2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

Enhancing HDR Prostate Brachytherapy Deep Learning Needle Reconstruction with Live Ultrasound-Assisted Object Detection

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ABSTRACT

CorneliUS
An HDR brachytherapy automated catheter reconstruction algorithm with a sensitivity of approximately 93% on ultrasound images[1].

The Knowledge Gap
Remaining undetected needles are typically obscured by image artifacts, making manual identification difficult and time-consuming.

The Method
We trained a real-time neural network (CorneliOLO) using the YOLO11 framework to track catheters on live ultrasound during implantation..

The Findings
CorneliOLO estimated missed needle positions with a Mean Euclidean Distance (MED) of (1.52±0.95) mm.

Take-home message
Live ultrasound tracking reliably infers obscured needle coordinates, accelerating clinical workflows and establishing a foundation for real-time adaptive dosimetry in prostate brachytherapy.

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INTRODUCTION

The Problem
Manual 3D needle reconstruction in ultrasound imaging is time-consuming, labor-intensive, and prone to human error. Furthermore, artifacts and mutual catheter obscuration in static post-implant images can severely impede the reconstruction process.

Study Objective
To develop a machine-learning tool that identifies catheters directly from live ultrasound feeds during implantation, providing accurate positional estimates for AI-missed needles.

METHODS AND MATERIALS

Data Acquisition
Live ultrasound feeds from 13 clinical prostate HDR implants were captured via HDMI. A total of 1,300 representative axial frames were manually annotated.

CorneliOLO Training
The live catheter detection model was trained utilizing the YOLOv11 framework on 1,100 images and exported as a TensorRT engine.

Live Inference
Video capture and GPU inference achieved an average processing speed of 160 ms per frame during actual implants.

Estimation Strategy
If a needle was missing from the post-implant 3D reconstruction, its final location was inferred from its last visible position on the live feed using an affine registration framework.

RESULTS

Accuracy for Missed Needles
Across 25 AI-missed needles from 15 implants, CorneliOLO achieved a Mean Euclidean Distance (MED) of (1.52±0.95) mm against manually segmented ground-truth positions (Figure 1).

Clinical Acceptability
CorneliOLO successfully reconstructed 84% of missed needles within 2 mm of the clinical reference.

Performance Context
While this error exceeds the reported MED of (0.59±0.41) mm for standard CorneliUS detections, it provides highly accurate initial estimates for otherwise hidden needles.

