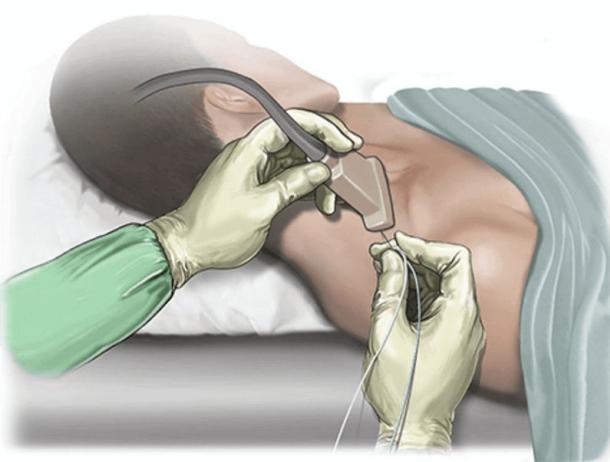


# Efficient video-based deep learning for ultrasound guided needle insertion

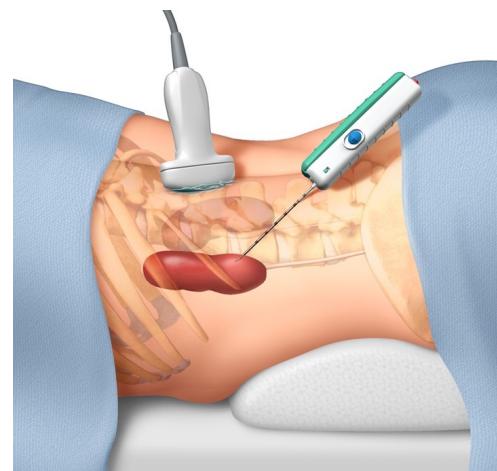
Jonathan Rubin, Alvin Chen, Anumod Odungattu Thodiyil, Raghavendra Srinivasa Naidu, Ramon Erkamp, Jonathan Fincke, Balasundar Raju



- Common application of medical ultrasound
- Portable, non-invasive, real-time
- Suitable for use in point-of-care settings
- Improved safety and efficacy compared to blind placement



Regional anesthesia

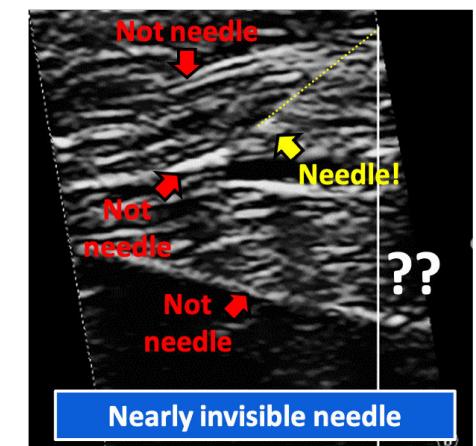
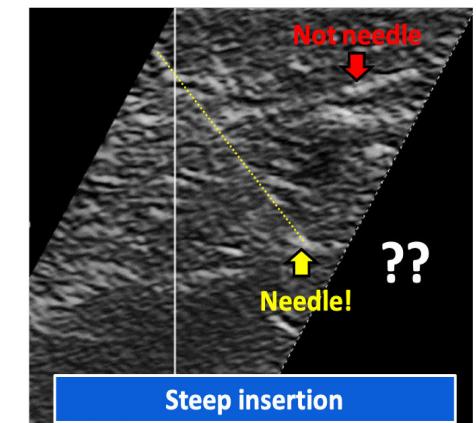


