Comparison of procedural and neural network algorithms for segmentation of regions of non-perfusion in retinal OCTA scans

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Poster #2057 – F0046

PURPOSE

- **Segmentation of regions of nonperfusion (RNP) with an automated algorithm enables detection of these regions by personnel that have not been trained in interpreting optical coherence tomography angiography (OCTA) scans**
- This study is to determine whether a deep-learning based algorithm has advantages over conventional procedural algorithms for segmenting these areas

METHODS

- **The procedural, or conventional algorithm uses vessel binarization and image processing to detect areas without vessels**
  - Subject to error in regions with noise or low signal
- The neural network algorithm is based on a convolutional neural network (CNN)
  - Inputs: OCTA retina projections and OCT reflectance images
  - Targets: Annotations made by expert clinicians
  - Training set: 60,000 patches obtained from 14 15x15mm and 46 12x12mm OCTA scans (PLEX® Elite 9000, ZEISS, Dublin, CA) of eyes having significant areas of ischemia, along with expert segmentations of RNP
  - 21 scans not used for the training were segmented using the procedural and DL algorithms. Dice coefficients were calculated for each output vs. the expert segmentation for each acquisition

RESULTS

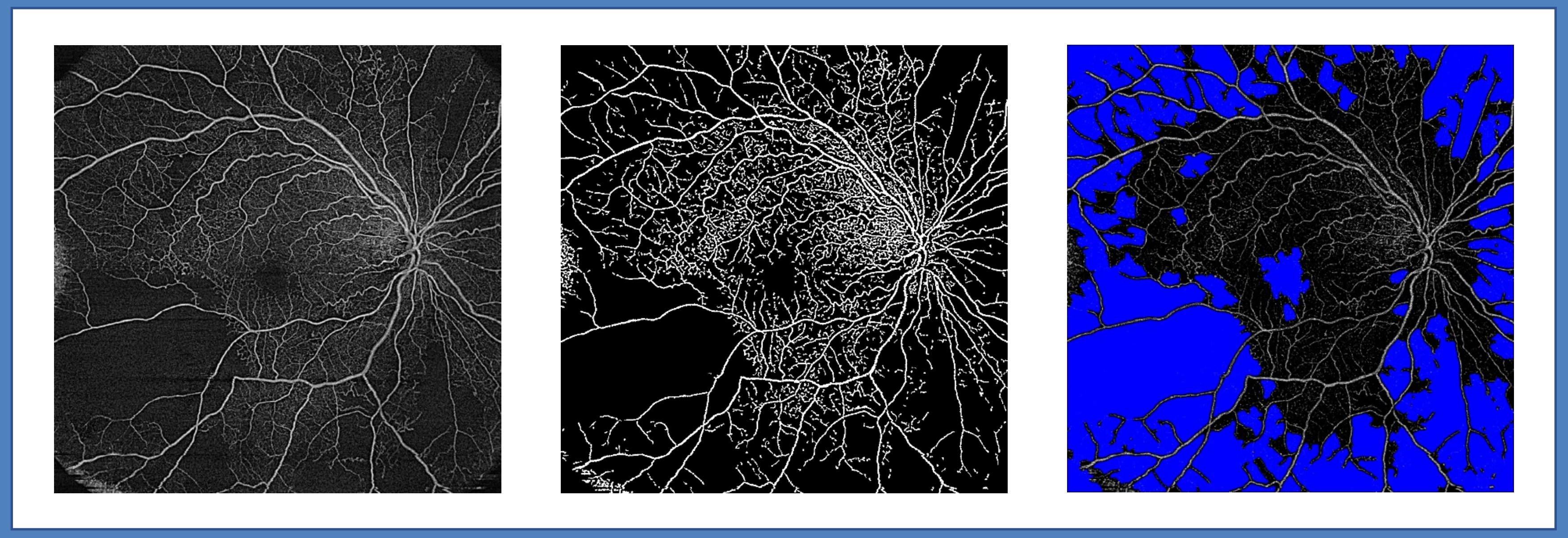
- **For the 21 scans in the test dataset, the CNN outperformed the procedural algorithm ($p < 0.001$)**
- See Table 1, Fig 3
- Undesired segmentation of the FAZ as RNP was reduced but not eliminated in the CNN output
- Anecdotally, some regions of low signal were incorrectly segmented by the CNN, which may be improved by modifying the training dataset and architecture

