Deep Learning – Driven Assessment of IVC Filter Strut Penetration on CT

[1]Samidha Nageshwar, [2]Sophie Vu, [3]Wes Parker, [4]Harsha Pillarisetti, [5]Mykle Buhrow, [5]Ian Nie, [5]Dr. Rahul Gomes, [6]Dr. Joe Wildenberg
[1]University of Maryland, Computer Science and Mathematics | [2]Pennsylvania State University, Applied Data Sciences | [3]UC Santa Barbara, Computer Science | [4]UC San Diego, Computer Science | [5]UW Eau Claire, Computer Science | [6]Mayo Clinic Health System

Introduction

The inferior vena cava (IVC) is the largest vein in the human body, bringing unoxygenated blood from the lower body back to the heart. IVC filters, cage-like devices, break up blood clots to prevent them from reaching the lungs. Designed for temporary use, low retrieval rates lead to complications, necessitating automated detection and follow-up.

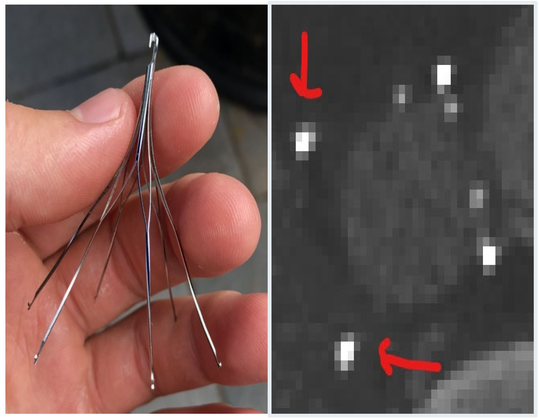


Figure 1: Image of an unused IVC filter (left); image of strut penetration visible in a CT scan (right)

Project Goals

- **3D IVC Filter & Organ Segmentation:** 3D model segmentation of IVC filter and nearby organs and structures of abdominopelvic CT scans to accurately map the location of the filter in the body.
- **Locate Extravascular Extensions**: Measure distances from extension site to IVC wall, to identify penetration severity and locate any organ breaches.

Previous Work

- **3D IVC Filter Segmentation:** 3D segmentation of abdominopelvic CT scans to accurately map the filter and the vessel.[1, 2]
- **Extravascular Extension Detection:** Localizes metal struts relative to the vessel wall to identify penetration into adjacent tissues, preventing organ injury and chronic pain.

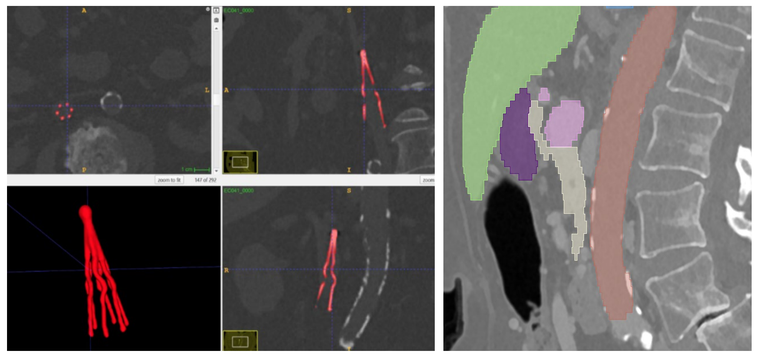


Figure 2: CT scan showing skeletonization of the IVC filter (left); IVC and organ segmentation output from BTCV-trained nnU-Net model (right)

3D IVC Segmentation with nnU-Net

- **Dataset:** Used public dataset Beyond the Cranial Vault (BTCV)[3] containing 30 3D CT scans with 13 labeled organs for training.
- **Architecture & Training:** Utilized a 3D full-resolution nnU-Net[4] trained for 250 epochs with a 48 x 192 x 192 patch size.
- **Results and Validation:** Deployed automated segmentation on unseen scans; The model achieved a good accuracy with a mean Dice score of 0.774.



