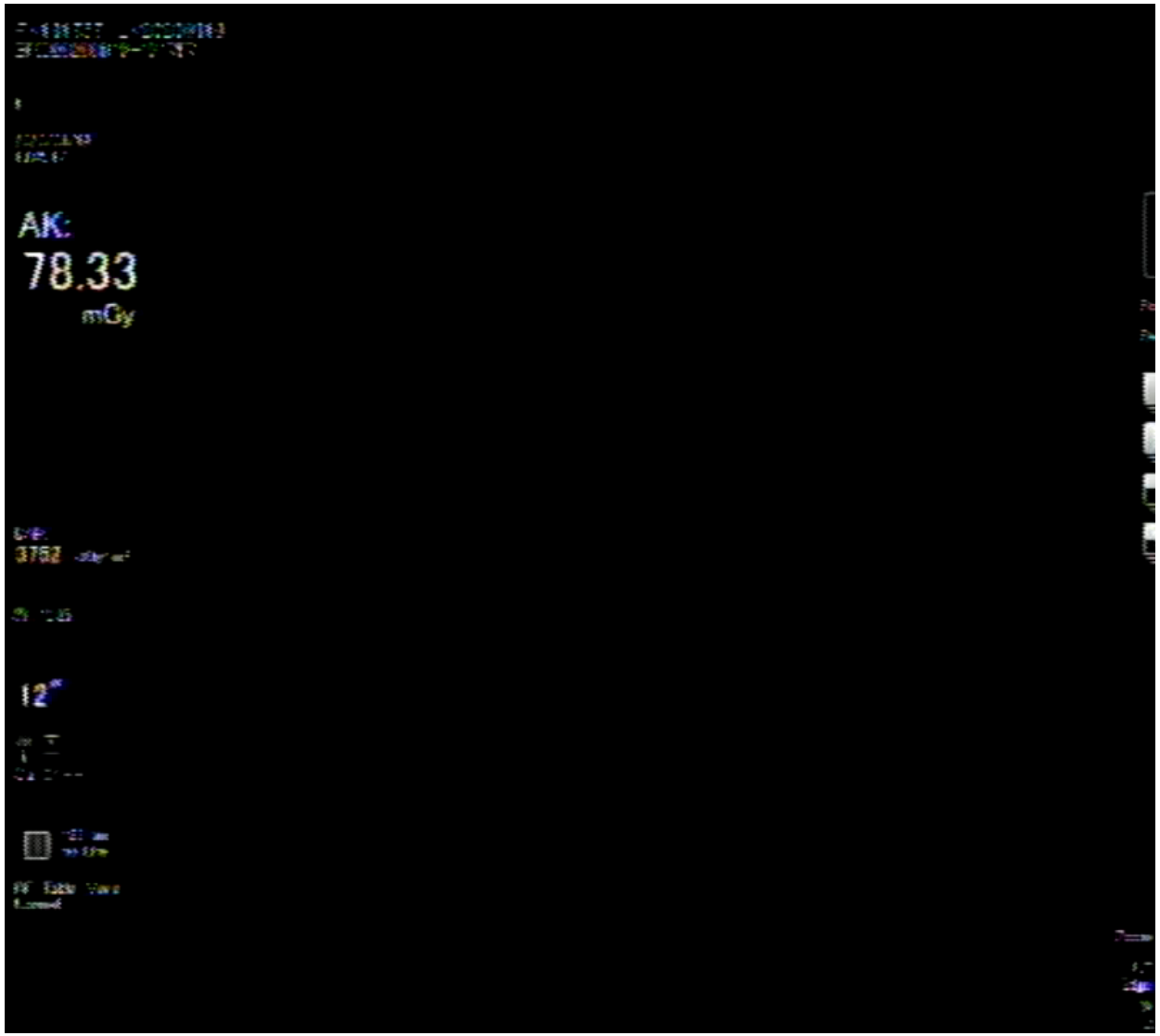


Tongue muscle abnormality from MRI in presbyphagia. Nakao, Yuta, et al. Dysphagia 36.3 (2021): 483-491.

