SPIE Photonics West 2022

ADVANCED EAR EXAMINATION USING DEEP LEARNING-ASSISTED MOBILE OTOSCOPE

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[1]Department of Biomedical Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan, South Korea
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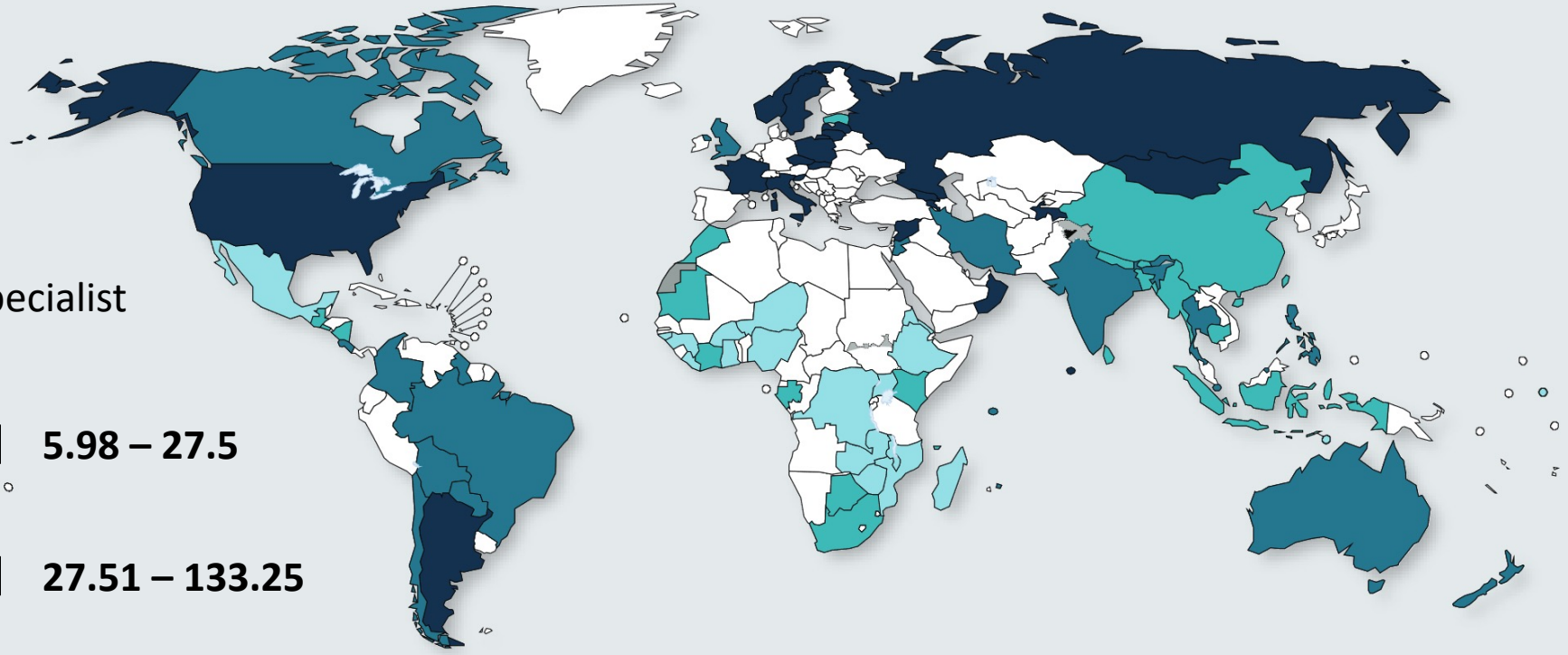
[3]Kyungpook National University, Daegu, South Korea
[4]Ajou University Hospital, Suwon, South Korea

Table of Contents

Number of ENT specialists per million population, worldwide in 2013 [1]

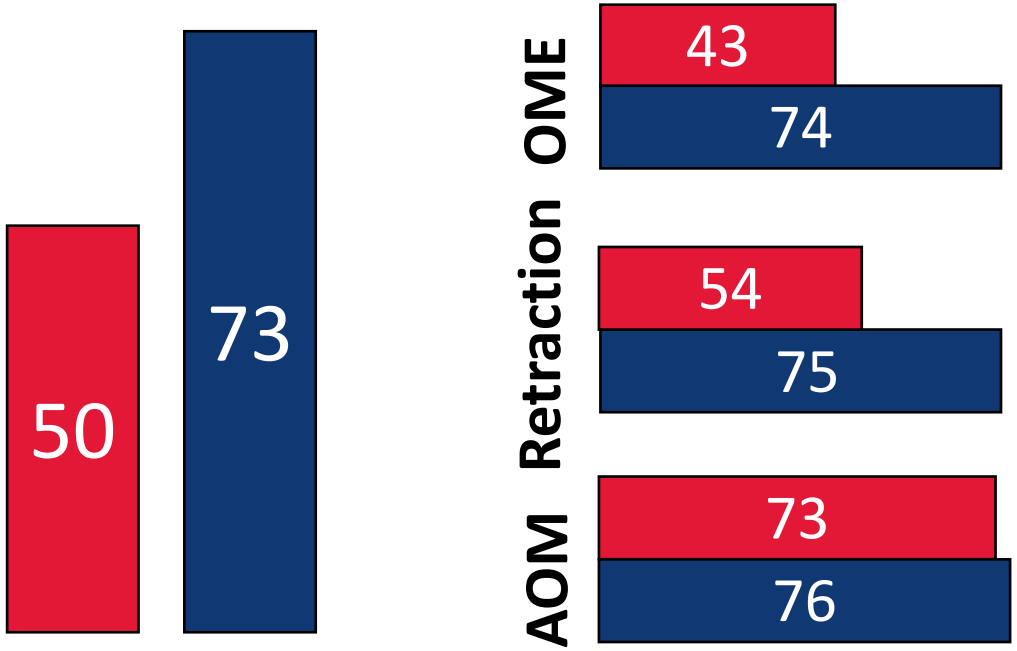


***ENT:** Otolaryngologist.
Short for ear, nose and throat specialist

- 0 - 0.88
- 0.89 - 5.97
- Data not available
- 5.98 – 27.5
- 27.51 – 133.25
- Not applicable

[1] World Health Organization. "Multi-country assessment of national capacity to provide hearing care." (2013).

Comparison of diagnostic accuracy (%) between pediatrician and ENT specialist [2]



***OME:** Otitis media with effusion, **AOM:** Acute otitis media

[2] Pichichero, Michael E., and Michael D. Poole. "Assessing diagnostic accuracy and tympanocentesis skills in the management of otitis media." Archives of pediatrics & adolescent medicine 155.10 (2001): 1137-1142.

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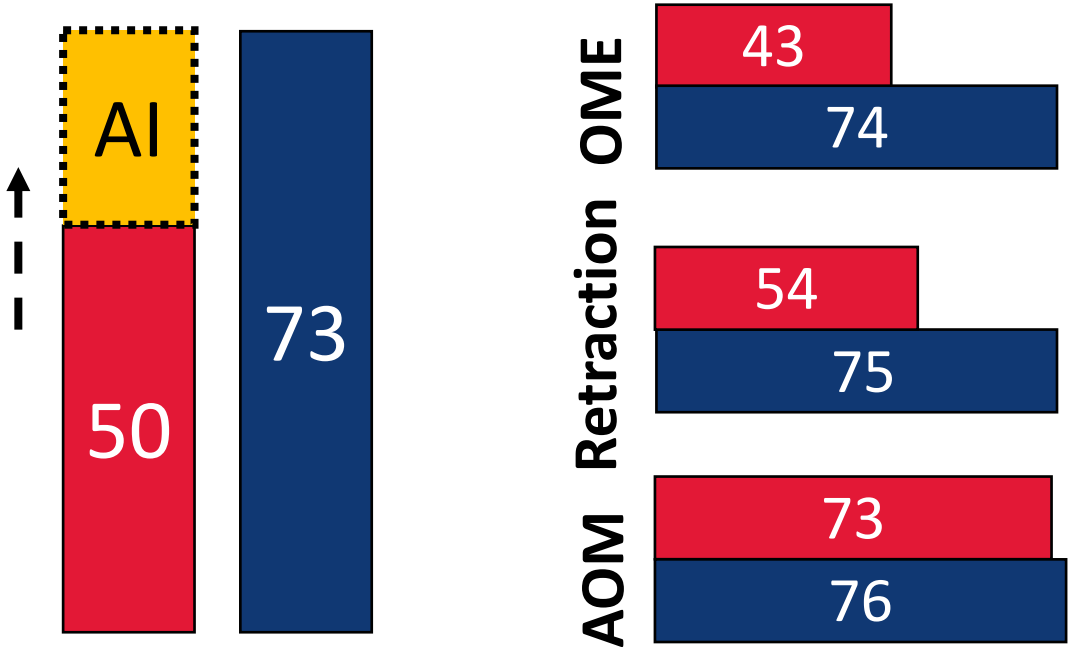

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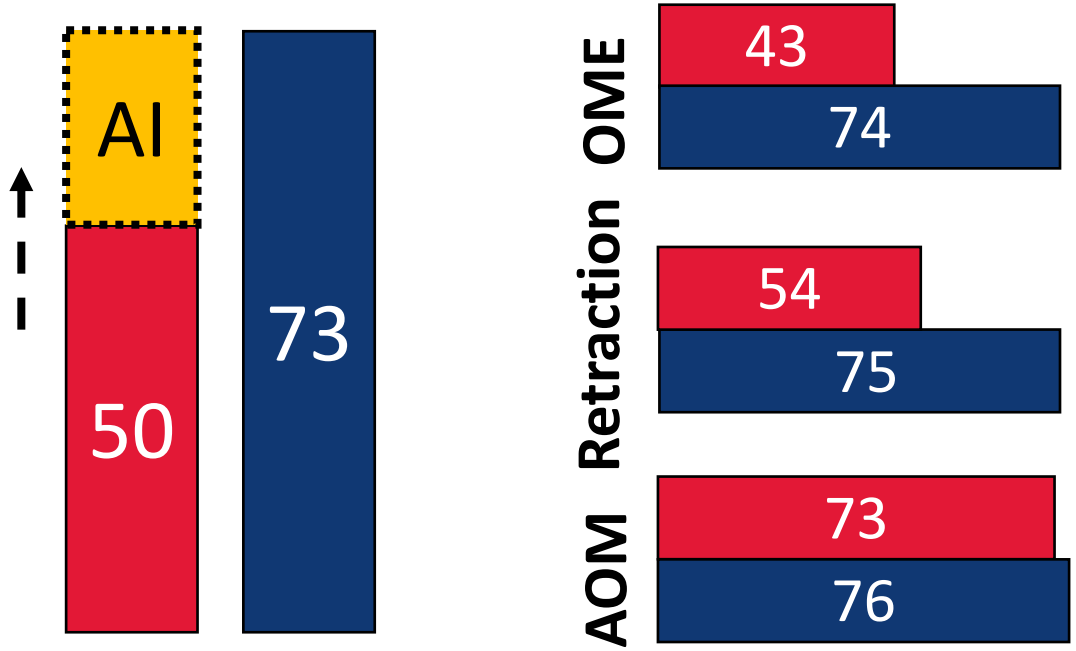

