Frédérique FROUIN

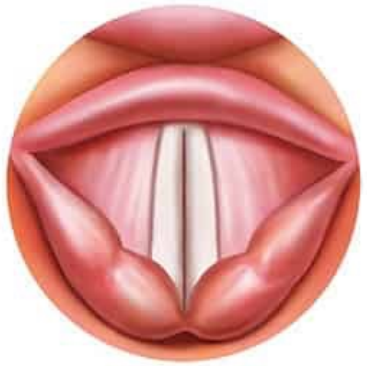
Detection of vocal fold paralysis after neck surgery: how can ultrasound, image processing and artificial intelligence help?

- Detection of Vocal Fold Palsy
- Visual interpretation
- Our databases
- Estimation of handcrafted features
- Machine learning prediction
- Deep learning approaches
- Future work

• Detection of vocal fold palsy

- Lesion of recurrent nerve is one adverse effect following neck surgery
- It occurs in about 5%-10% of cases, with possible transient symptoms
- Associated troubles are: dysphonia / swallowing difficulties / dyspnea

vocal cords in open position

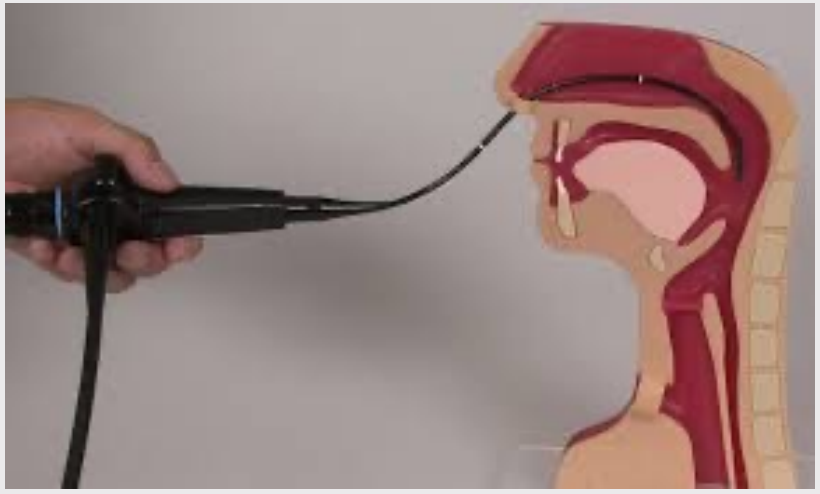


vocal cords in closed position

vocal cords attempting closed position (with one sided palsy)

• Detection of vocal fold palsy

Laryngoscopy: the reference



Current recommendations:
A systematic use before and after surgery, but:

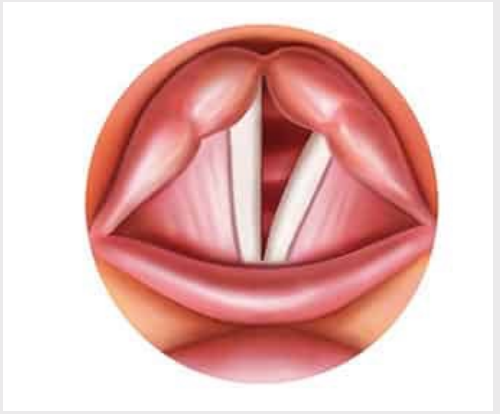
- invasiveness
- cost
- availability

TransLaryngeal UltraSound (TLUS) : an alternative

Dynamic Acquisitions:
Axial View
10 s during free breathing
(30 frames per s)

First large clinical studies:
Wang CP et al, Eur J Radiol (2012)