Axis 2 : new methodology

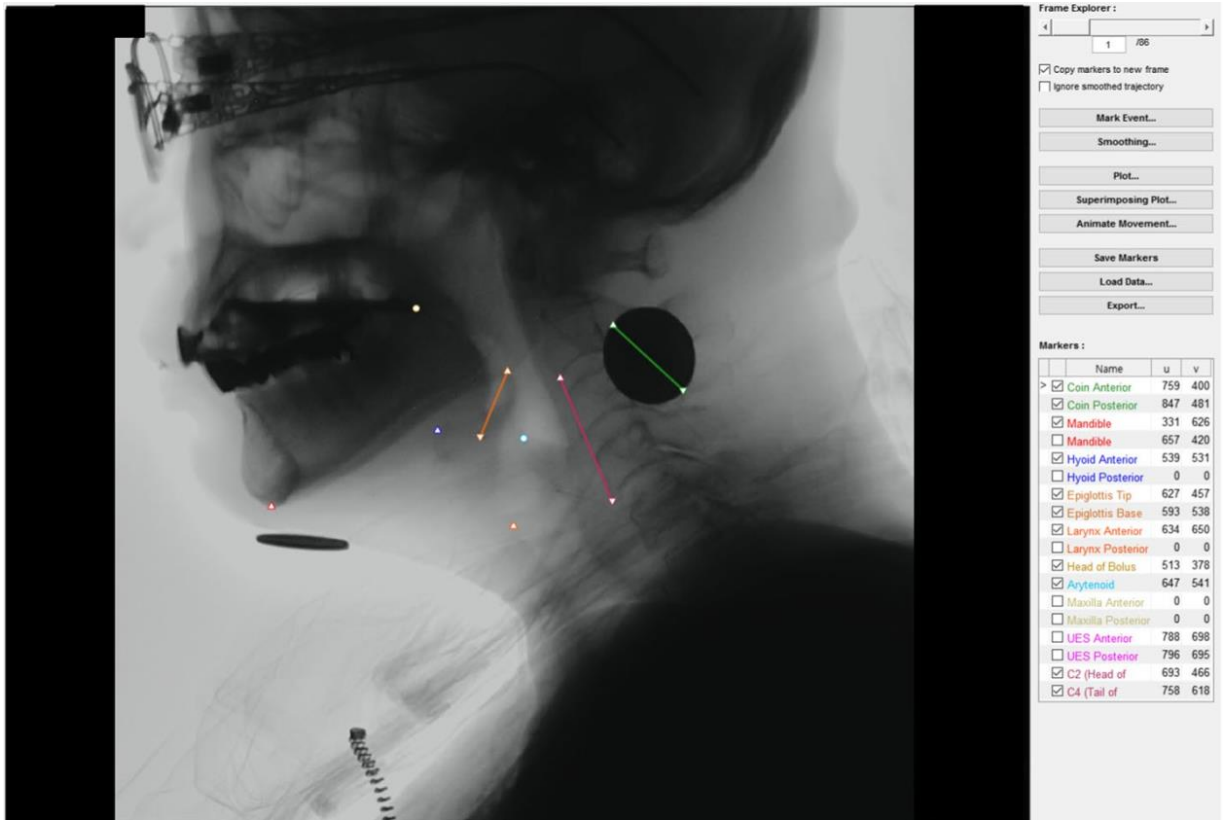
VFSS refinement : VF adduction maneuver in AP viewer