Tissue biopsy



Vascular access

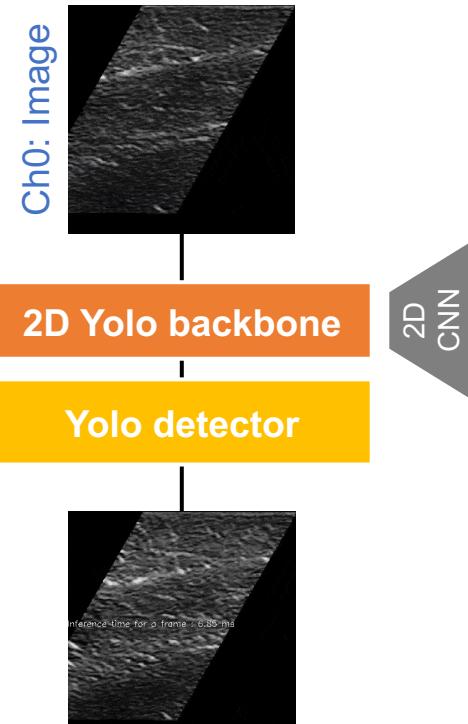
*Examples of difficult cases:*



*But can be challenging → requires clinical training and skill!*

# Approaches (UltraTiny models)

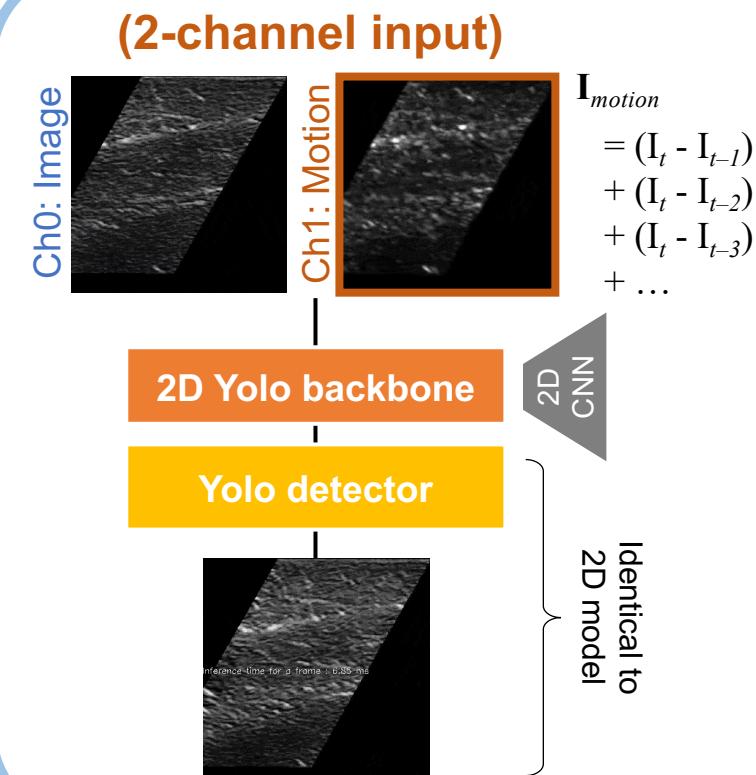
## 2D UltraTiny



*single frame, single label*

Model size: 546K params  
FLOPS: 0.4G  
CPU speed: ~8 ms (125 Hz)

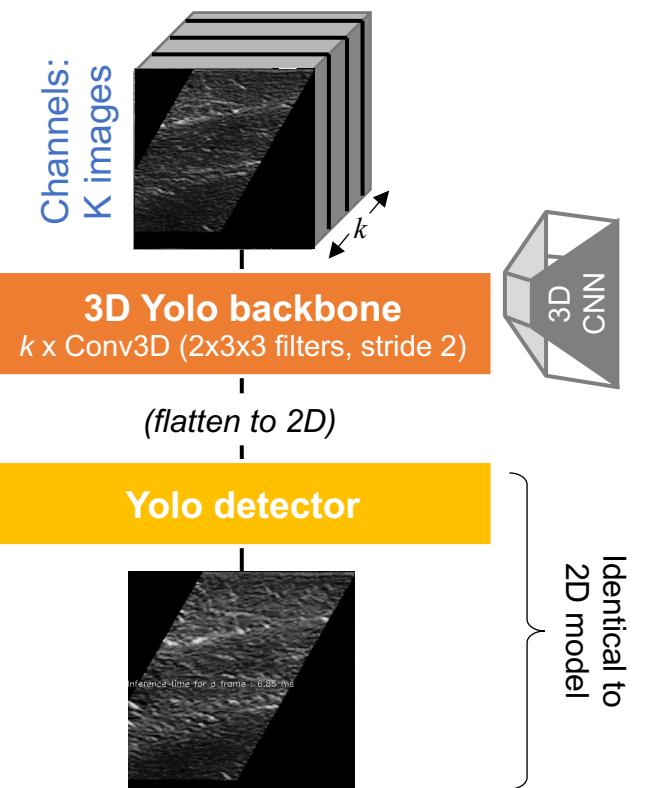
## 2.5D UltraTiny



*multi-frame, single label*

Model size: 546K params  
FLOPS: 0.4G  
CPU speed: ~10 ms (100 Hz)