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We suggest development of non-specialist and affordable ear examination tool

2. Research approach

Deep learning for otolaryngology

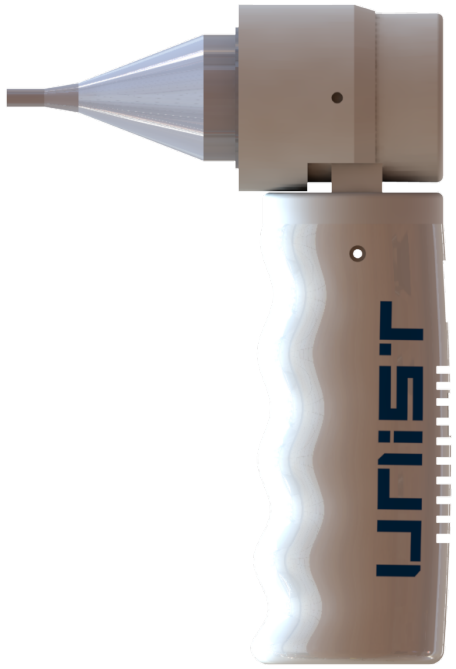
Study	Application	Accuracy
Basaran (2020) [3]	Diagnosis of middle ear inflammation	**90.48%**
Cha (2019) [4]	Detection of ear and mastoid disease	**93.67%**
Livingstone (2019) [5]	Otologic disease screening	**84.4%**

✓ **Convolutional neural networks** are reported strong performance

[3] Cha, Dongchul, et al. "Automated diagnosis of ear disease using ensemble deep learning with a big otoendoscopy image database." EBioMedicine 45 (2019): 606-614.
[4] Livingstone, Devon, et al. "Building an Otoscopic screening prototype tool using deep learning." *Journal of Otolaryngology-Head & Neck Surgery* 48.1 (2019): 1-5.
[5] Başaran, Erdal, Zafer Cömert, and Yüksel Çelik. "Convolutional neural network approach for automatic tympanic membrane detection and classification." *Biomedical Signal Processing and Control* 56 (2020): 101734.