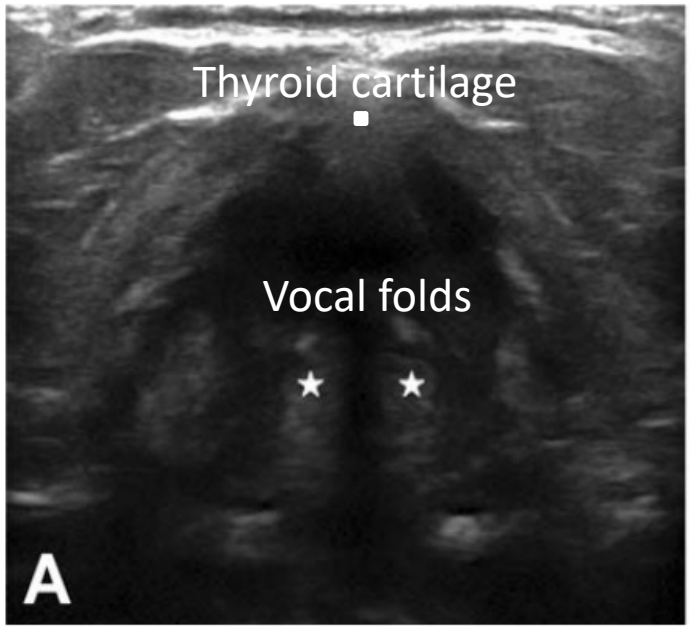
• Visual assessment

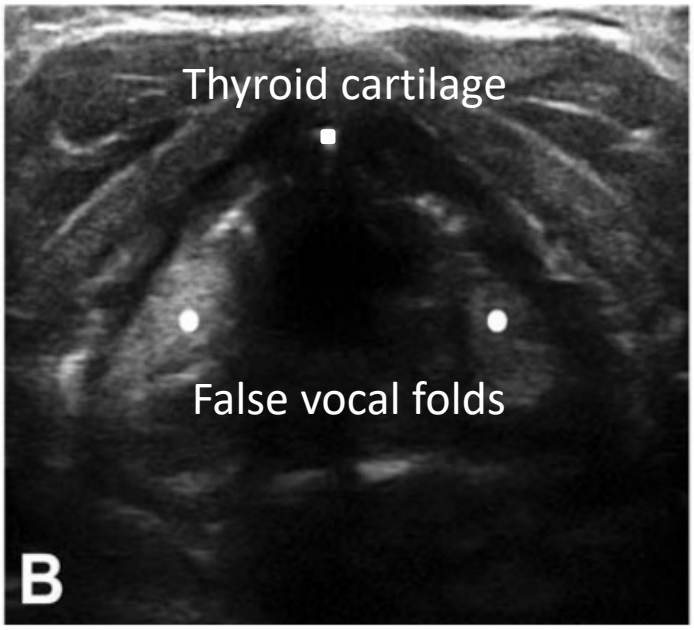


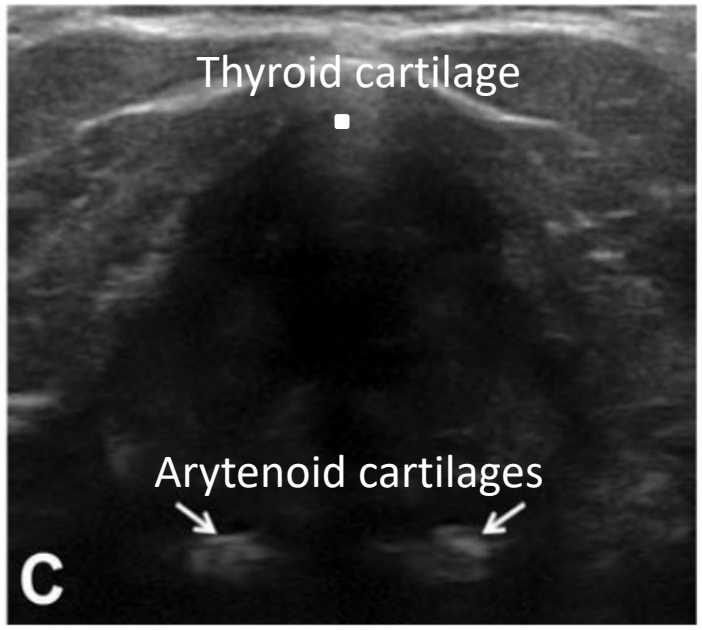
Flexible Laryngoscopy

Greater Baltimore Medical Center