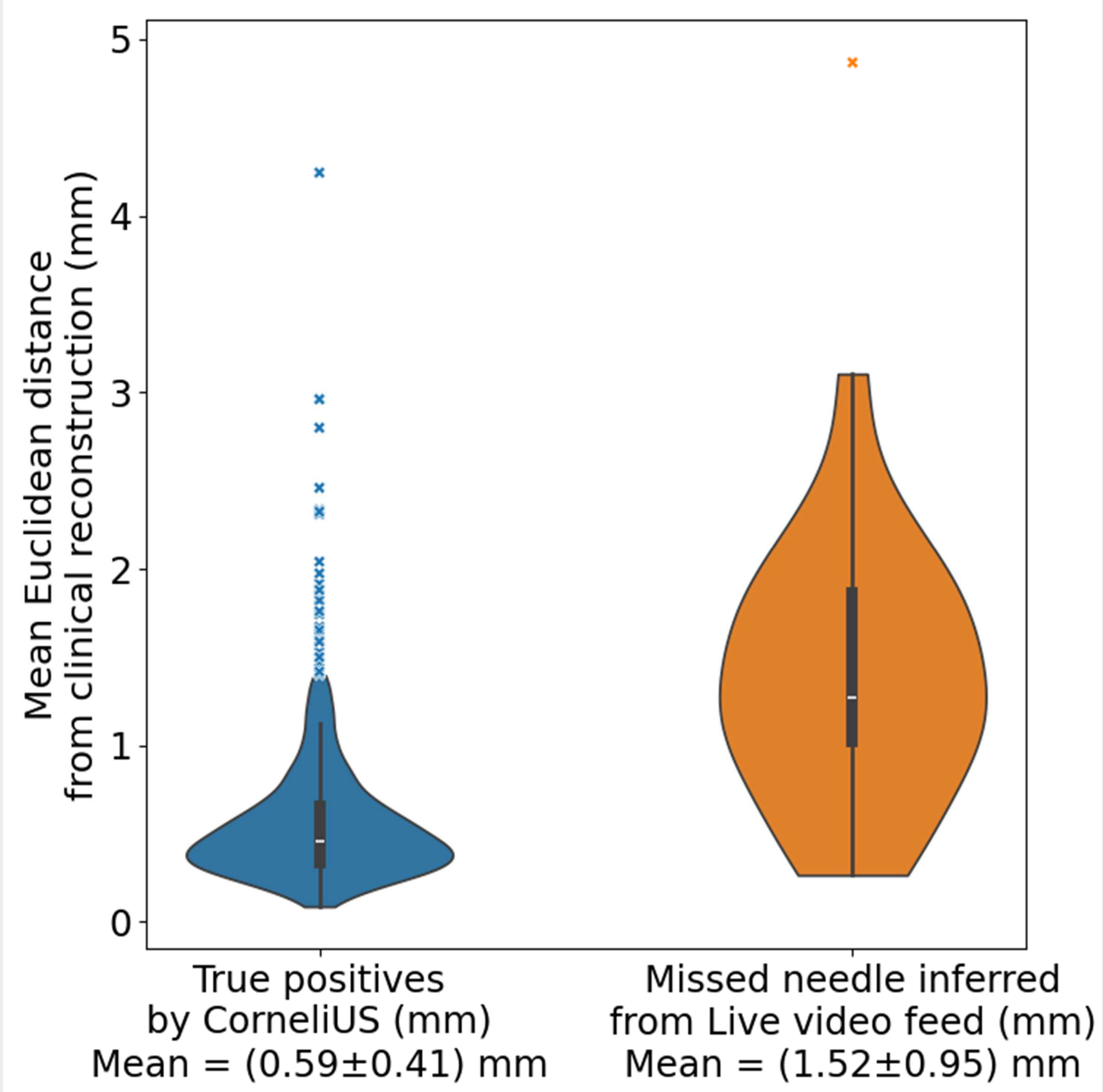

Figure 1. Distribution of Mean Euclidean Distance (MED) for needle reconstructions. **Left**: True positive needles reconstructed on 3D ultrasound using CorneliUS. **Right**: Missed needles inferred from live feed data using CorneliOLO.

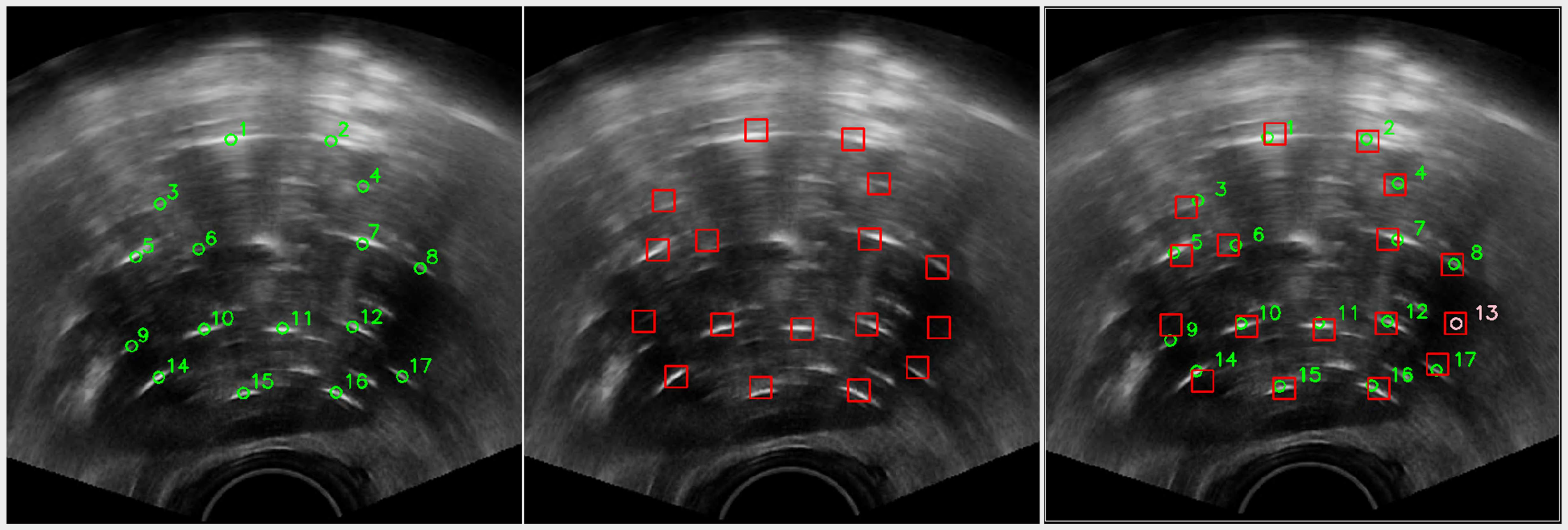

Figure 2. Left: CorneliUS automated catheter reconstruction (numbered green circles) on a post-implant 3D ultrasound image. **Center**: Needle instances detected by CorneliOLO during implantation (red squares) on a 2D axial ultrasound. **Right**: Affine registration aligning post-implant and live-implant needles. The final location of needle 13 (missing from the 3D reconstruction) is inferred from its live-implant coordinates.

DISCUSSION

Workflow Acceleration
By delivering accurate coordinate estimates for obscured catheters, this live-feed approach decreases the need for tedious manual searching.

Real-Time Integration
The processing time of approximately 6 frames per second demonstrates that object detection can run parallel to the surgical implantation without disruption.

The Bottom Line
Leveraging live ultrasound creates a robust safety net for automated post-implant reconstruction, ensuring efficient identification of all implanted needles.

CONCLUSIONS

Successful Integration
Incorporating live ultrasound data enables reliable estimation of obscured needle positions on post-implant images.

Reduced Manual Effort
Providing precise initial estimates significantly reduces manual workload and accelerates clinical reconstruction.

Future Impact
This framework establishes an important technological step toward achieving real-time adaptive prostate brachytherapy dosimetry.

FINANCIAL SUPPORT

Fondation Hôtel-Dieu de Lévis

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