Korean Circ J. 2024 Jan;54(1):40-42
https://doi.org/10.4070/kcj.2023.0297
pISSN 1738-5520·eISSN 1738-5555

kcj
Korean Circulation Journal

Editorial

Check for updates

Deep Learning-Based Intravascular Ultrasound Images Segmentation in Coronary Artery Disease: A Start Developing the Cornerstone

Nghia Nguyen Ho , MSc[1], Kwan Yong Lee , MD, PhD[2,3], Junhyug Noh , PhD[4], and Sang-Wook Lee , PhD[1]

[1]School of Mechanical Engineering, University of Ulsan, Ulsan, Korea
[2]Cardiovascular Center and Cardiology Division, Seoul St. Mary's Hospital, The Catholic University of Korea, Seoul, Korea
[3]Cardiovascular Research Institute for Intractable Disease, College of Medicine, The Catholic University of Korea, Seoul, Korea
[4]Department of Artificial Intelligence, Ewha Womans University, Seoul, Korea

▸ See the article "Deep Learning-Based Lumen and Vessel Segmentation of Intravascular Ultrasound Images in Coronary Artery Disease" in volume 54 on page 30.

Intravascular ultrasound (IVUS) is a cornerstone of interventional cardiology, providing high-resolution vascular images for the diagnosis of coronary artery disease. However, the traditional approach to interpreting these images has been both time-consuming and highly dependent on the expertise of medical professionals. Various efforts have been made to reduce this reliance on experts, using traditional methods such as computer vision and image processing with an accuracy of 0.30 mm error in segmented lumen and 0.22 mm error in segmented media.[1)] However, these methods largely depend on a specific algorithm with thresholds to segment images, which becomes difficult when the image contains various artifacts such as bifurcations, shadows, and side branches. Recent advances in artificial intelligence (AI), especially deep learning, hold great promise for objectively and quickly diagnosing IVUS findings and improving interventional outcomes.

The significance of this study is that it validates the convolutional neural network (CNN) model by creating a new IVUS dataset benchmark in patients with coronary artery disease.[2)] A total of 1,063 cases were divided into training and test sets. Finally, an independent dataset of 111 IVUS pullbacks was utilized to evaluate the vessel-level performance. Efficient-UNet was used for the automatic segmentation of IVUS images. Agreement between the derived model and expert-measured minimum lumen area and plaque volume was comparable with expert agreement (r=0.92 and 0.95, respectively). Segmentation and analysis time was also significantly reduced.

The major breakthrough in the application of deep learning to image processing began with the ImageNet competition in 2012 when the AlexNet model won with a significantly lower error rate.[3)] Since then, fully convolutional networks (FCNs) have been developed and applied not only to image classification tasks but also to semantic segmentation. One of the first studies to apply FCNs to semantic segmentation for IVUS images was by Yang et al.,[4)] called IVUS-Net. IVUS-Net can provide results very quickly, in as little as 0.15 seconds, and according

Received: Nov 7, 2023
Accepted: Nov 12, 2023
Published online: Nov 29, 2023

Correspondence to
Kwan Yong Lee, MD, PhD
Cardiovascular Center and Cardiology Division, Seoul St. Mary's Hospital, The Catholic University of Korea, 222, Banpo-daero, Seocho-gu, Seoul 06591, Korea.
Email: cycle0210@gmail.com

ORCID iDs
Nghia Nguyen Ho
https://orcid.org/0009-0001-7575-0661
Kwan Yong Lee
https://orcid.org/0000-0002-0480-1046
Junhyug Noh
https://orcid.org/0000-0003-1239-8178
Sang-Wook Lee
https://orcid.org/0000-0002-8600-9991

Funding
This research was supported by grants from the Basic Science Research Program through the National Research Foundation of Korea (NRF), funded by the Ministry of Education (NRF-2020R1C1C1010316).

Conflict of Interest
The authors have no financial conflicts of interest.

Data Sharing Statement
The data generated in this study is available from the corresponding author upon reasonable request.

Author Contributions
Conceptualization: Lee KY; Writing - original draft: Ho NN, Noh J, Lee KY; Writing - review & editing: Lee SW, Lee KY.