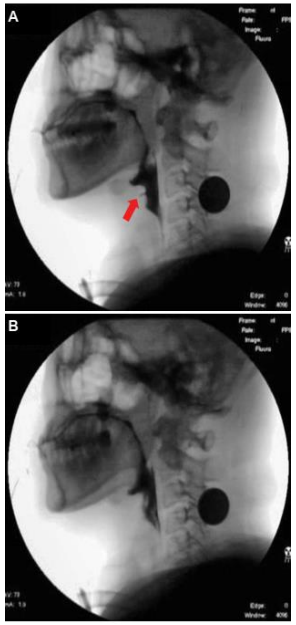


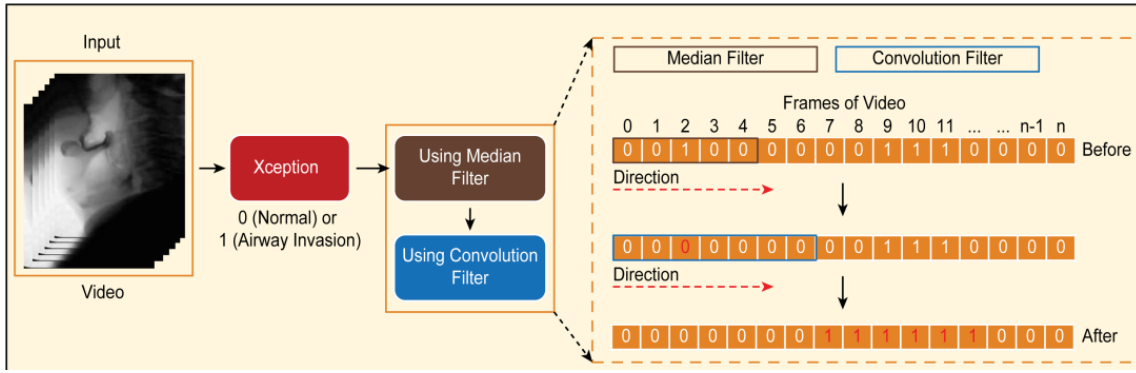
Axis 3 : Digital technology

VFSS Kinematic analysis -> machine learning



spatio-temporal analyzer for motion and physiologic study (STAMPS). Lee, Woo Hyung, et al. Biomedical engineering online 16.1 (2017): 1-12.





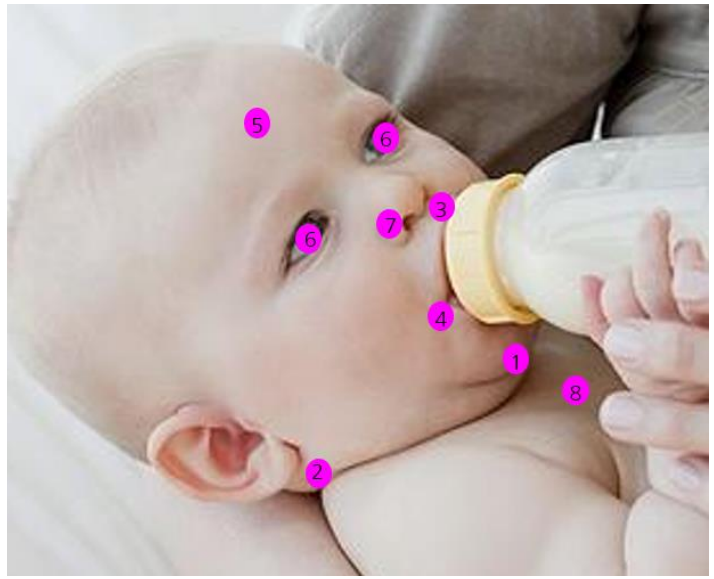
Automatic Detection of Airway Invasion from Videofluoroscopy via Deep Learning Technology. Lee, Seong Jae, et al. Applied Sciences 10.18 (2020): 6179.