Our ear examination platform

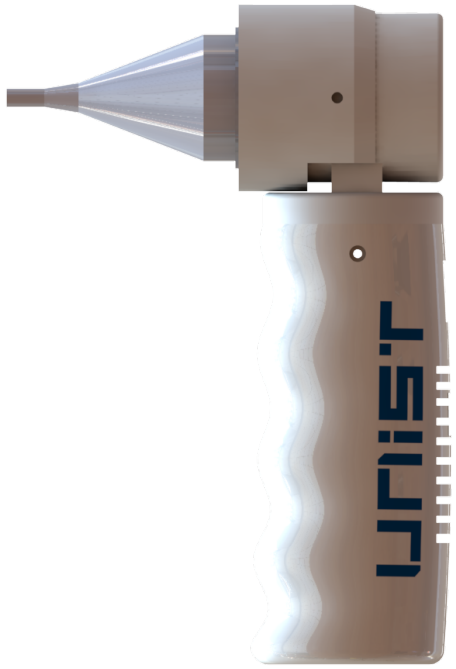
A. Otoscope ⟷ **B. Mobile app**

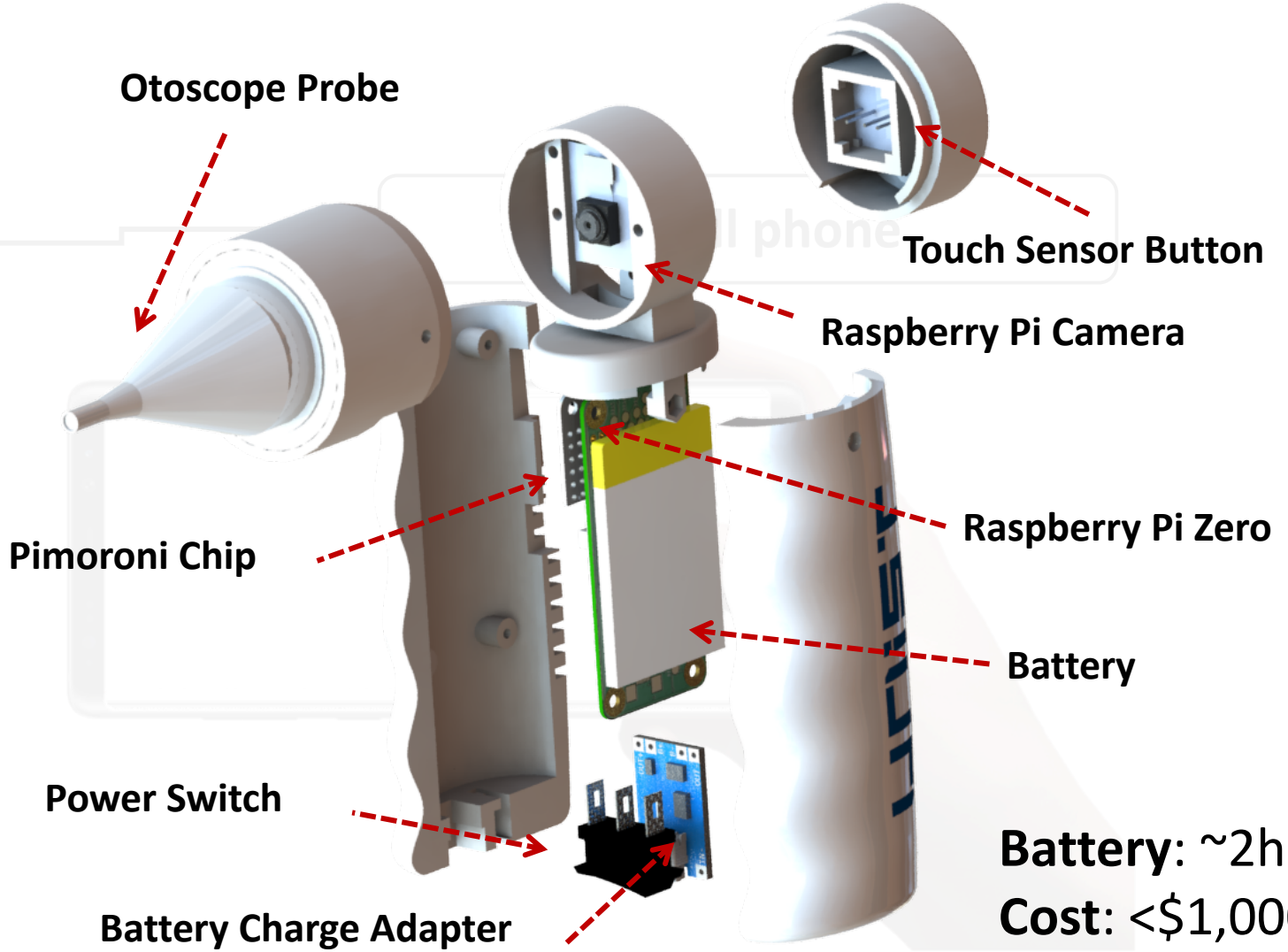


C. Otolaryngology AI

Our platform

A. Otoscope





Battery: ~2h
Cost: <$1,000

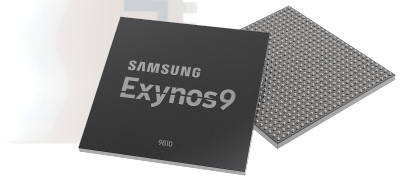
Our platform

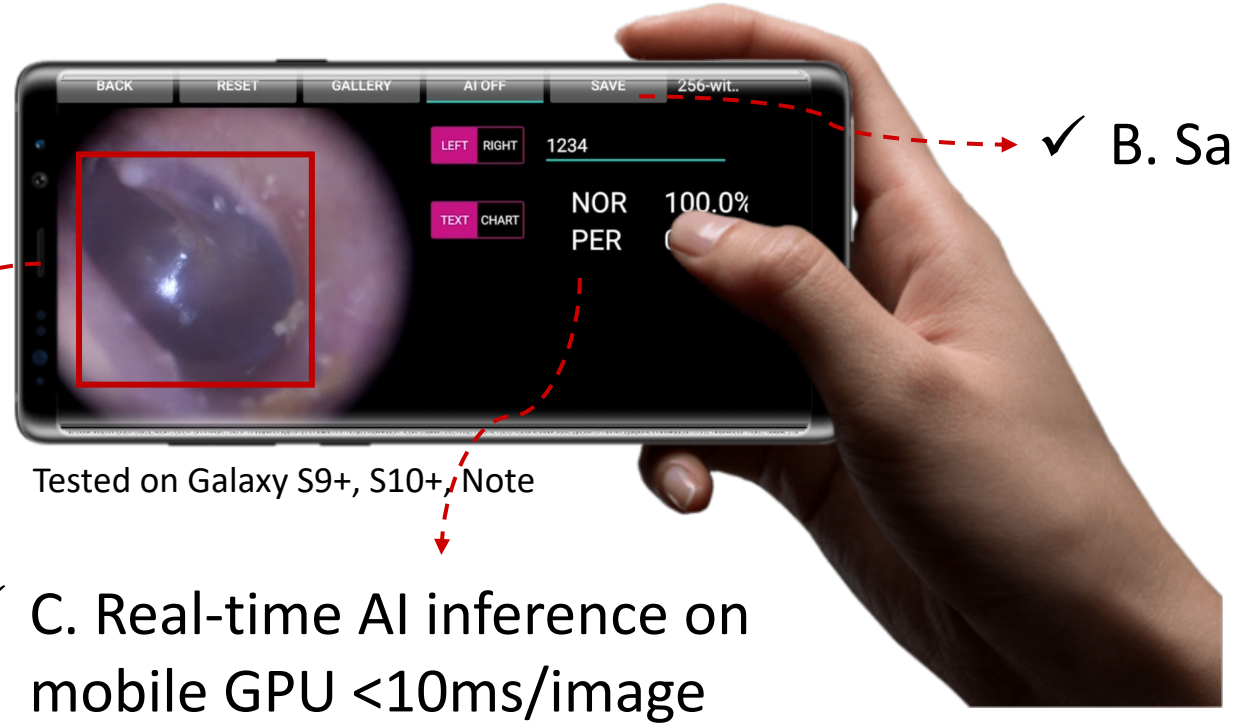
A. Otoscope

B. Mobile app

Custom developed
Android application

✓ A. Wireless Stream:
<100ms low-latency





✓ B. Save

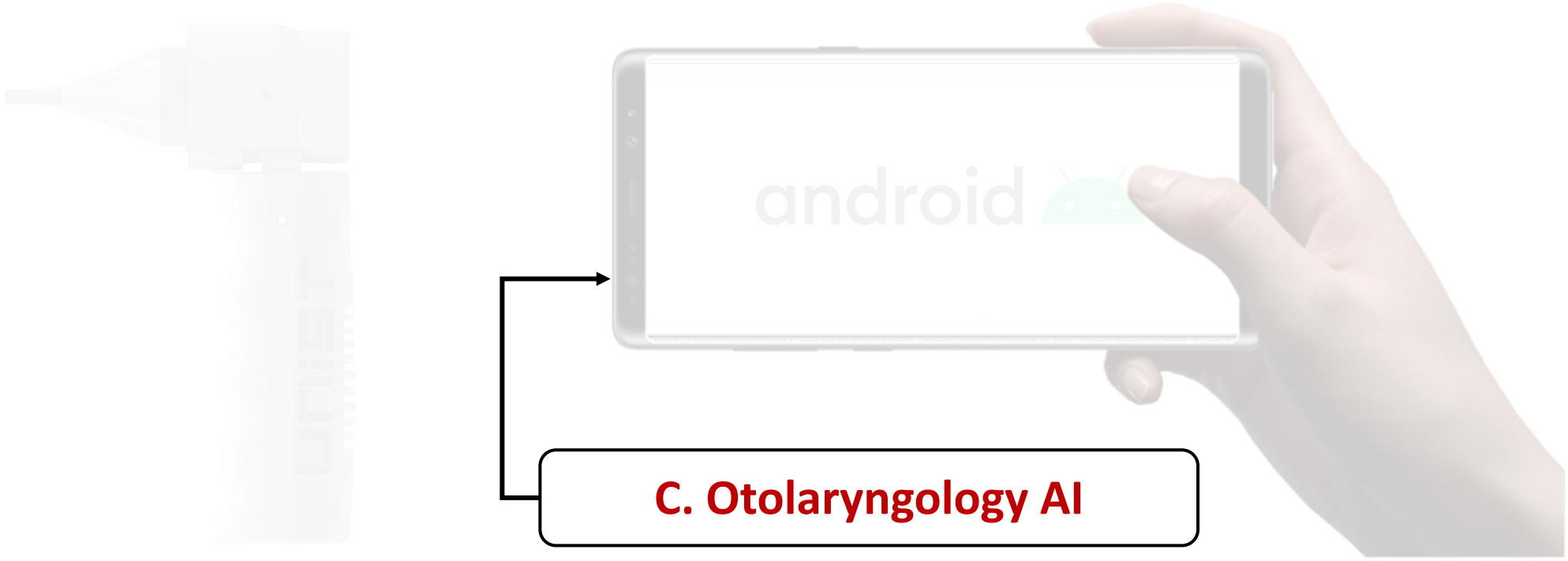
Tested on Galaxy S9+, S10+, Note

✓ C. Real-time AI inference on
mobile GPU <10ms/image

Our platform

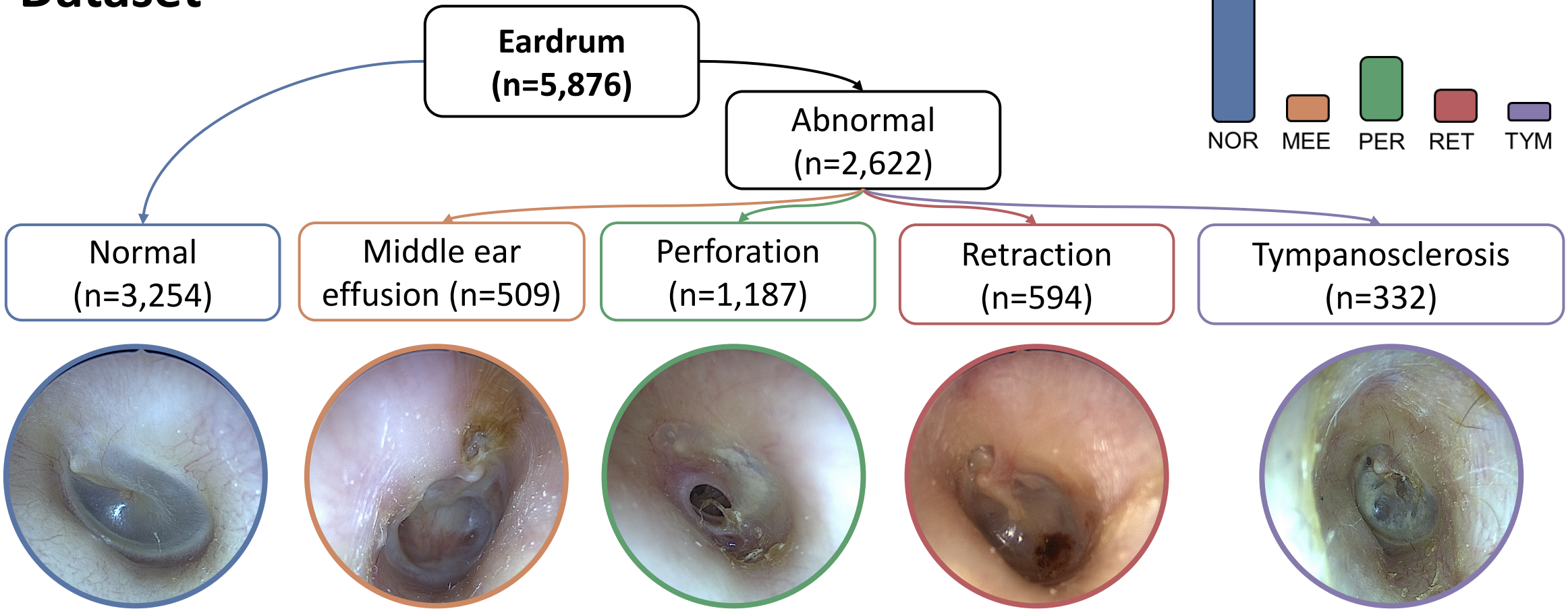
A. Otoscope

B. Mobile app



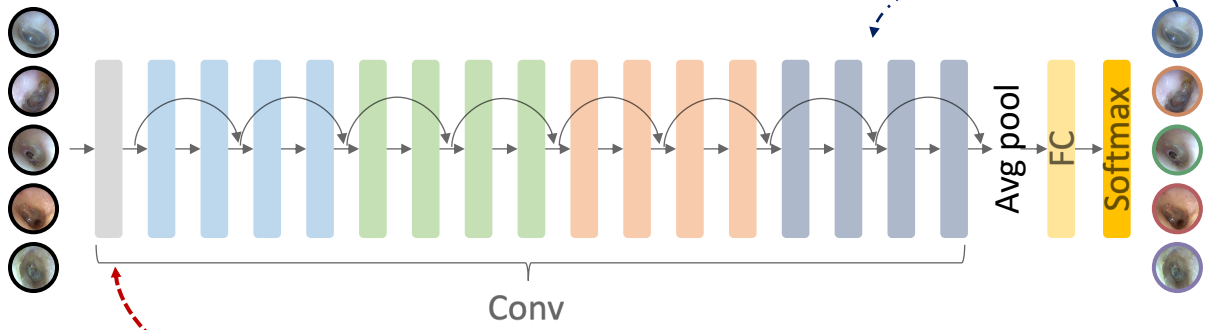
C. Otolaryngology AI

Dataset



Received from Department of Otorhinolaryngology, Ajou University Hospital, IRB (AJIRB-MED-OBS-21-409)

Dataset

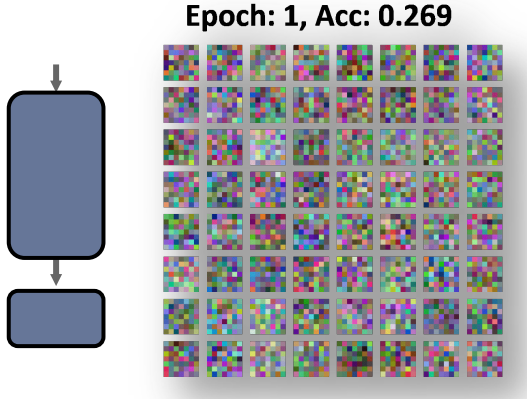


Revealing classification using Grad-CAM [7]

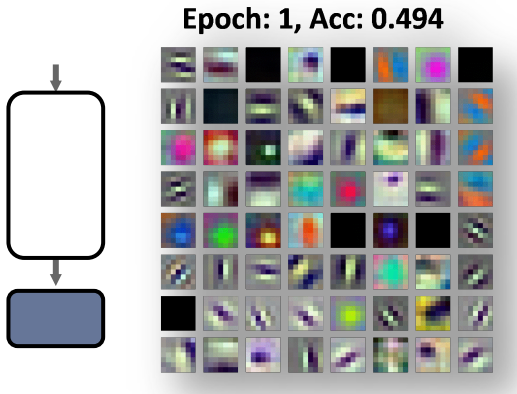
$$L^{c}_{Grad-CAM} = ReLU\left(\frac{1}{Z}\sum_{k}\sum_{i}\sum_{j} A^{k}\frac{\partial y^{c}}{\partial A^{k}_{i,j}}\right)$$

*Linear combination; Global average pooling; Backprop gradients

Extracting features using ResNet-18 [6]