The contents of the report are the author's own views and do not necessarily reflect the views of the Korean Circulation Journal.

to the Jaccard measure, it achieves results that are 4% to 8% better than existing methods for the lumen and media region. However, the IVUS-Net model has difficulties with IVUS images containing various artifacts because it was trained on a small dataset, and the authors limited it to lumen and vessel segmentation only. This raises the need for a more advanced deep learning model, which requires extensive training on different datasets to ensure its generalizability. At the same time, the segmentation also needs to become more general with regions such as external elastic membrane (EEM), lumen, and plaque. In 2021, Nishi et al.[5] applied a state-of-the-art CNN architecture called Deeplabv3 to improve the above problems. They achieved certain results where they were able to delineate the shape of the stent, lumen, and vessel area with the highest correlation coefficient of 0.98 for the lumen area. However, Nishi et al.[6] only stop at the frame level without analyzing the accuracy at the vessel level; in addition, Deeplabv3 may not be the most efficient architecture in terms of computational and memory requirements. In this study,[2] the authors tried to solve the remaining problems using EfficientNet-B2 as a backbone based on U-net architecture. This architecture has already been proposed in other papers but is slightly different in that it adds some new structures.[6] Using this model, the authors were able to outline the structure of a vessel not only at the frame level but also at the vessel level, providing access to cross-sectional and volumetric parameters for a better understanding of vessel structure and prognosis. The results show that the model proposed by the authors gives better results than previous studies according to the DSCs score (0.93±0.05 and 0.97±0.03 for lumen and EEM segmentation, respectively).

This study[2] supports the idea of on-site AI-assisted IVUS assessment with an accuracy comparable to manual annotation. However, there are some limitations to this study as it is based only on internal data and excludes poor-quality images, which is unavoidable in practice. Further validation studies on multi-center datasets are needed to improve the generalizability and reliability of machine learning models. Furthermore, this model is only trained on the 40 Mhz dataset, and the IVUS images in this data are only naive coronary artery disease without a stent area.

Recently, the utility of non-invasive fractional flow reserve as a treatment decision tool for cardiovascular diseases has been highlighted, and researchers have been developing auto-segmentation of intravascular or non-invasive imaging data as a preliminary step.[7-9] While diagnostics using deep learning have the advantage of being faster and more objective than traditional methods used by human experts, there are concerns that they can be somewhat inaccurate.[10] Therefore, it is important to carefully interpret the performance of models developed to date, acknowledge their limitations, and improve them before applying them to clinical studies. We hope the authors can extend the model to a multi-center, multi-frequency IVUS dataset with segmentation for stents in coronary lesions to make the model more complete. Ultimately, IVUS automated segmentation techniques using machine learning have the potential to play a major role in improving treatment decisions and prognosis of coronary plaque.

REFERENCES

1. Faraji M, Cheng I, Naudin I, Basu A. Segmentation of arterial walls in intravascular ultrasound cross-sectional images using extremal region selection. *Ultrasonics* 2018;84:356-65.
PUBMED | CROSSREF
2. Jeong G, Lee G, Lee J, Kang SJ. Deep learning-based lumen and vessel segmentation of intravascular ultrasound images in coronary artery disease. *Korean Circ J* 2024;54:30-39.
CROSSREF

3. Krizhevsky A, Sutskever I, Hinton GE. ImageNet classification with deep convolutional neural networks. In: *Advances in Neural Information Processing Systems*. Red Hook (NY): Curran Associates, Inc.; 2012.

4. Yang J, Tong L, Faraji M, Basu A. IVUS-Net: an intravascular ultrasound segmentation network. In: Basu A, Berretti S, editors. Proceedings of the International Conference on Smart Multimedia; 2018 August 24–26; Toulon, France. Cham: Springer; 2018. p.367-77.

5. Nishi T, Yamashita R, Imura S, et al. Deep learning-based intravascular ultrasound segmentation for the assessment of coronary artery disease. *Int J Cardiol* 2021;333:55-9.
PUBMED | CROSSREF

6. Baheti B, Innani S, Gajre S, Talbar S. Eff-UNet: a novel architecture for semantic segmentation in unstructured environment. In: Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops; 2020 June 14–19; Seattle (WA), USA. New York (NY): IEEE; 2020.

7. Coenen A, Kim YH, Kruk M, et al. Diagnostic accuracy of a machine-learning approach to coronary computed tomographic angiography-based fractional flow reserve: result from the MACHINE consortium. *Circ Cardiovasc Imaging* 2018;11:e007217.
PUBMED | CROSSREF

8. Ziedses des Plantes AC, Scoccia A, Gijsen F, van Soest G, Daemen J. Intravascular imaging-derived physiology-basic principles and clinical application. *Interv Cardiol Clin* 2023;12:83-94.
PUBMED | CROSSREF

9. Yang S, Koo BK. Coronary physiology-based approaches for plaque vulnerability: implications for risk prediction and treatment strategies. *Korean Circ J* 2023;53:581-93.
PUBMED | CROSSREF

10. Ihdayhid AR, Sakaguchi T, Kerrisk B, et al. Influence of operator expertise and coronary luminal segmentation technique on diagnostic performance, precision and reproducibility of reduced-order CT-derived fractional flow reserve technique. *J Cardiovasc Comput Tomogr* 2020;14:356-62.
PUBMED | CROSSREF