Machine learning for neonatal dysphagia (NOMAS)

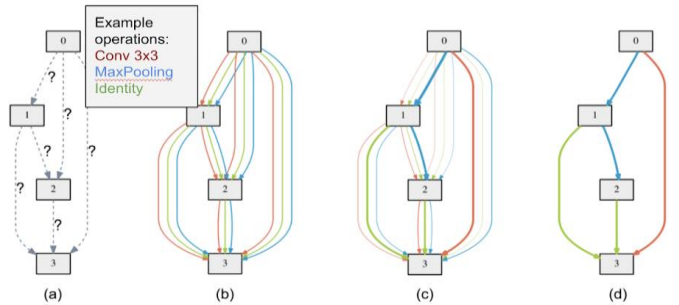
Table 2. Neonatal Oral-Motor Assessment Scale (NOMAS)

	Normal	Disorganization	Dysfunction
Jaw	__ consistent degree of jaw depression	__ inconsistent degree of jaw depression	__ excessively wide excursion that interrupt the intra-oral seal on the nipple
	__ rhythmical excursions	__ arrhythmical jaw movements	
	__ spontaneous jaw excursions occur upon tactile presentation of the nipple up to 30 minutes prior to feed	__ difficulty initiating movements:	__ minimal excursion; clenching
		__ inability to latch	
		__ small, tremor-like start-up movements noted	__ asymmetry; lateral jaw deviation
	__ jaw movement occurs at the rate of approximately one per second	__ does not respond to initial cue of nipple until jiggled	__ absence of movement (% of time)
	__ sufficient closure on the nipple during the expression phase to express fluid from the nipple	__ persistence of immature suck pattern beyond appropriate age	__ lack of rate change between NNS and NS (NNS=2/sec; NS=1/sec)
		__ under 40 weeks	
Tongue	__ cupped tongue configuration (tongue groove) maintained during sucking	__ excessive protrusion beyond labial border during extension phase of sucking without interrupting rhythm	__ flaccid; flattened with absent tongue groove
	__ extension-elevation-retraction movements occur in anterior-posterior direction	__ arrhythmical movements	__ retracted; humped and pulled back into or-pharynx
		__ unable to sustain suckle pattern for two minutes due to:	__ asymmetry; lateral tongue deviation
	__ rhythmical movements	__ habituation	
		__ poor respiration	__ excessive protrusion beyond labial border before/after nipple insertion with out/down movement
	__ movements occur at the rate of one per second	__ fatigue	
	__ liquid is sucked efficiently into the oro-pharynx for swallow	__ incoordination of suck/swallow and respiration which results in nasal flaring, head turning, extraneous movement	__ absence of movement

Clinical observation



Continuous relaxation of discrete operations enables gradient descent



Goal: Find the optimal cell, by placing proper operations (e.g. conv, pooling) at edges

Superpose: each edge is the sum over the outputs of multiple operations, weighted by continuous "architecture parameters" α