• Visual assessment



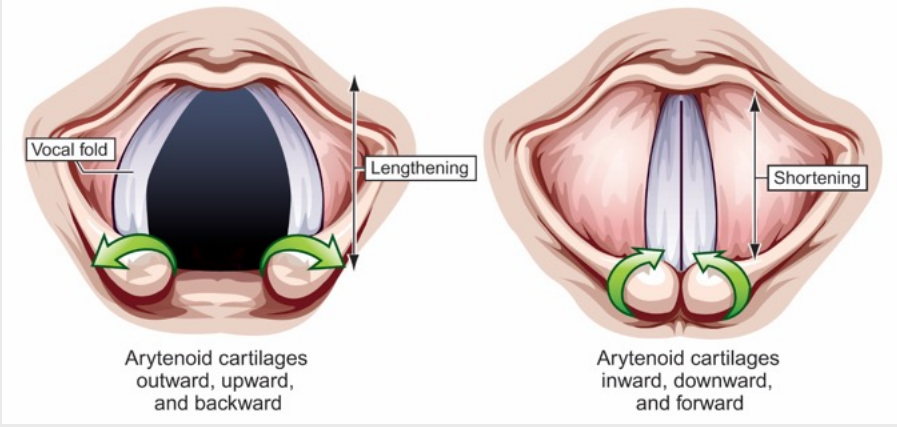




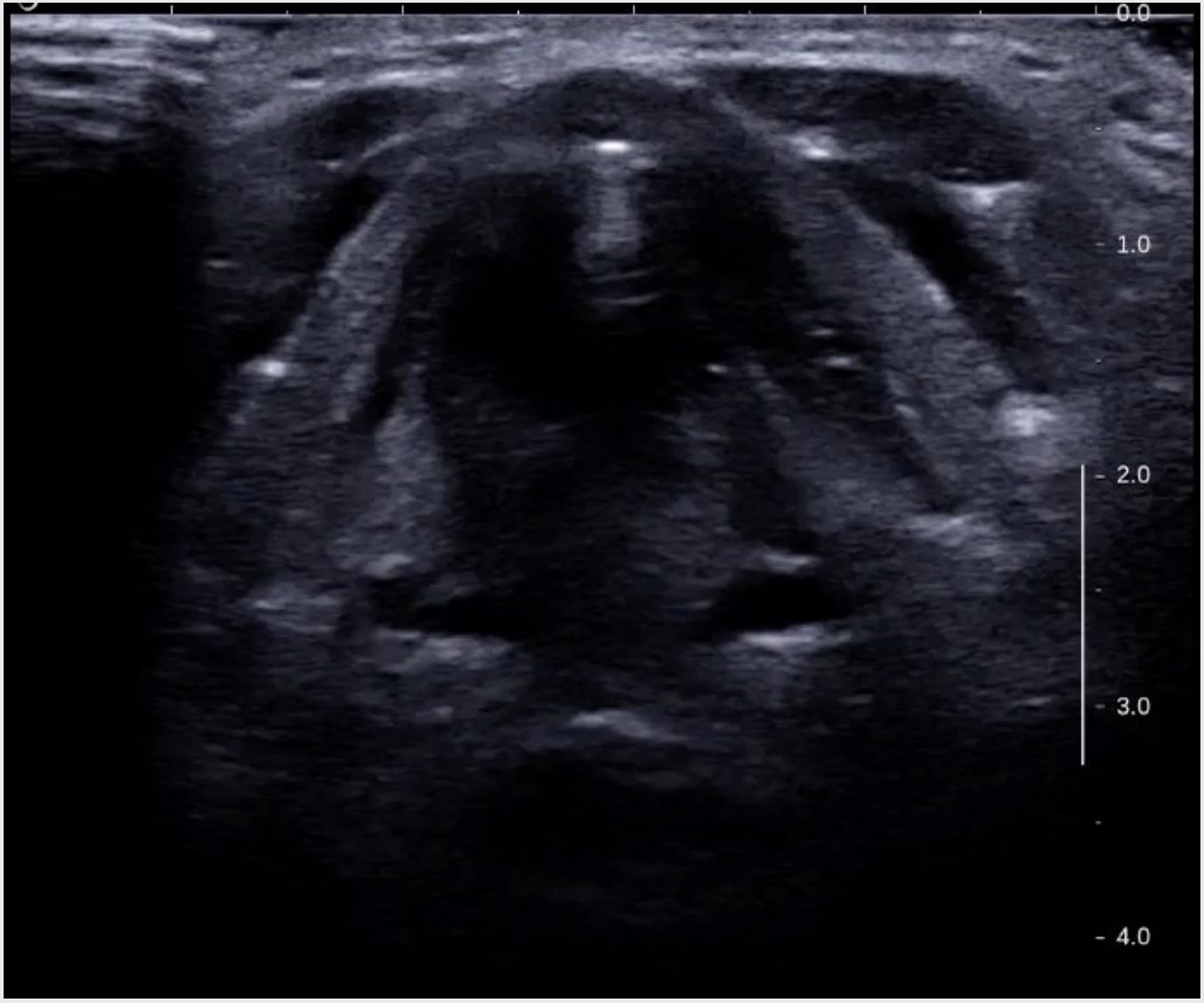
Bergeret-Cassagne et al J Ultrasound Med (2017)

Defining landmarks:

- Thyroid cartilage
- Arytenoids



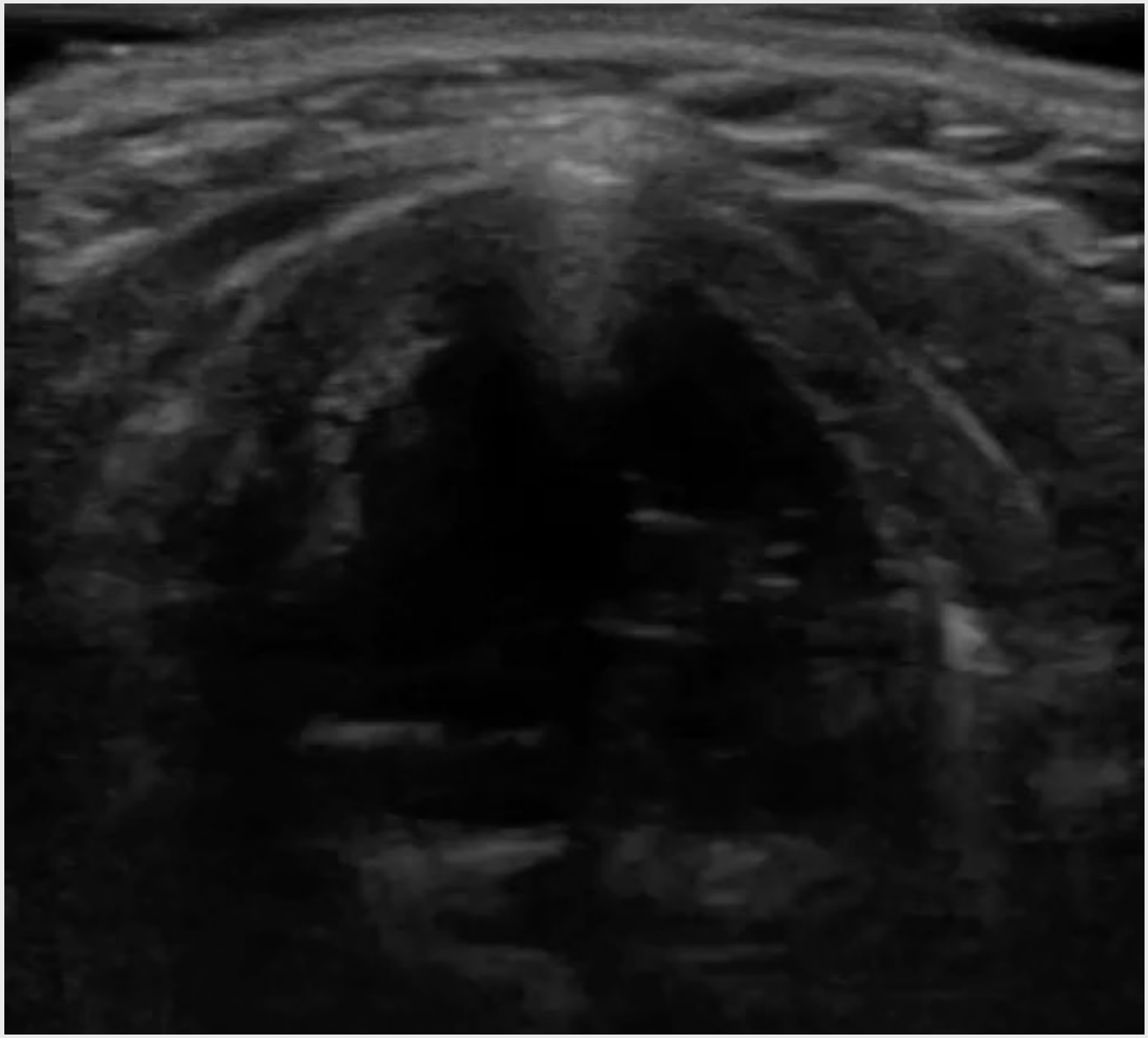
• Visual assessment



Dynamic TransLaryngeal UltraSound (TLUS)

Normal motion

• Visual assessment



Dynamic TransLaryngeal UltraSound (TLUS)

Palsy (Right)

• Our databases

Database 1
- 100 Patients with voice complaints after thyroid surgery
- Laryngoscopy (reference)
- Dynamic TLUS

Database 2
- 50 control subjects
- Dynamic TLUS

Visual assessment: Sensitivity 100% - Specificity 96%

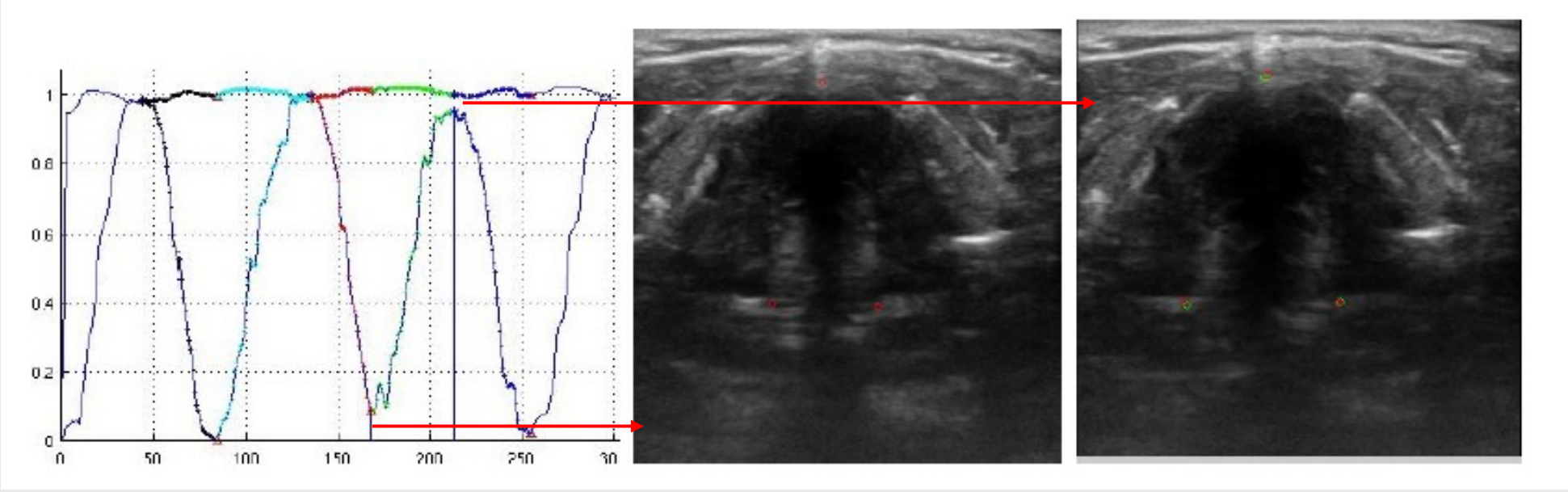
Database 1	Palsy (Laryngoscopy)	Normal cases (Laryngoscopy)
Palsy (TLUS)	50	2
Normal motion (TLUS)	0	48

Lazard et al World J Surg (2018)

• Estimation of handcrafted features

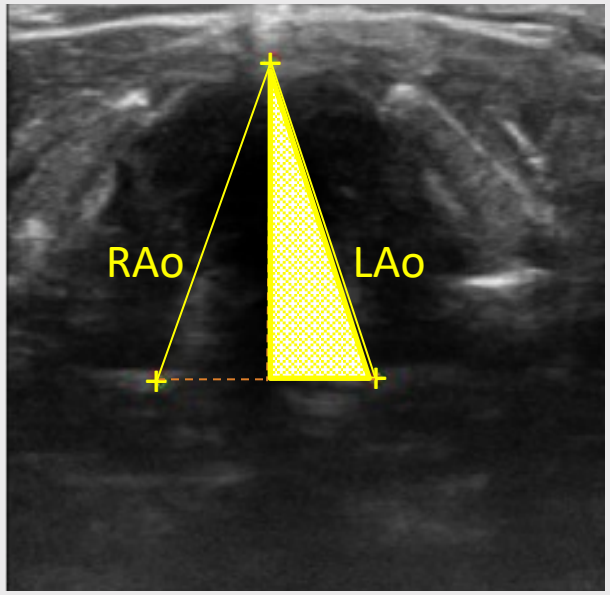
Selection of a subset of images: abduction or adduction phase
Selection of the two images corresponding to the extreme positions (maximal closing / maximal opening)