CONCLUSIONS

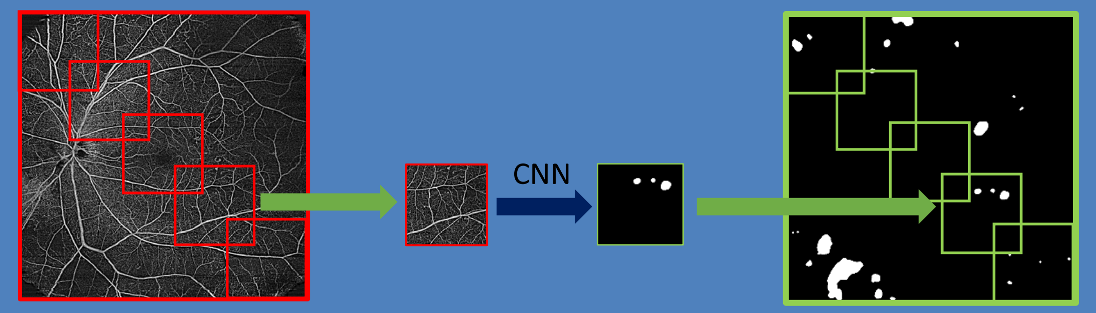
- **A CNN algorithm for segmentation of RNP compares favorably with a procedural one based on binarization and thresholding of OCTA scans**
- The greater ability of the CNN to accommodate differences in signal level and scan quality may also make it useful for other applications such as macular density quantification or FAZ delineation

Deep neural networks use nonlinear techniques to more effectively accommodate variations in signal and noise across the scan area

Fig 1



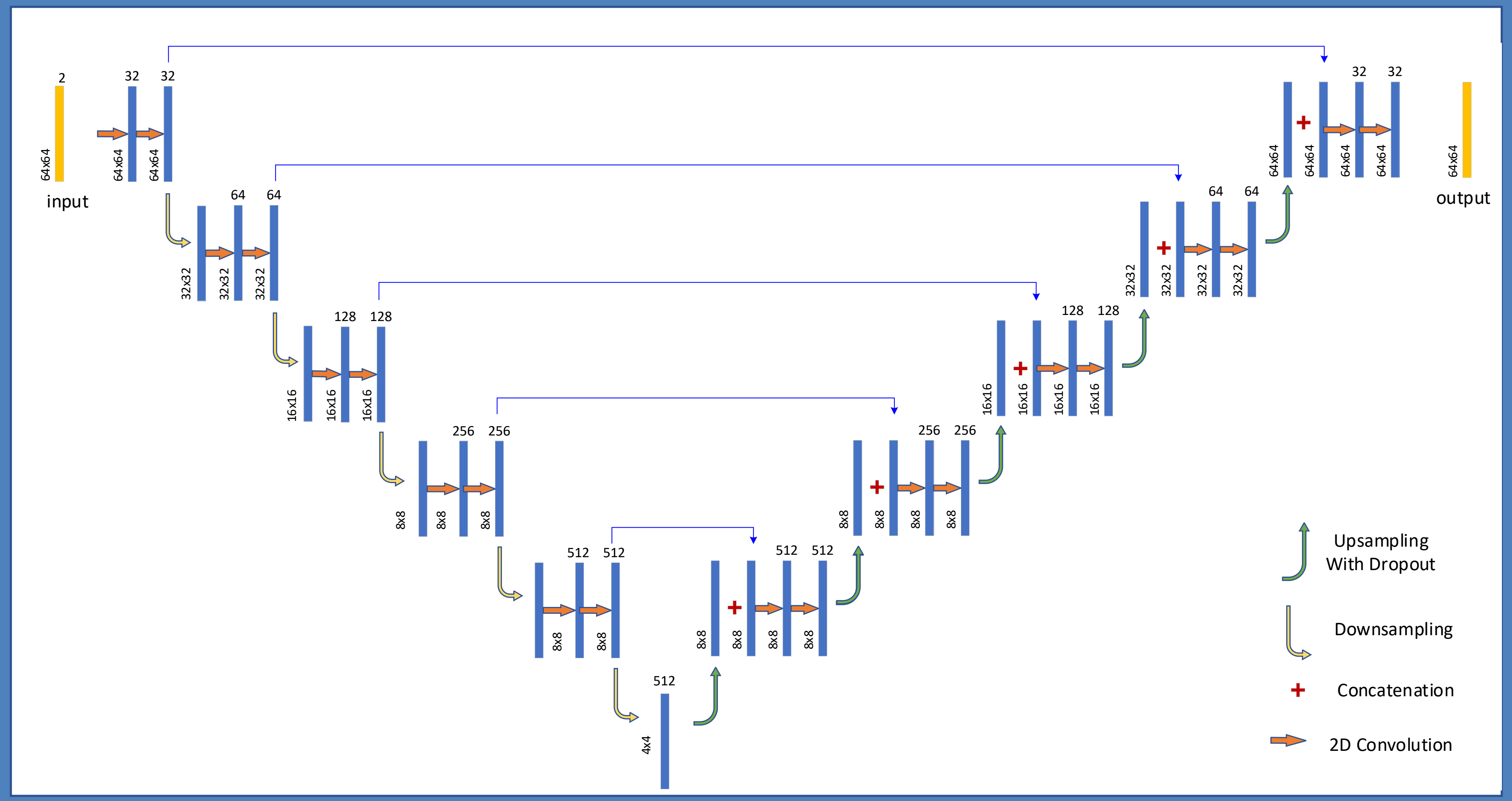
- *Procedural algorithm: thresholded and binarized OCTA en face slab is processed to identify areas greater than a defined threshold (here about 140µm radius)*
  - *Thresholding may be inaccurate in areas of lower signal or contrast*
  - *Tendency to falsely segment non-ischemic areas*