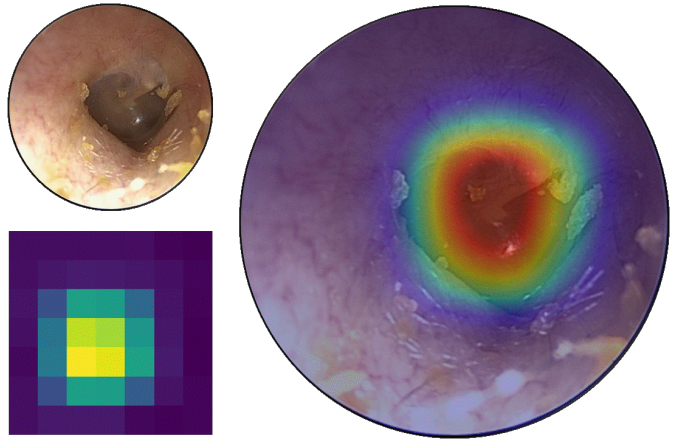


Training entire model



Transfer learning

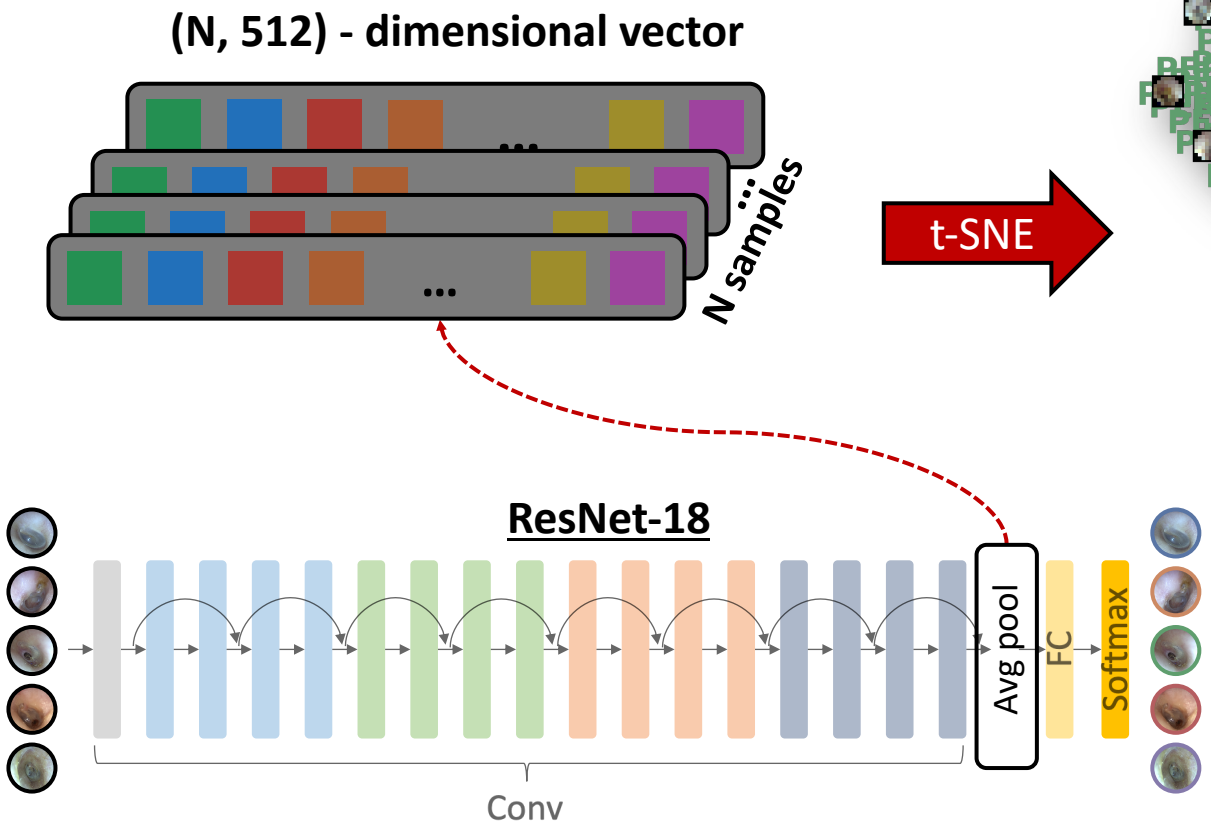
NORMAL



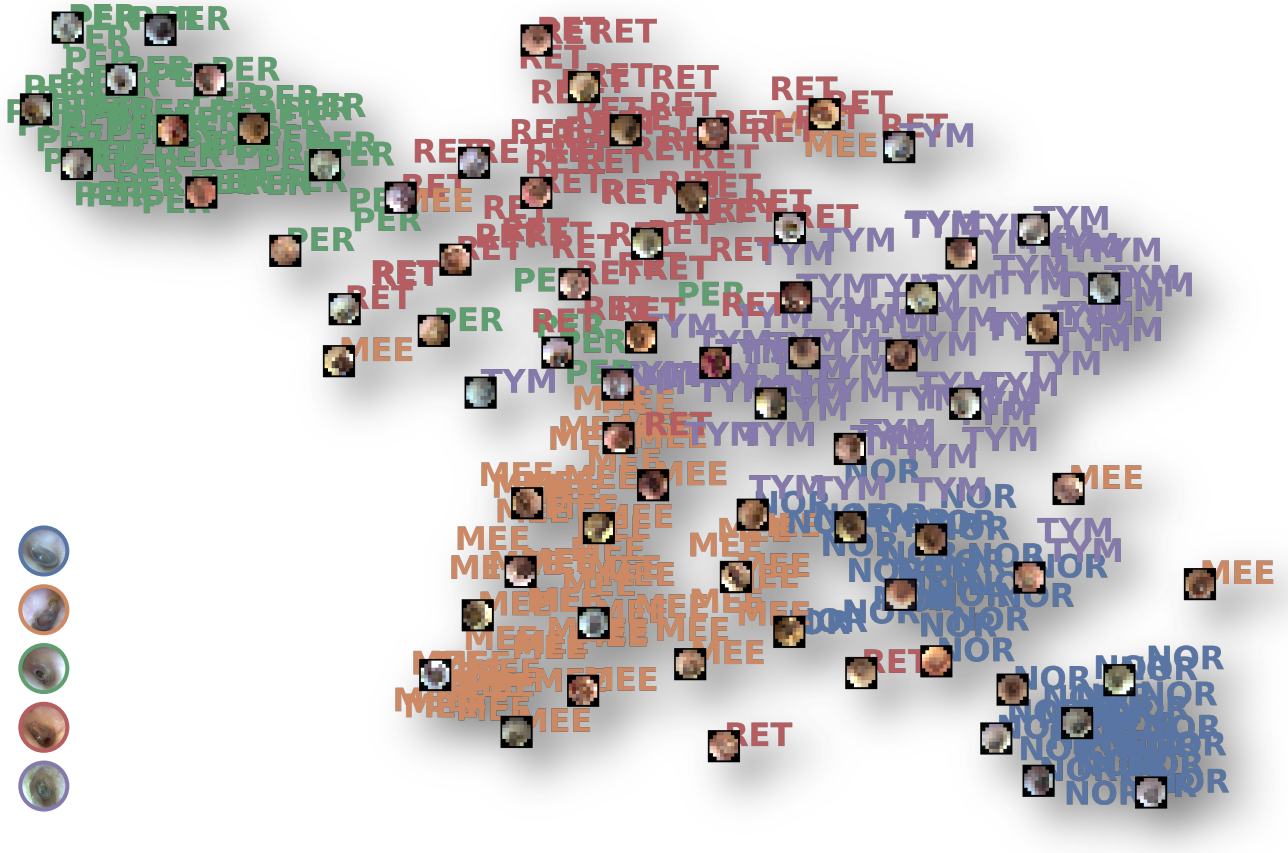
[6] He, Kaiming, et al. "Deep residual learning for image recognition." *Proceedings of the IEEE conference on computer vision and pattern recognition*. 2016.

[7] Selvaraju, Ramprasaath R., et al. "Grad-cam: Visual explanations from deep networks via gradient-based localization." *Proceedings of the IEEE international conference on computer vision*. 2017.

Dataset

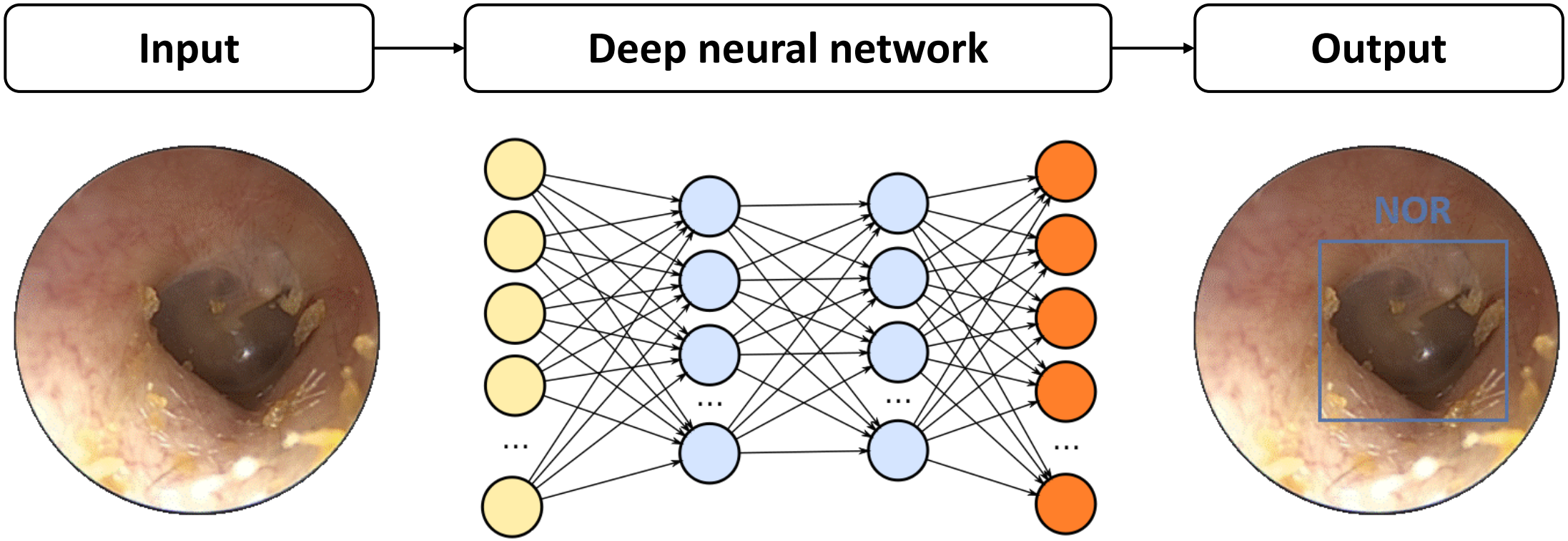


Visualizing feature latent space using t-SNE [8]



[8] Van der Maaten, Laurens, and Geoffrey Hinton. "Visualizing data using t-SNE." *Journal of machine learning research* 9.11 (2008).