- Manual selection
- Automated selection of images PCA based extraction of motion curve

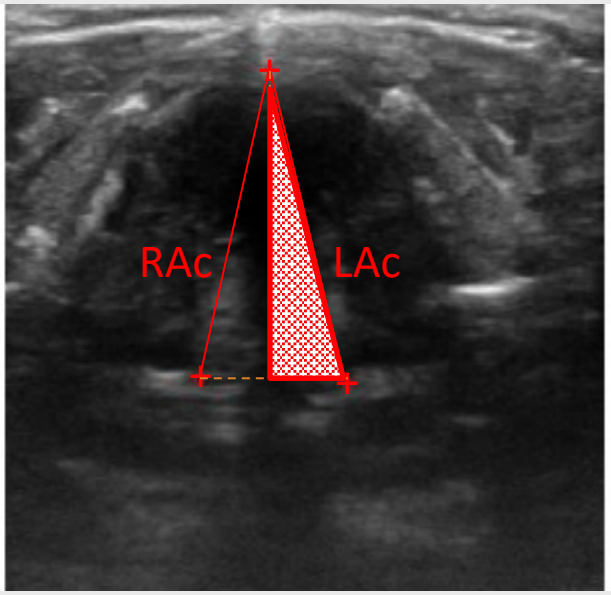


Diebold et al Ultrasound in Med & Biol (2005) - Cohen et al SPIE Medical Imaging (2015)

• Estimation of handcrafted features



Open



Closed

Two main indices :

- Motion amplitude (MA)

  Right MA = (RAo-RAc)/RAo
  Left MA = (LAo-LAc)/LAo
  MA= Minimum (Right MA, Left MA)

- Symmetry Index (SI)

  SIo = ABS(RAo-LAo)/(RAo+LAo)
  SIc = ABS(RAc-LAc)/(RAc+LAc)
  SI = (SIo+SIc)/2

Definition of reference values on Database 2 (control subjects)

- SI: mean <1% standard deviation 5%
- MA: mean 25% standard deviation 10%

  Small SI, Large MA

Bergeret-Cassagne et al J Ultrasound Med (2017)

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• Estimation of handcrafted features

Database 2 (50 control subjects) : Small Symmetry Index (SI)
Large Motion Amplitude (MA)

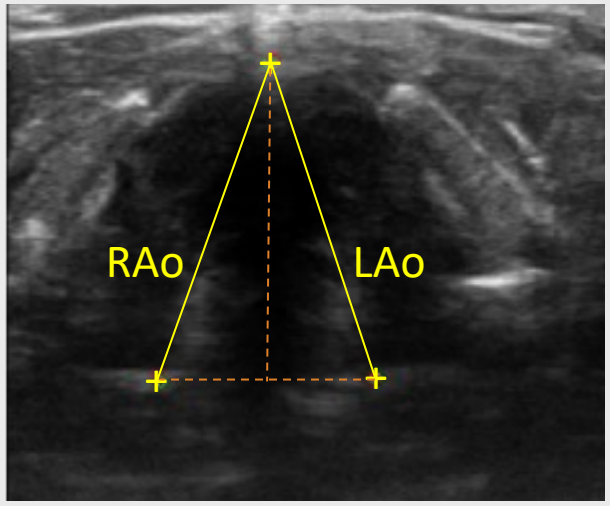
Database 1 (50 subjects with Palsy – 50 subjects without Palsy)

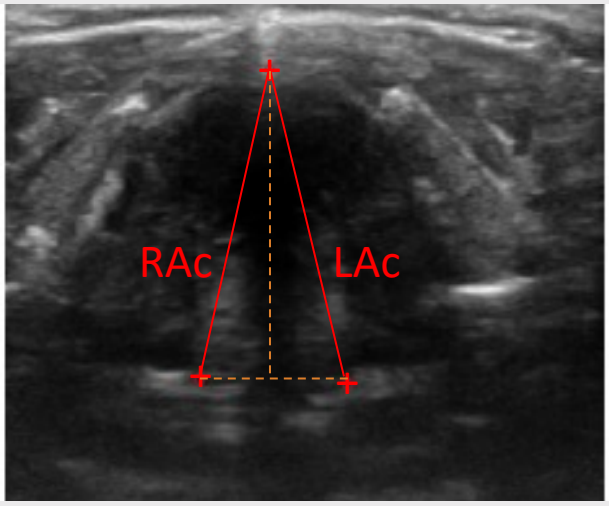
- Cut-off for SI : 10%.
  If (SI>10%) then Palsy
  82% sensitivity - 82% specificity

- Cut-off for SI : >10% - Cut-off for MA <10%
  If (SI>10%) or (MA<10%) then Palsy
  94% sensitivity - 66% specificity

