Deep learning-based vessel and nerve recognition model for lateral lymph node dissection

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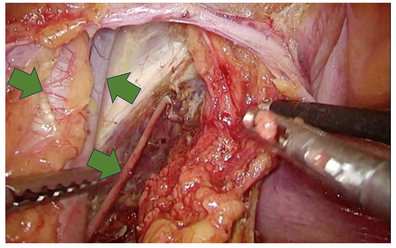
Background / Aim

Recent evidence has led to a growing recognition globally of the importance of LLN dissection (LLND) in reducing local recurrence, particularly in patients with suspected LLN metastasis.

However, LLND is technically challenging because the lateral pelvic area contains major blood vessels, which pose a risk for substantial intraoperative hemorrhage, and numerous nerves critical for postoperative genitourinary function and leg movements.

A deep learning-based surgical support system holds promise for assisting in precisely identifying these critical anatomical structures during LLND.

Therefore, we aimed to develop a semantic segmentation model to automatically recognize and visualize critical anatomical structures during laparoscopic LLND and evaluate the model's performance.



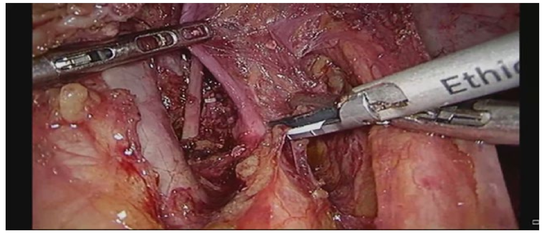
External iliac artery and vein and obturator nerve

Materials and methods

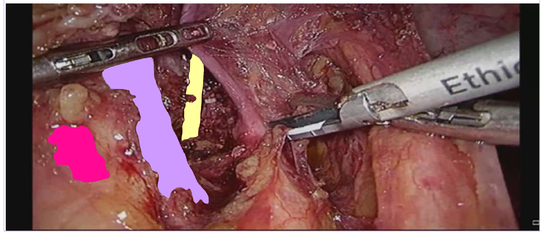
1. Study design and dataset
   Retrospective feasibility study used intraoperative video data from laparoscopic LLND performed at our hospital between 2018 and 2021
   Still images were extracted depicting LLND procedure.

2. Annotation
   The areas of the obturator nerve (ON), external iliac artery and vein (EIA and EIV) were annotated at the pixel level for the Semantic Segmentation task.

Raw image

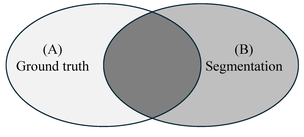


Annotated image



3. Computing and model details
   We trained a semantic segmentation model using the Feature Pyramid Network architecture with an EfficientNet-B7 backbone.
   The model was trained to classify four classes: background, nerve, vein, and artery. The backbone was pre-trained on ImageNet.

4. Evaluation
   Precision (positive predictive value), recall (sensitivity) , and the Dice efficient (DC) were used as evaluation metrics.



$$Dice\ Coefficient = \frac{2\,(|A \cap B|)}{|A| + |B|}$$

Five-fold cross-validation was done, where the data were split at a per-case level rather than a per-image level.

Results

Table 1. Patients' characteristics

Factor		N-22
Age (year-old)*		64 [33-78]
BMI (kg/m^2)*		22 [16-28]
Preoperative diagnosis	Adenocarcinoma	20 (90%)
	GIST	1 (5%)
	NET	1 (5%)
cStage in carcinoma case (UICC 8th edition)	I	0
	II	0
	III	20 (100%)
	IV	0
Tumor lower edge form AV (cm)*		6 [4-9]
Preoperative therapy	Yes	15 (68%)
	No	7 (32%)

*Median [range]
BMI, body mass index; AV, anal verge

Table 2. Evaluation parameters

➢ **Dice efficient**

Class	Fold 1	Fold 2	Fold 3	Fold 4	Fold 5	Mean	SD
Background	0.983	0.983	0.984	0.982	0.986	0.984	0.002
ON	0.805	0.788	0.795	0.782	0.778	0.789	0.009
EIV	0.783	0.750	0.716	0.746	0.685	0.736	0.033
EIA	0.582	0.421	0.613	0.588	0.666	0.574	0.082
Average	0.788	0.735	0.777	0.774	0.779	0.771	0.032

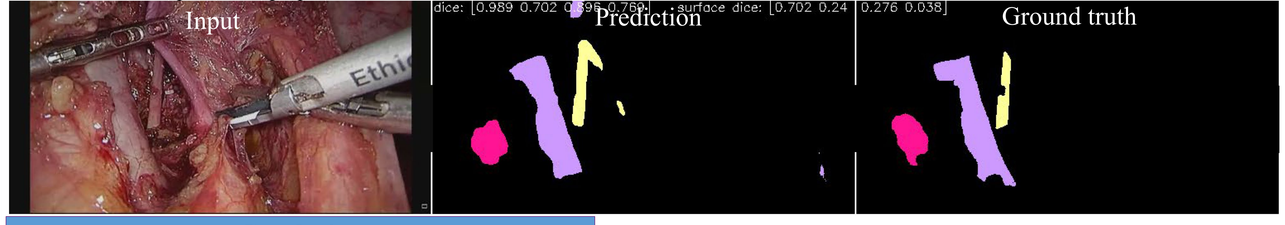
➢ **Precision**

Class	Fold 1	Fold 2	Fold 3	Fold 4	Fold 5	Mean	SD
Background	0.982	0.986	0.980	0.982	0.990	0.984	0.004
ON	0.731	0.723	0.730	0.690	0.768	0.728	0.025
EIV	0.789	0.740	0.839	0.748	0.613	0.746	0.075
EIA	0.662	0.372	0.651	0.643	0.623	0.590	0.110
Average	0.791	0.705	0.800	0.765	0.749	0.762	0.053

➢ **Recall**

Class	Fold 1	Fold 2	Fold 3	Fold 4	Fold 5	Mean	SD
Background	0.984	0.980	0.988	0.982	0.982	0.983	0.003
ON	0.895	0.865	0.873	0.903	0.789	0.865	0.041
EIV	0.778	0.760	0.625	0.744	0.778	0.737	0.058
EIA	0.520	0.484	0.580	0.542	0.714	0.568	0.079
Average	0.794	0.772	0.766	0.793	0.816	0.788	0.045

Fig 1. Representative image of the prediction by the developed deep learning-based semantic segmentation model and its ground truth.
Yellow, ON; pink, EIA; purple, EIV



Conclusion

Our deep leraning-based semantic segmentation model automatically recognizes the ON, EIV, and EIA in laparoscopic LLND. It demonstrated high recognition performance, indicating its feasibility. This model may be a foundational technology for constructing surgical navigation systems to improve the safety and efficiency of LLND procedures.