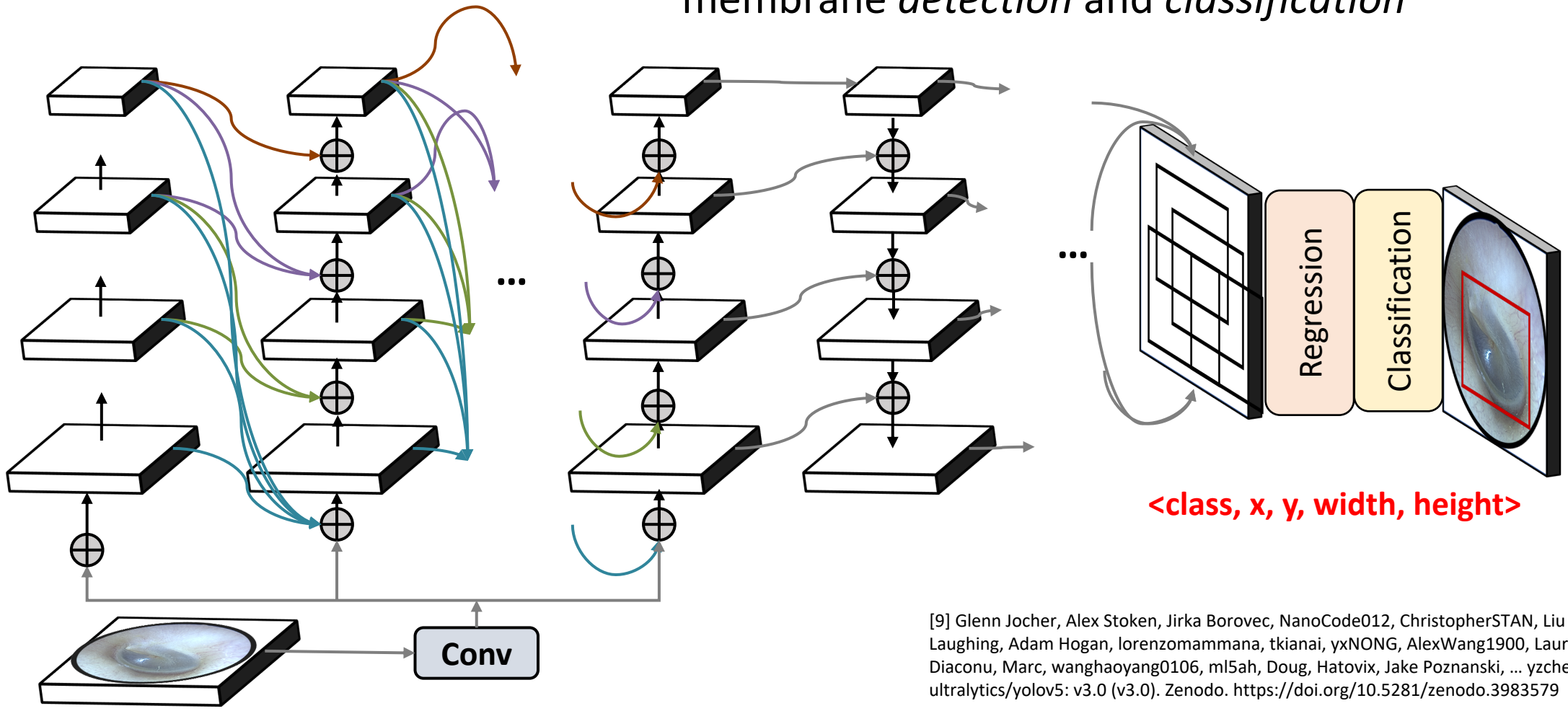
Model



✓ We want to model tympanic membrane ROI and its class as output

Model

✓ We utilize **YOLOv5** [9] for simultaneous tympanic membrane *detection* and *classification*



[9] Glenn Jocher, Alex Stoken, Jirka Borovec, NanoCode012, ChristopherSTAN, Liu Changyu, Laughing, Adam Hogan, lorenzomammana, tkianai, yxNONG, AlexWang1900, Laurentiu Diaconu, Marc, wanghaoyang0106, ml5ah, Doug, Hatovix, Jake Poznanski, … yzchen. (2020). ultralytics/yolov5: v3.0 (v3.0). Zenodo. https://doi.org/10.5281/zenodo.3983579

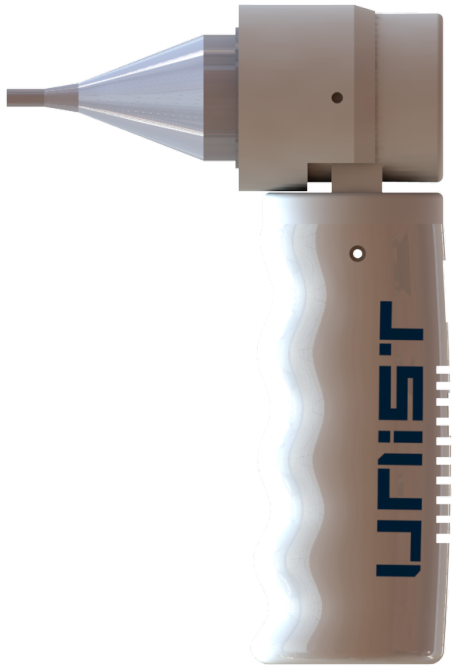
Ear examination platform

A. Otoscope

✓ **Wireless**: WiFi

✓ **Real-time**: <100ms

B. Mobile app



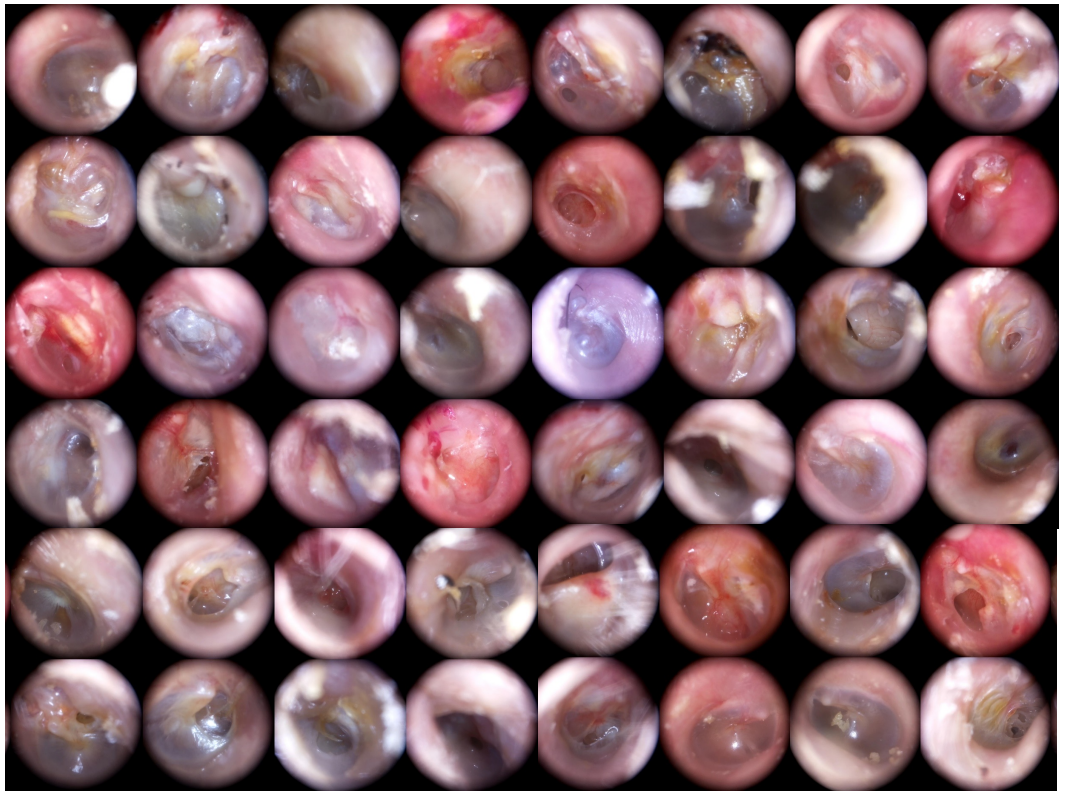
C. Otolaryngology AI

✓ **Affordable**: Total < $1500

3. Validation

Image quality

Ours



Clinical

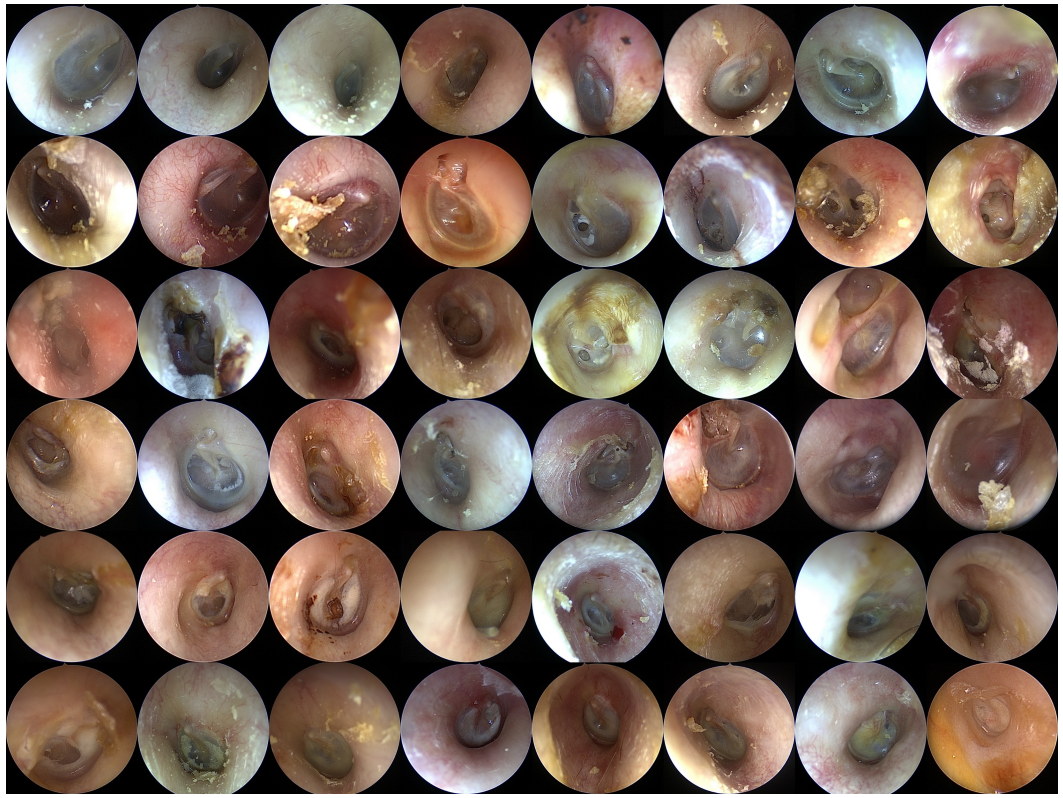
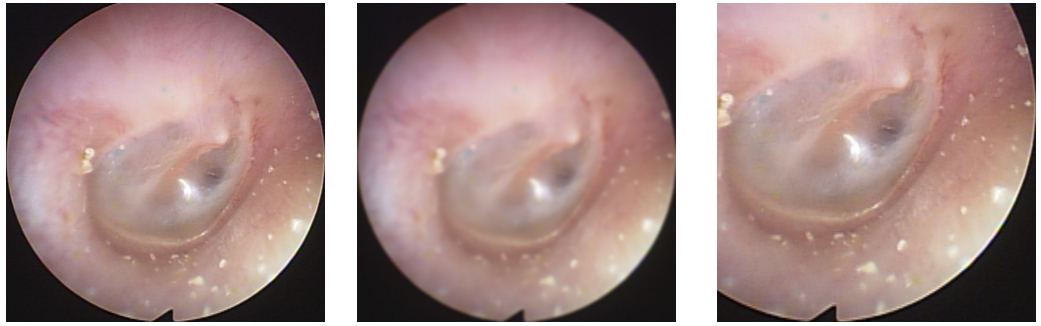