Lazard et al World J Surgery (2018)

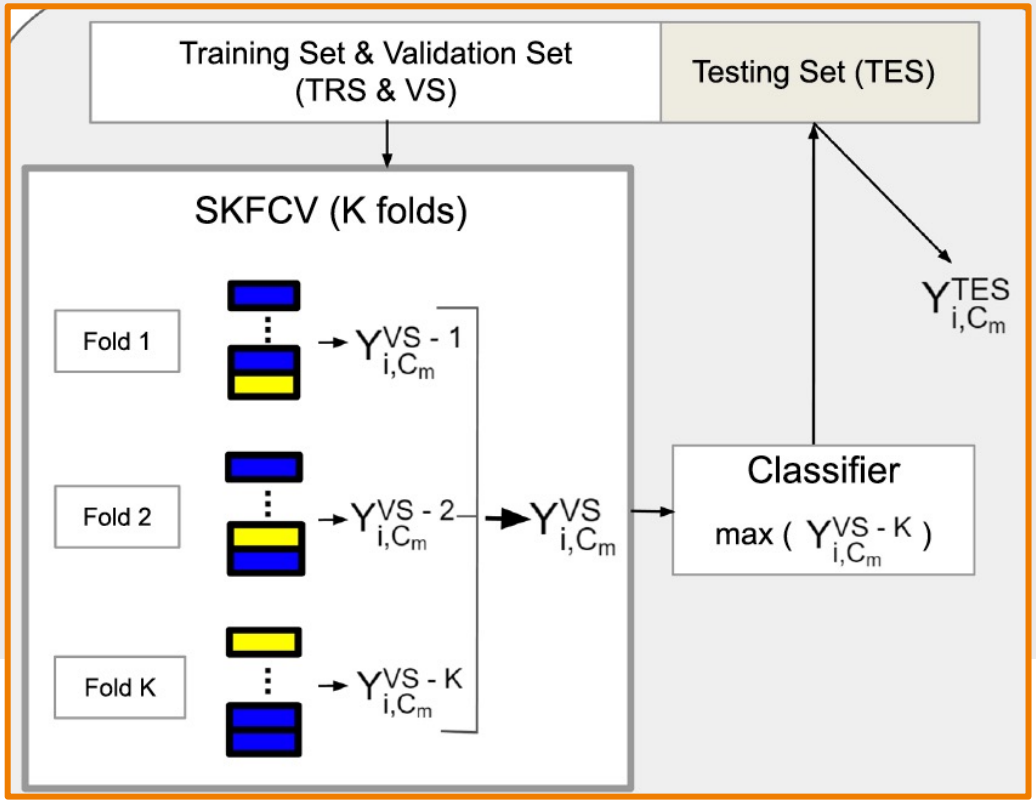
• Machine Learning prediction





Increasing the number of handcrafted features (26)

- Distance
- Angles
- Areas
- Ratios Left/Right
- Ratios Closing/Opening…



- Training: balanced Database 1
  SVM with Recursive Feature Elimination Cross-Validation (SKFCV) (5 folds)

- Independent Test : Database 2

Dirand et al, Sci Rep (2019)

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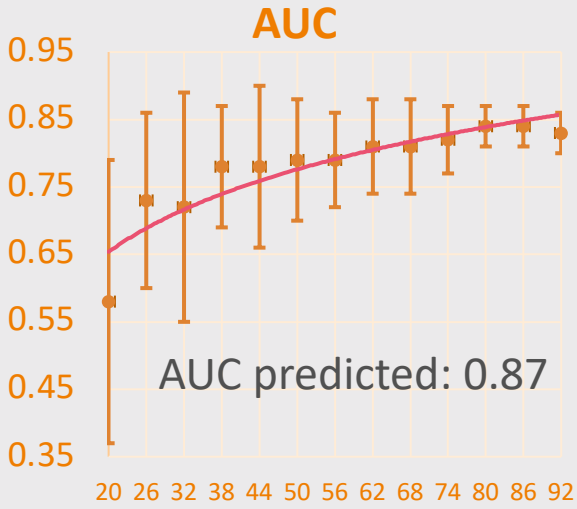
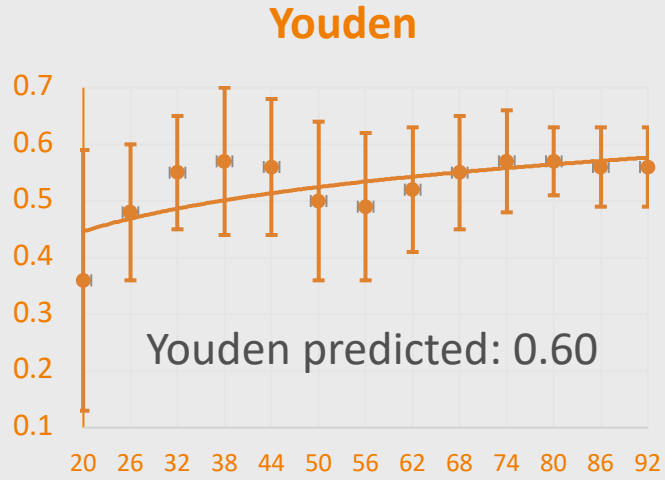
• Machine Learning prediction