- *Neural network algorithm: OCTA en face slab is divided into patches and processed*
  - *OCTA and OCT full retina slabs included to allow algorithm to better identify low signal areas*
  - *Network has modified 5-layer U-net architecture*

Fig 2

U-net with repeated convolutional layers and without batch normalization



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Disclosures: WL (C), SK (E), LE (E), Carl Zeiss Meditec, Inc.; LdS (E), Carl Zeiss, Inc.; KL (N), AC (N), JG (N); NKW: (C), (F) - Nidek Medical Products, (C) - Boehringer Ingelheim, (C), (F) - Topcon, (F) - Carl Zeiss Meditec, Inc., (F) - Heidelberg Engineering, (S) - Gyroscope Therapeutics, (I) - Ocudyne; JR (C) Carl Zeiss Meditec, Inc.; HAK (N); MS (N); KL (N); GG (F), Carl Zeiss Meditec, Inc.; PJR (C), (F) Carl Zeiss Meditec, Inc.

Table 1. Dice obtained with CNN and procedural algorithms vs expert annotation

	imageNo	CNN_DiceCoeff	Procedural_DiceCoeff
15x15 data	2	0.29	0.02
	2	0.38	0.05
	5	0.66	0.63
	10	0.41	0.16
	14	0.78	0.64
	mean	0.50	0.30
	stdev	0.18	0.28
12x12 data	3	0.46	0.18
	4	0.75	0.53
	5	0.78	0.60
	12	0.50	0.17
	13	0.33	0.20
	16	0.62	0.56
	20	0.51	0.19
	21	0.64	0.29
	22	0.81	0.70
	30	0.27	0.21
	36	0.44	0.41
	41	0.42	0.36
	51	0.46	0.25
	65	0.17	0.10
	66	0.81	0.62
	69	0.72	0.56
	mean	0.54	0.37
	stdev	0.19	0.19