Image augmentation



Original image

Blurring

75% random crop

Random brightness

Random contrast

Random color shift

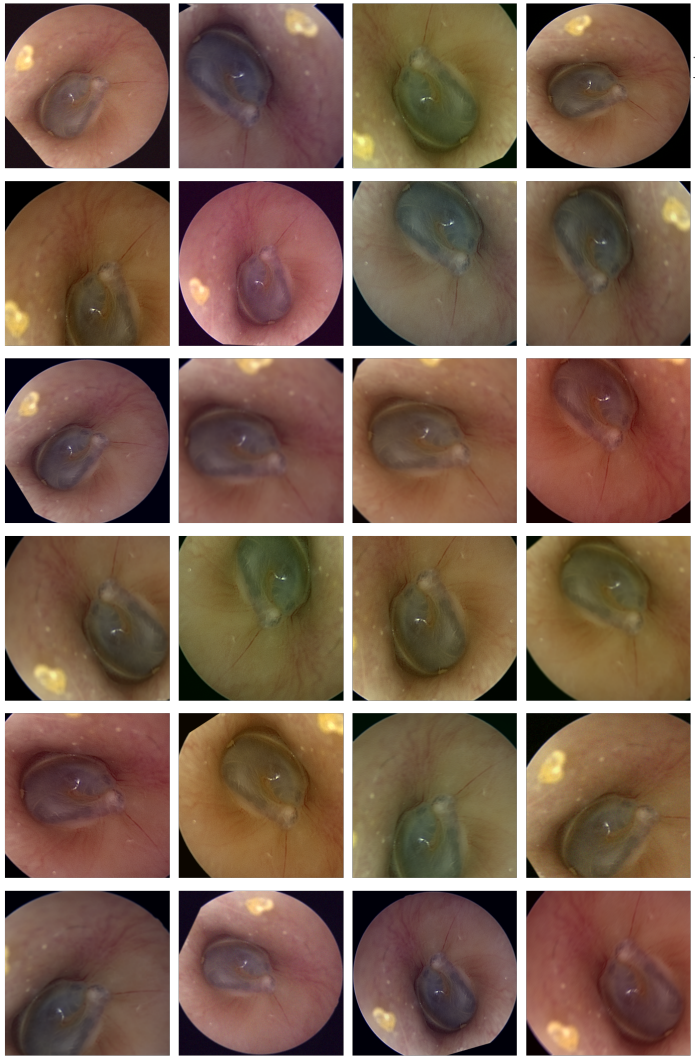
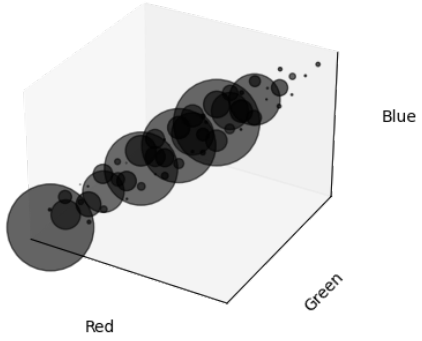
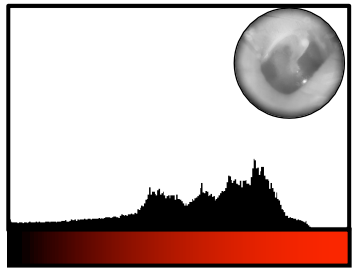


Image color

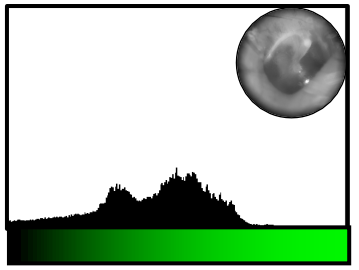
Ours

(512,512,3)

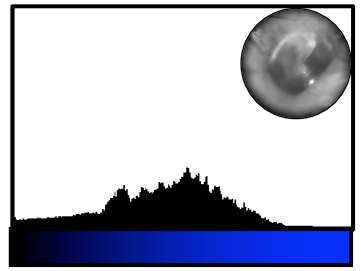




$\mu = 121.7$
$\sigma = 67.9$

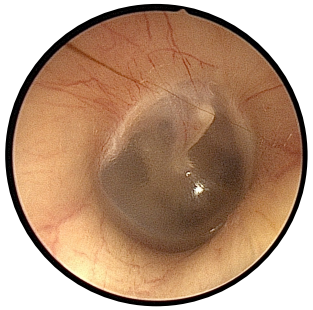


$\mu = 93.3$
$\sigma = 55.9$



$\mu = 95.3$
$\sigma = 56.9$

Clinical



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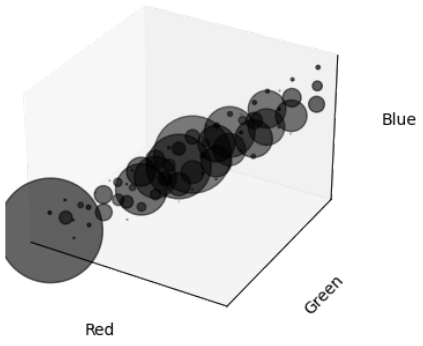
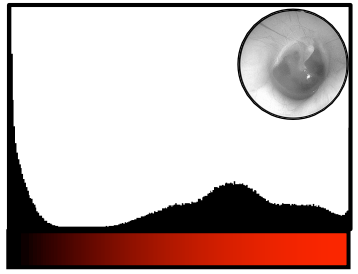
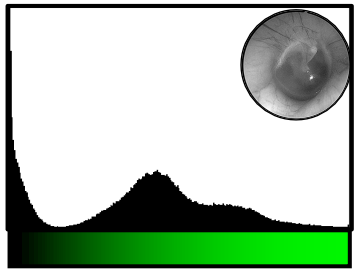




$\mu = 129.2$
$\sigma = 81.6$



$\mu = 93.2$
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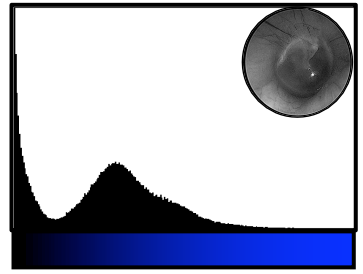
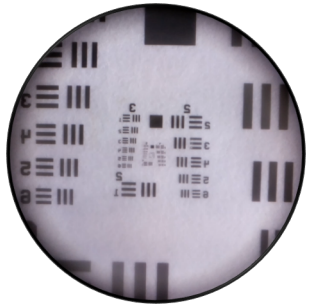