- Database 1: 5-fold Cross-Validation
  AUC of ROC curve: Mean 0.80 (standard deviation 0.07)
  Youden index (Sensitivity + Specificity -1): Mean 0.60 (standard deviation 0.16)

- Independent test: Database 2
  Correct prediction in 94% of cases

- Down-sampling and bootstrap to predict AUC and Youden index on large cohorts



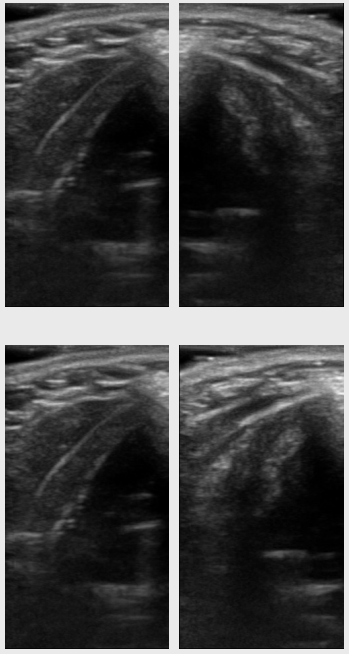


Dirand et al, Scientific Reports (2019)

Deep learning approaches

- Data preprocessing and strategies for data augmentation

Split and Flip

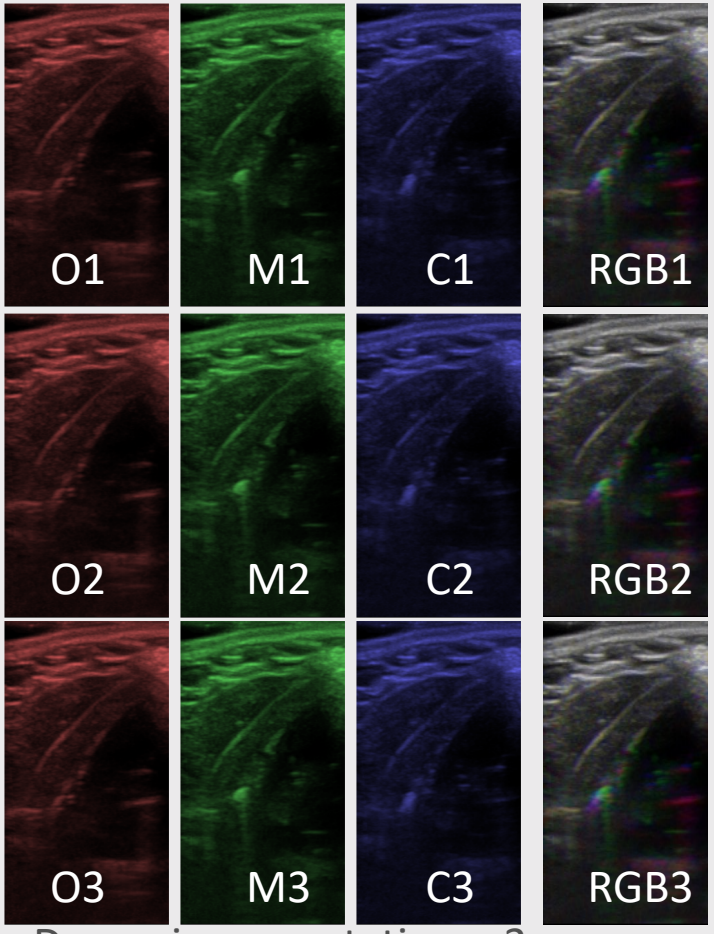


hemi-larynx:
x2

Square images
even / odd rows

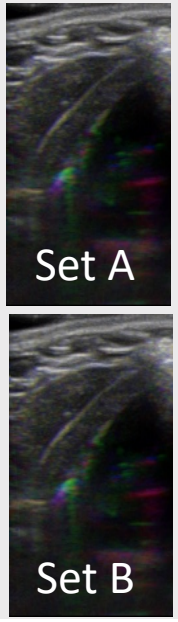
Square:
x2 or more

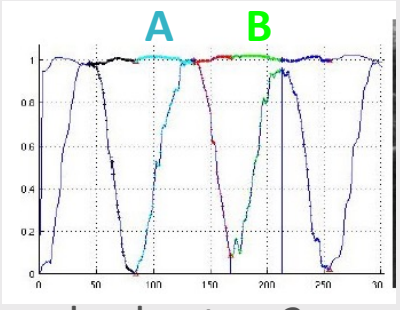
Selection & display of dynamic images



Dynamic permutation: x3 or more

Selection of
dynamic subsets





Several subsets: x2 or more

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• Deep learning approaches

Learning database (joining databases 1 and 2):

- 82 subjects without palsy (N)
- 41 subjects with palsy (P)