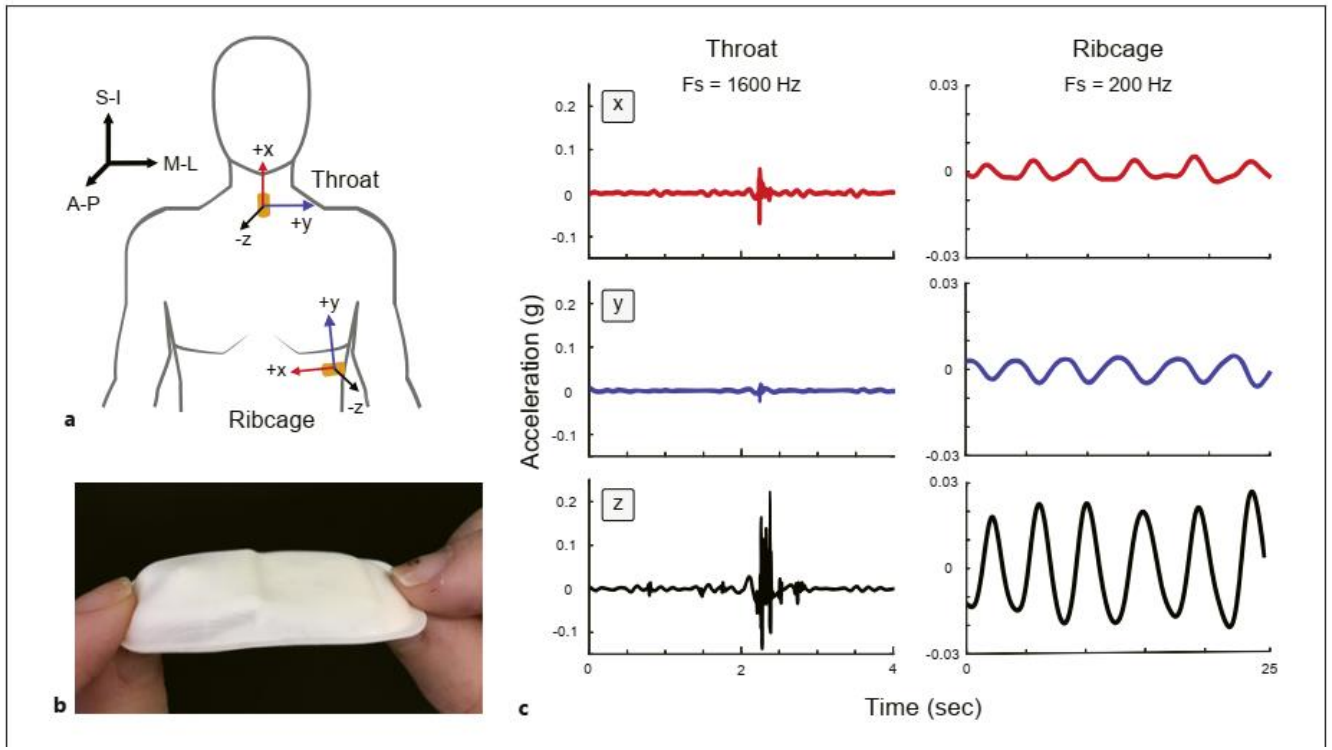
Search: Optimize the architecture weights α, using gradient descent on validation loss

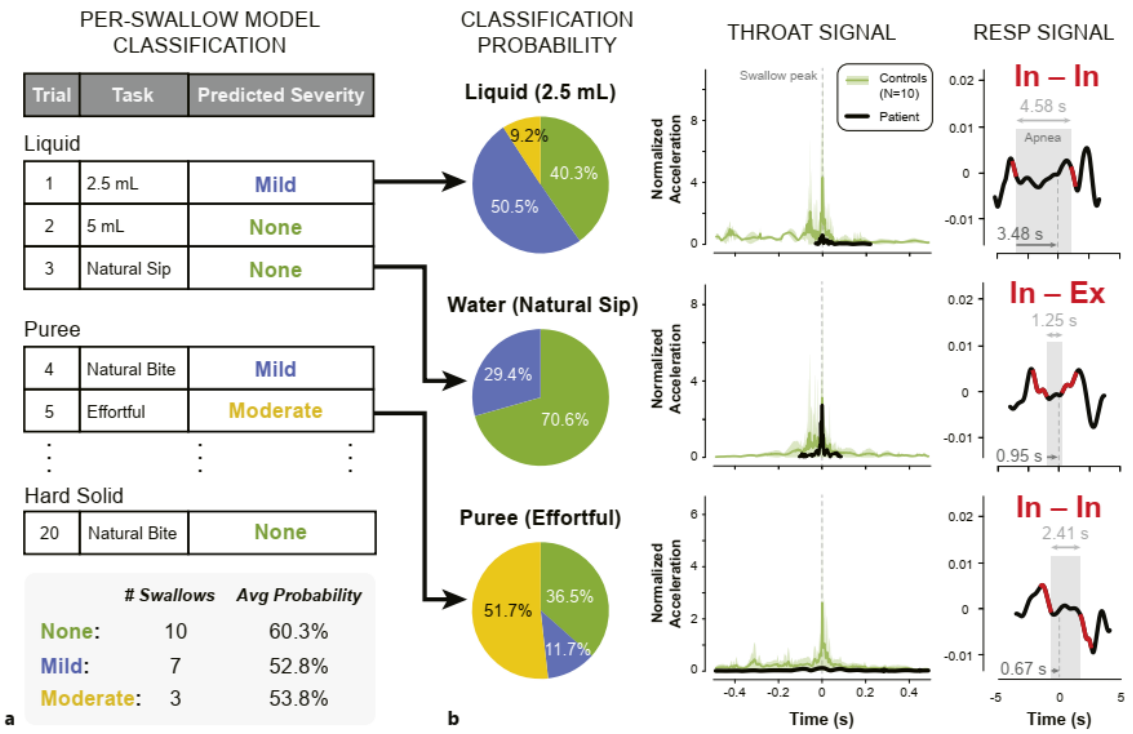
Discretize: select the operation with the highest architecture weight, to be the final architecture