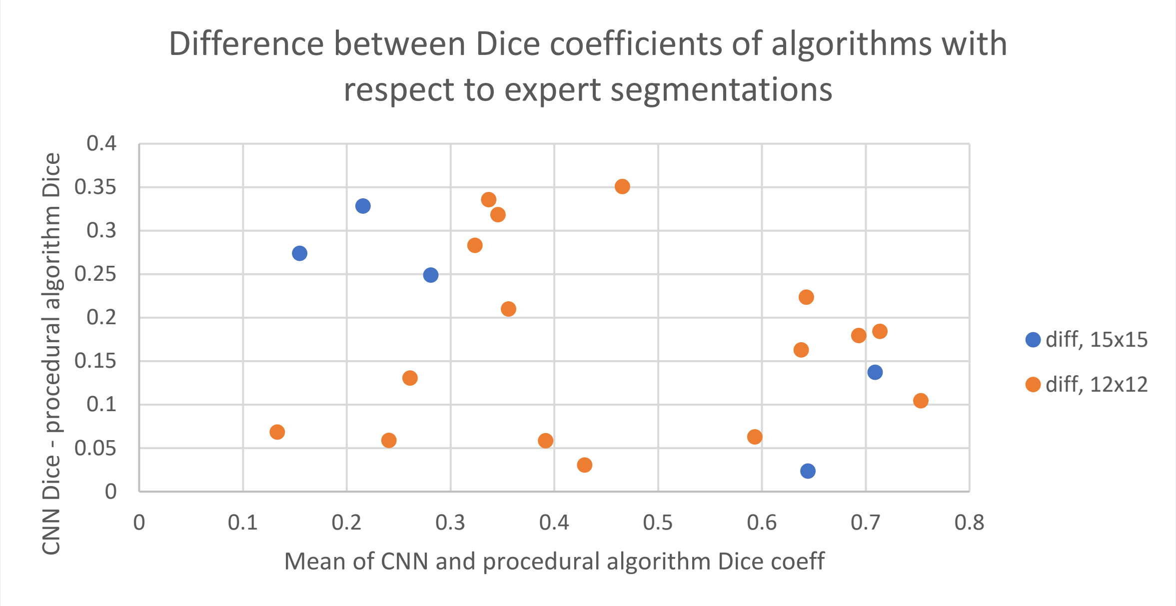

Fig 3

The CNN consistently outperformed the procedural algorithm with respect to expert annotations

Example scan of an eye exhibiting non-perfusion

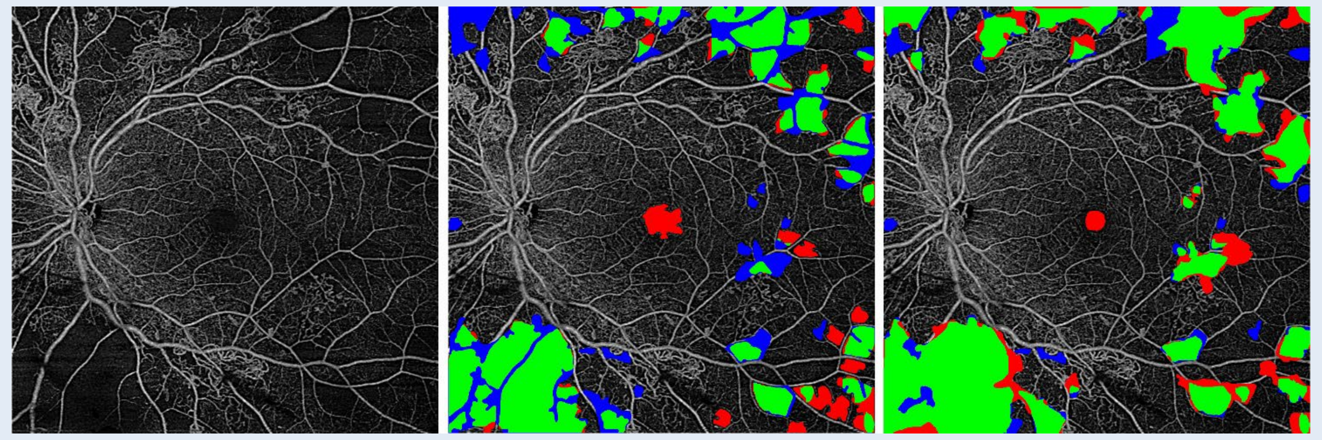

Fig 4

Left: Retina slab without segmentations. Center: comparison of procedural algorithm and expert annotation. Green: areas segmented by both the algorithm and the expert. Blue: segmented by the expert but not the algorithm. Red: segmented by the algorithm and not the expert. Right: comparison of CNN output and the expert. CNN shows greater agreement and a higher Dice coefficient (0.81 vs 0.70).