Training database: 66 N +33 P patients

- 1056 ‘normal’ images
- 1056 ‘palsy’ images

Validation database: 16 N + 8 P patients

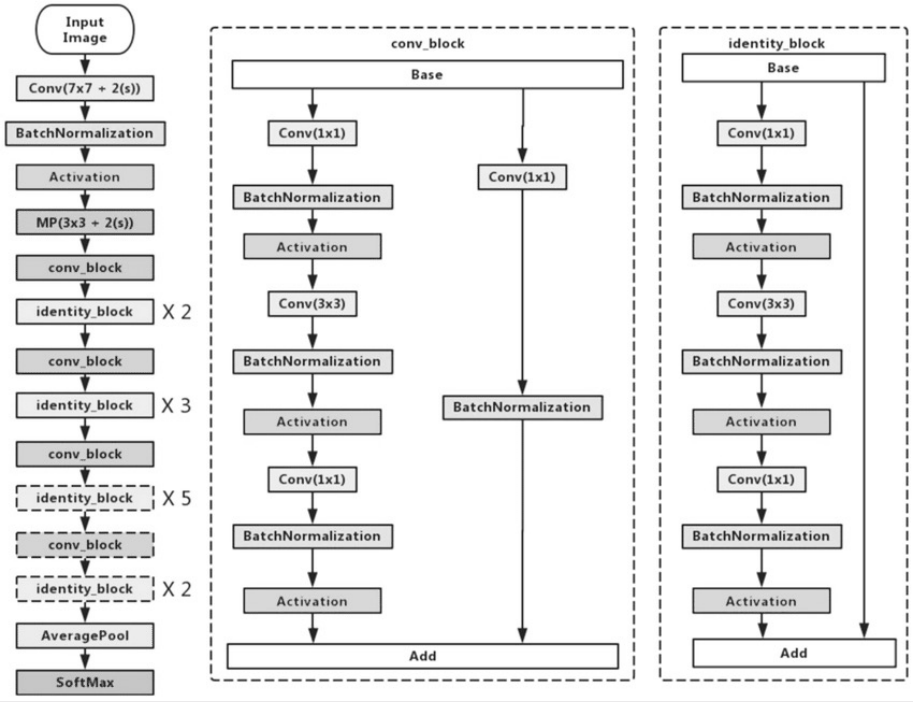
- 256 ‘normal’ images
- 256 ‘palsy’ images

Test database (randomly selected from database 1)

- 18 subjects without palsy
- 9 subjects with palsy

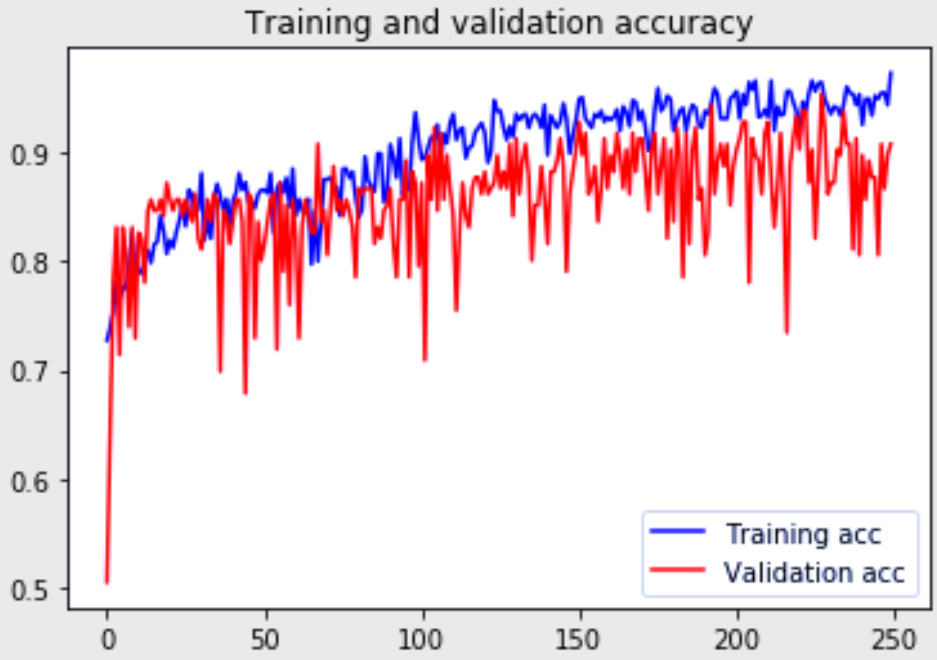
Deep learning approaches

ResNet50 network



- Random initialization
- 250 epochs
- Size batch: 8

Results on the learning database

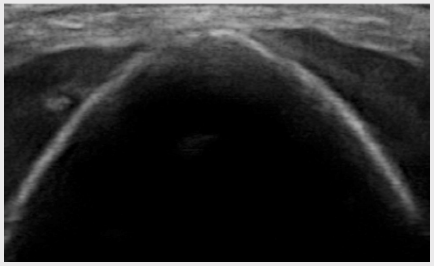


Results on the test database

- Accuracy: 78%
- Sensitivity: 44% - Specificity: 88%

Future work

- Improve ultrasound acquisition



- Improve data analysis (deep learning)
  - Increase Data augmentation, improve stability procedures…
  - Add voice quality indices

- Increase database

  Ongoing multi-centric clinical trial

  https://clinicaltrials.gov/ct2/show/NCT03976011

  Expected: 500 subjects, 40 with palsy

Acknowledgments

Special thanks to

- Fahad Khalid, PhD Student, LITO (Deep Learning)
- Anne-Sophie Dirand, PhD Student, LITO (Machine Learning)
- Muriel Lefort, LIB, Sorbonne Université (Clinical Research)
- Dr Diane Lazard, Sorbonne Université (Laryngoscopy)
- Dr Agnès Rouxel, Sorbonne Université (Clinical Ultrasound)
- Pr Christophe Trésallet, Sorbonne Université (Surgery)

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