Computer vision !!

Axis 3 : Digital technology

Wearable sensor





Mechano-acoustic sensors with machine learning to monitor biomarkers of dysphagia.
O'Brien, Megan K., et al. Digital Biomarkers 5.2 (2021): 167-175.

Take home messages

- 연하장애의 병태생리에는 다양한 요소들이 관여하며, 그 자체로 매우 복잡하다
- 연하장애는 정의가 명확하지 않고 기준이 되는 biomarker가 없어 진단에 어려움이 있다
- 연하장애의 진단적 평가 시에는 단순히 흡인여부를 판단하는 것에 국한하기 보다 연하과정 전반에서 문제점을 파악하고, 추후 재활계획을 세우는 것까지 포함해야 한다
- 연하장애의 진단, 평가 대상군이 확대되고 있다
- MRI와 같은 새로운 도구가 연하장애의 평가에 사용될 수 있고, 기존의 방식도 변형하여 적용해볼 수 있다
- 최근에 Machine learning을 포함한 디지털 기술들이 연하장애의 진단평가에 활용되고 있다

References

- 재활의학 6th, 한태륜, 방문석, 정선근
- Maeda, Keisuke, and Junji Akagi. "Decreased tongue pressure is associated with sarcopenia and sarcopenic dysphagia in the elderly." *Dysphagia* 30.1 (2015): 80-87.
- Mori, Takashi, et al. "Development, reliability, and validity of a diagnostic algorithm for sarcopenic dysphagia." *JCSM Clinical Reports* 2.2 (2017): 1-10.
- Chang, Min Cheol, and Soyoung Kwak. "Videofluoroscopic swallowing study findings associated with subsequent pneumonia in patients with dysphagia due to frailty." *Frontiers in medicine* 8 (2021): 1049.
- Layly, Julie, et al. "Can we reduce frame rate to 15 images per second in pediatric videofluoroscopic swallow studies?." *Dysphagia* 35.2 (2020): 296-300.
- Martin-Harris, Bonnie, et al. "BaByVFSSImP© a novel measurement tool for videofluoroscopic assessment of swallowing impairment in bottle-fed babies: establishing a standard." *Dysphagia* 35.1 (2020): 90-98.
- Olthoff, Arno, et al. "Evaluation of dysphagia by novel real-time MRI." *Neurology* 87.20 (2016): 2132-2138.
- Nakao, Yuta, et al. "Association among age-related tongue muscle abnormality, tongue pressure, and presbyphagia: a 3D MRI study." *Dysphagia* 36.3 (2021): 483-491.
- Lee, Woo Hyung, et al. "STAMPS: development and verification of swallowing kinematic analysis software." *Biomedical engineering online* 16.1 (2017): 1-12.
- Lee, Seong Jae, et al. "Automatic Detection of Airway Invasion from Videofluoroscopy via Deep Learning Technology." *Applied Sciences* 10.18 (2020): 6179.
- O'Brien, Megan K., et al. "Advanced Machine Learning Tools to Monitor Biomarkers of Dysphagia: A Wearable Sensor Proof-of-Concept Study." *Digital Biomarkers* 5.2 (2021): 167-175.