Figure 3: Train and validation loss and pseudo-Dice score over 250 epochs for IVC filter segmentation

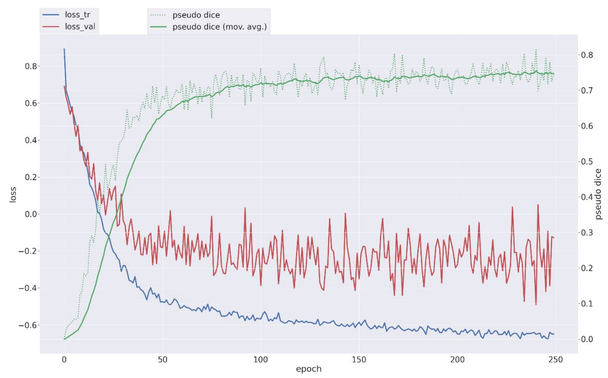


Figure 4: Train and validation loss and pseudo-Dice score over 250 epochs for IVC and organs in the BTCV dataset

IVC Penetration Model Pipeline

- **Dataset:** 89 images of CT scans with no IVC filter penetration and 7 contrast-enhanced CT scans with IVC filter penetration.
- **Step 1:** Uses Marching Cubes to create a 3D triangle mesh of the IVC filter and the IVC.
- **Step 2:** Calculates distances to IVC of each voxel on the IVC filter. Distance is visualized by the colored filter shown in Figure 5.
- **Step 3:** Identifies likely breach sites by clustering breach points together and distinguishing individual struts (see Figure 6).
- **Step 4:** Verifies the real-world breach coordinates using the CT scan and Morphological Geodesic Active Contours.

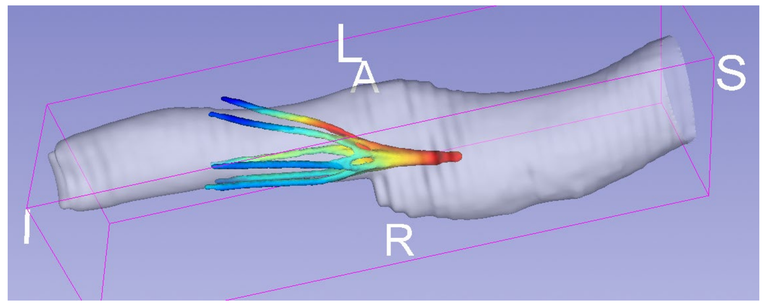


Figure 5: 3D meshes of both the IVC and the filter in CT scan 1. The filter is colored using a heat map representing distance from the IVC wall

breach_site	coordinates (X, Y, Z)	max_penetration (mm)
1	(-9.060, -165.790, 1493.344)	2.41
2	(-12.679, -175.402, 1493.81)	3.877
3	(-25.813, -165.762, 1487.586)	2.188
4	(-23.384, -160.248, 1490.155)	1.294
5	(-16.312, -159.124, 1491.049)	1.347
6	(-19.291, -158.982, 1501.702)	1.07
7	(-23.876, -169.862, 1485.682)	1.263

Figure 6: Maximum distances from IVC wall and coordinates of various breach sites of the IVC filter shown in Figure 5.

Challenges and Limitations

- **Lack of Sufficient Data:** The 89 CT scans of IVC filters with no penetration did not have enough contrast for the model to segment the IVC correctly, making it difficult to test the accuracy.
- **Step 4 Issues:** Morphological Geodesic Active Contours did not correctly identify the IVC wall in the CT scan.

Future Work

- **Penetration Severity Assessment:** Assign each breach site a grade based on how far the filter strut extends past the IVC wall.
- **Organ Breach:** Automatically determine if the filter touches another organ or structure (such as the spine).

Acknowledgements & References

This research project was funded by the National Science Foundation (NSF)-Research Experience for Undergraduates OAC-2447779. The computational resources of the study were provided by the Blugold Center for High-Performance Computing under NSF grant CNS-1920220.

1. Buhrow, Mykle, et al. "YOLO-Based Object Detection for Automated Identification of IVC Filters in Abdominal CT Imaging." *2025 International Conference on Machine Learning and Applications (ICMLA)*. IEEE, 2025.
2. Gomes, Rahul, et al. "Analysis of Swin-UNet vision transformer for Inferior Vena Cava filter segmentation from CT scans." *Artificial Intelligence in the Life Sciences* 4 (2023): 100084.
3. Landman, Bennett, et al. "MICCAI Multi-Atlas Labeling Beyond the Cranial Vault—Workshop and Challenge." *Proc. MICCAI Multi-Atlas Labeling Beyond Cranial Vault—Workshop Challenge*, vol. 5, 2015, p. 12.
4. Isensee, F., Jaeger, P. F., Kohl, S. A., Petersen, J., & Maier-Hein, K. H. (2021). nnU-Net: a self-configuring method for deep learning-based biomedical image segmentation. Nature Methods, 18(2), 203-211.

We thank the Office of Research and Sponsored Programs for supporting this research, and Learning & Technology Services for printing this poster.