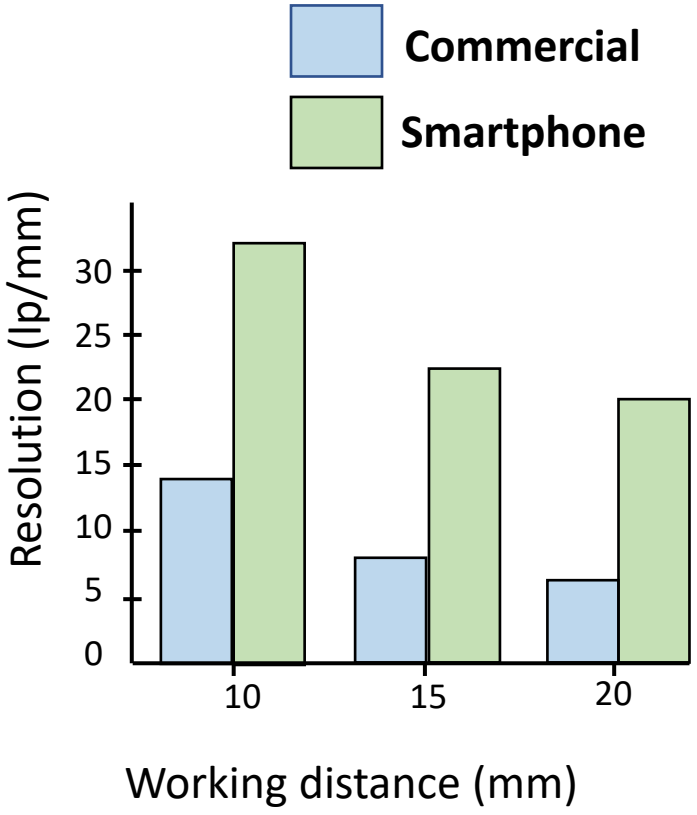
$\mu = 65.7$
$\sigma = 45.2$

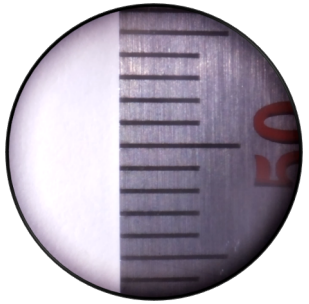
Image quality

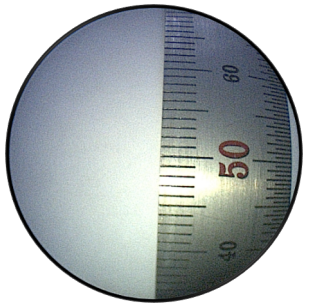
Ours

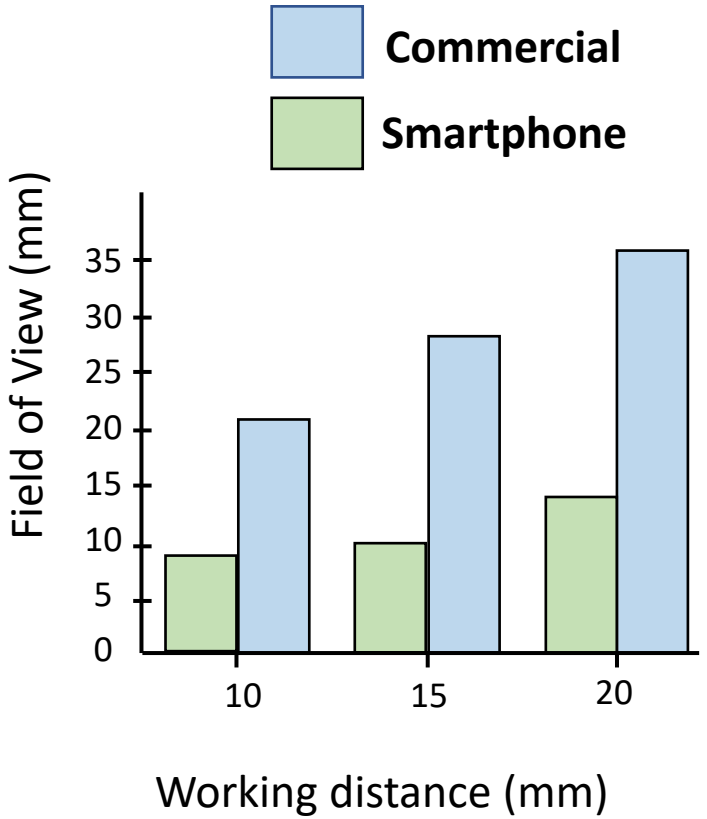


Clinical

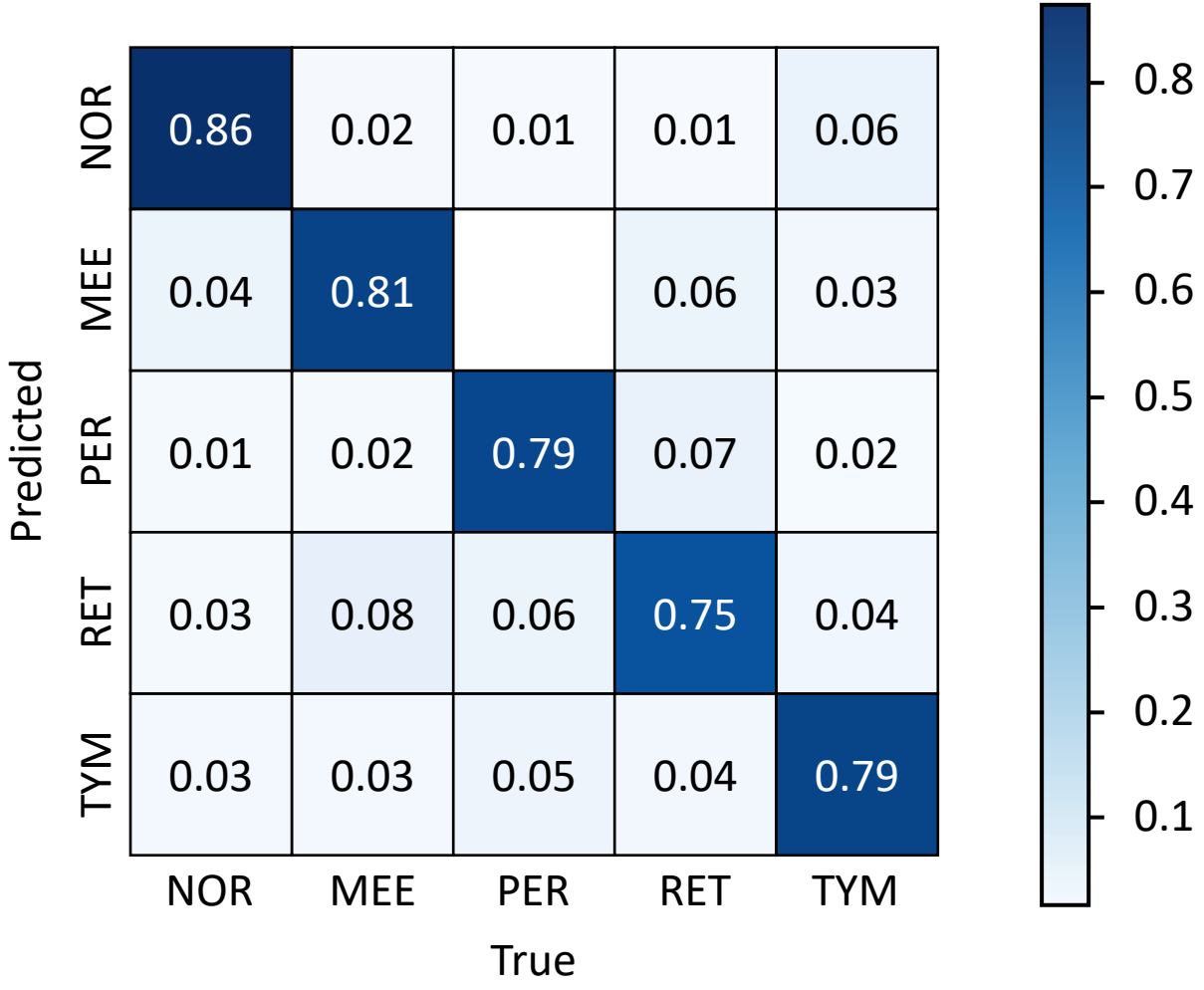


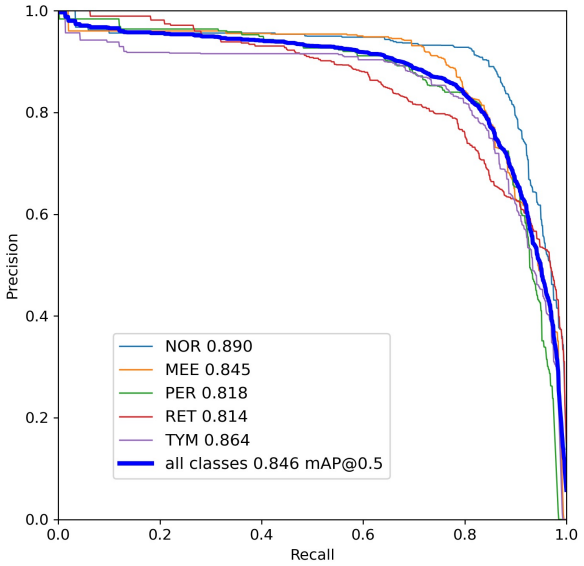


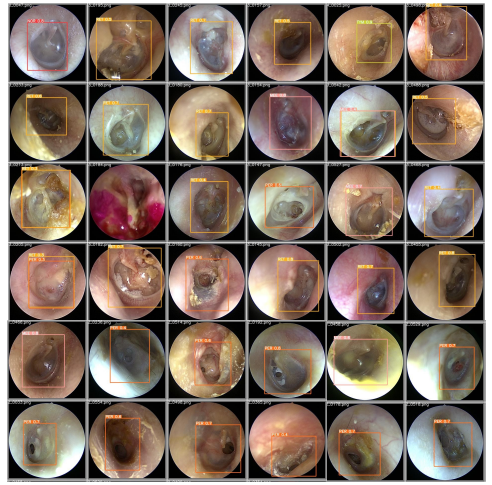




AI performance







Evaluation

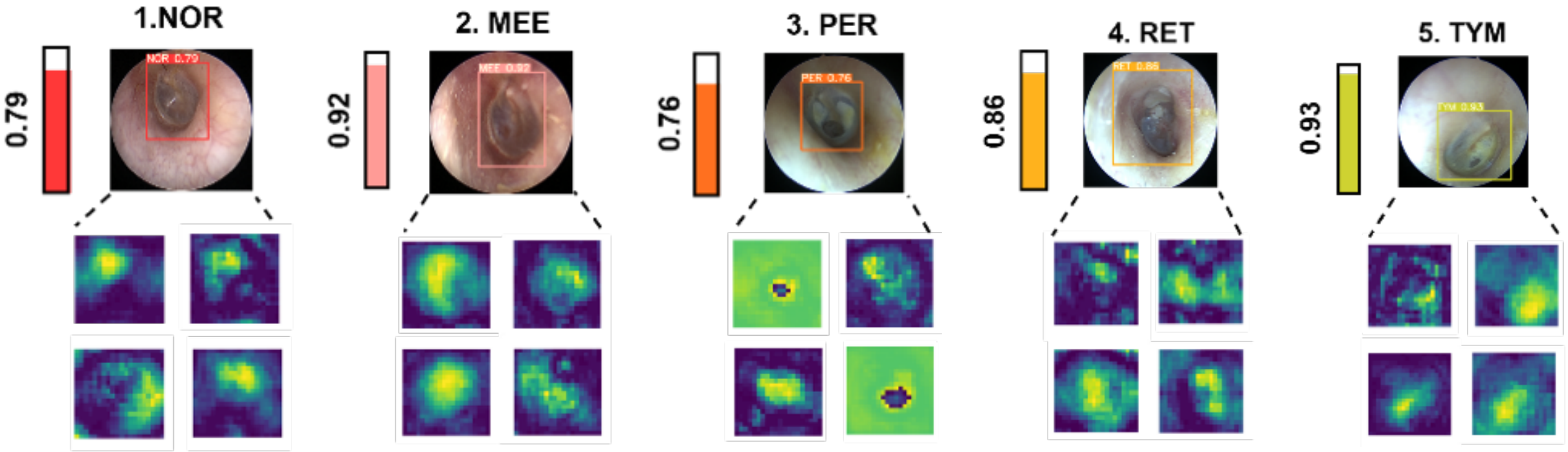
Metrics	Value
Epochs	300
Precision	0.834
Recall	0.808
$mAP_{0.5}$	0.87
$mAP_{0.5:0.95}$	0.568

Configuration

Parameter	Description
Layers	224
Hyperparams	7,064,698
GFLOPs	16.4
Size (MB)	14.4
Fp16 (MB)	6.9