## 3D UltraTiny



*multi-frame, single label*

Model size: 620K params  
FLOPS: 1.3G  
CPU speed: ~16 ms (60 Hz)

# Results

AP<sup>50</sup>, AP<sup>70</sup>,  
 $F_1$  and Mean IoU

## Additional improvements:

- Image, spatial, and temporal data augmentation
- Focal loss ( $\gamma=1.5$ )
- Prior knowledge via geometric pose constraints

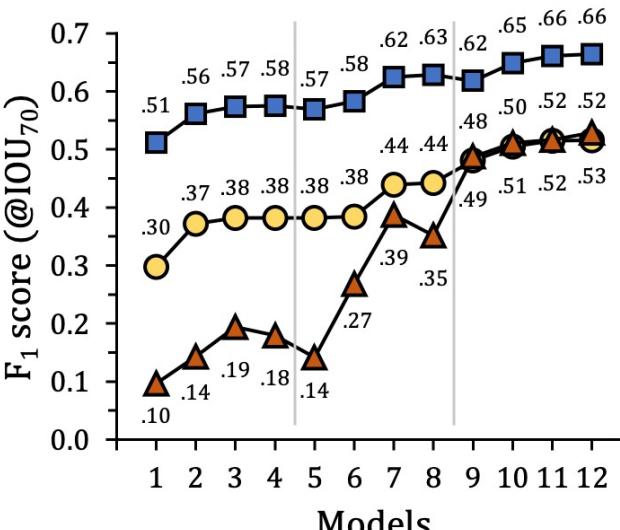
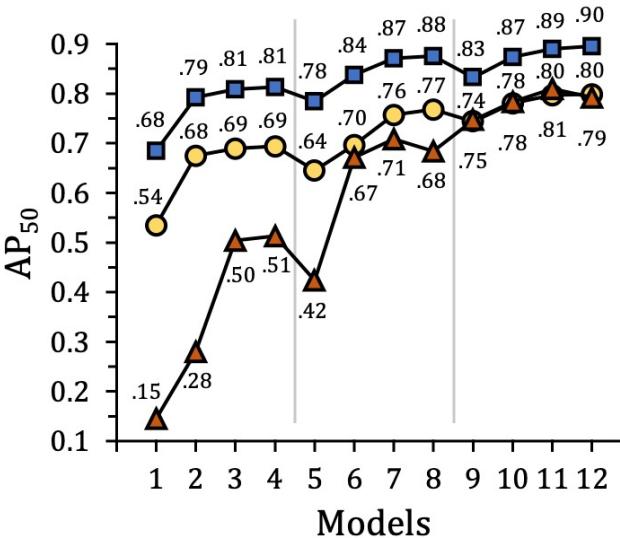
## Conclusions

- Efficient video-based deep learning methods significantly improve needle localization compared to standard baseline 2D models, particularly on challenging cases.
- The proposed methods can be implemented on low-cost ultrasound processing hardware to facilitate clinical translation

## Ongoing & future work

- Additional improvements in data, model and training to optimize speed-accuracy trade-off
- Deployment on hardware and further validation on clinical data (regional anesthesia, vascular access, interventional procedures)

| 2D |   |   |   | 2.5D |   |   |   | 3D |    |    |    |
|----|---|---|---|------|---|---|---|----|----|----|----|
| 1  | 2 | 3 | 4 | 5    | 6 | 7 | 8 | 9  | 10 | 11 | 12 |
| x  | ✓ | ✓ | ✓ | x    | ✓ | ✓ | ✓ | x  | ✓  | ✓  | ✓  |
| x  | x | ✓ | ✓ | x    | x | ✓ | ✓ | x  | x  | ✓  | ✓  |
| x  | x | x | ✓ | x    | x | x | ✓ | x  | x  | x  | ✓  |



| 2D |   |   |   | 2.5D |   |   |   | 3D |    |    |    |
|----|---|---|---|------|---|---|---|----|----|----|----|
| 1  | 2 | 3 | 4 | 5    | 6 | 7 | 8 | 9  | 10 | 11 | 12 |
| x  | ✓ | ✓ | ✓ | x    | ✓ | ✓ | ✓ | x  | ✓  | ✓  | ✓  |
| x  | x | ✓ | ✓ | x    | x | ✓ | ✓ | x  | x  | ✓  | ✓  |
| x  | x | x | ✓ | x    | x | x | ✓ | x  | x  | x  | ✓  |