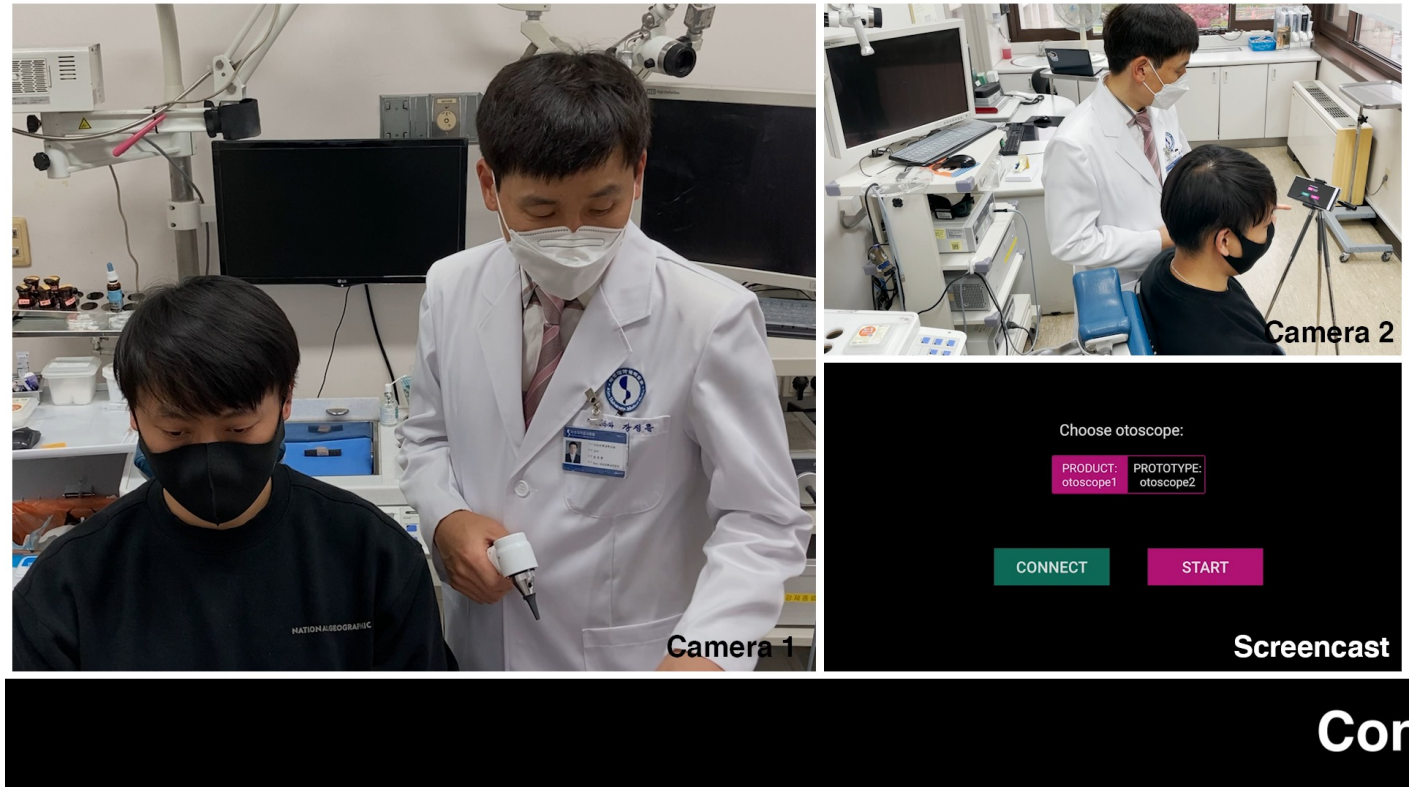
AI performance

Class probability identification in validation set



Reasoning results with class activation maps

Demo



(In collaboration with otologist (JHJ) from Ajou University Hospital, Suwon, South Korea, 2021)

4. Conclusion

Conclusion

✓ **Specialist ear examination remains common issue in low-income countries**

Conclusion

- ✓ **Specialist ear examination remains common issue in low-income countries**
- ✓ **To overcome, procedure needs to assistive and affordable technology**

Conclusion

- ✓ **Specialist ear examination remains common issue in low-income countries**
- ✓ **To overcome, procedure needs assistive and affordable technology**
- ✓ **Here, we propose a mobile, deep learning-assisted otoscope**

Conclusion

- ✓ **Specialist ear examination remains common issue in low-income countries**
- ✓ **To overcome, procedure needs assistive and affordable technology**
- ✓ **Here, we propose a mobile, deep learning-assisted otoscope**
- ✓ **Our results demonstrated high diagnostic accuracy indicating potential to become a viable screening solution in low-resource, non-specialist settings.**

Perspectives

✓ **Telemedicine applications with augmented reality**

Setup 1.

Google Glass

Otoscope

Contributors

Dr. Hyunmo Yang	UNIST
Nurbolat Aimakov	UNIST
Geoseong Na	UNIST
Dr. Yujin Ahn	UNIST
Dr. Joon S. Yoo	Incipian LLC
Professor Gil-Jin Jang	Kyungpook National University
Professor Jeong Hun Jang	Ajou University Hospital
Professor Woonggyu Jung	UNIST

Acknowledgement

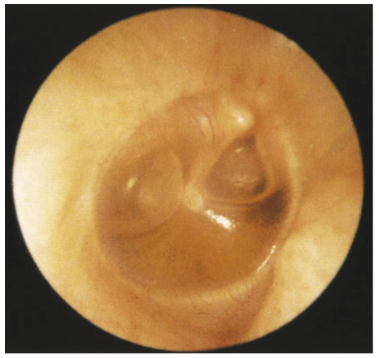
- ✓ This research was supported by a grant of the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare, Republic of Korea (grant number: HP20C0032).
- ✓ This work was supported by the Korea Medical Device Development Fund grant funded by the Korea government (the Ministry of Science and ICT, the Ministry of Trade, Industry and Energy, the Ministry of Health & Welfare, the Ministry of Food and Drug Safety) (Project Number: 1711137934, KMDF_PR_20200901_0024-03).

Thank you for attention!

Q&A

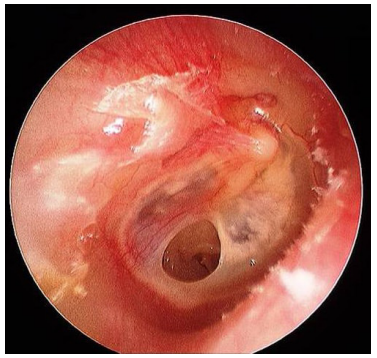
Correspondence:
s.askaruly@gmail.com

Middle ear effusion



Thick or sticky fluid behind the eardrum in the middle ear. [1]

Perforation

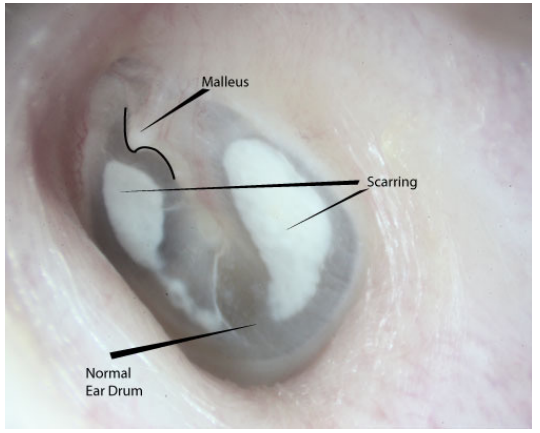


A ruptured eardrum (tympanic membrane perforation) is a hole or tear in the thin tissue that separates your ear canal from your middle ear (eardrum). [2]

Retraction

Is a condition where the tympanic membrane, or eardrum, gets pulled toward the middle of ear. [3]

Tympanosclerosis



Tympanosclerosis is the medical term for scarring of the ear drum. Scarring occurs after the ear drum is injured or after surgery. Commonly a small white area can be seen after a person has had middle ear ventilation tubes. [4]

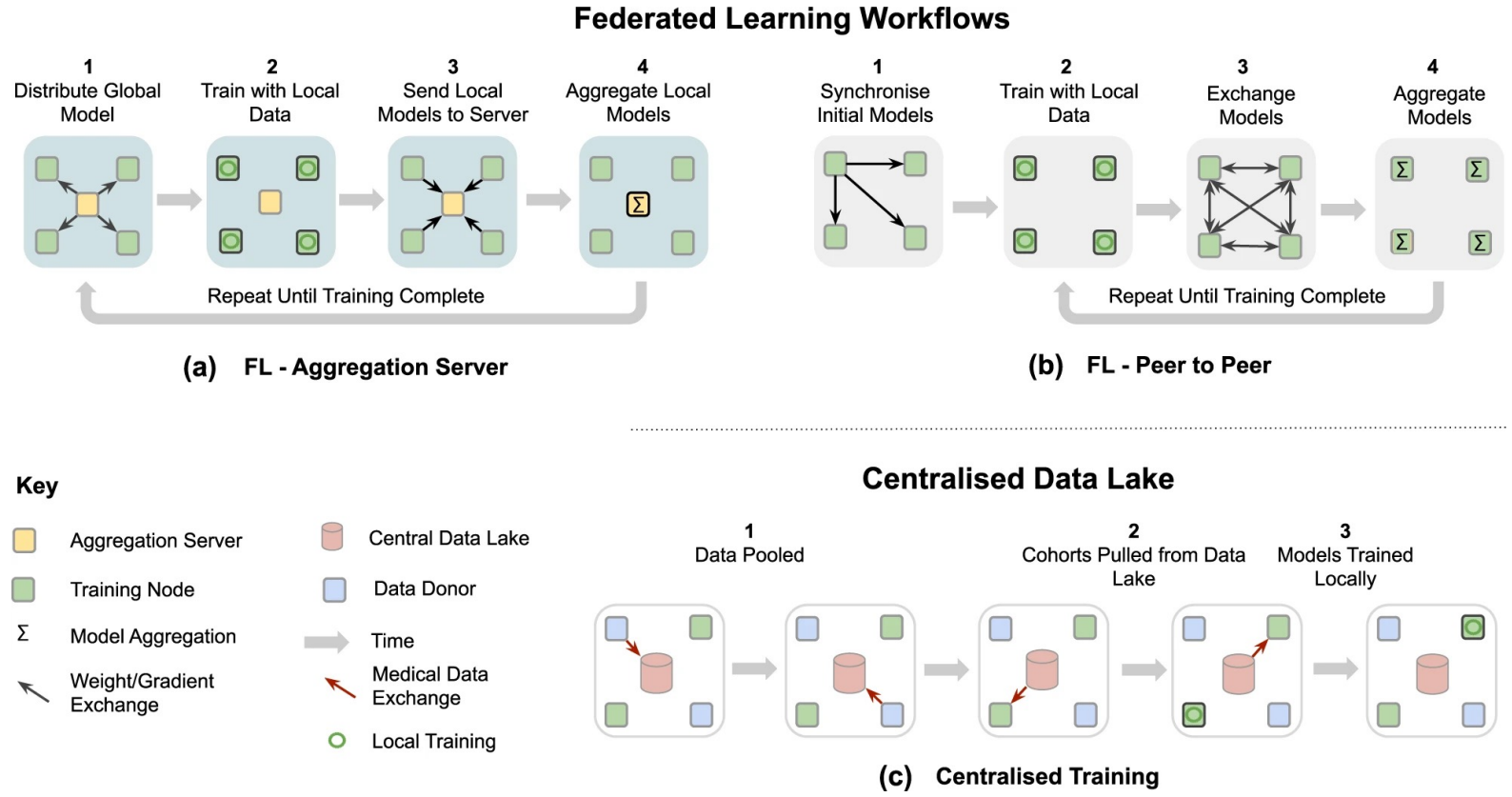
[1] https://medlineplus.gov/ency/article/007010.htm

[2] https://www.mayoclinic.org/diseases-conditions/ruptured-eardrum/symptoms-causes/syc-20351879

[3] https://www.webmd.com/a-to-z-guides/what-is-a-tympanic-membrane-retraction

[4] https://med.uth.edu/orl/online-ear-disease-photo-book/chapter-15-miscellaneous/tympanosclerosis/

Federated Learning



Rieke, Nicola, et al. "The future of digital health with federated learning." *NPJ digital medicine* 3.1 (2020): 1-7.