Title: Toward placental region identification and blood vessel classification using machine learning

Brian Vdasz, MD
Department of Pathology, Northwestern University, Chicago, IL

Background:
The placenta is a key driver of diseases of pregnancy and abnormalities in the placenta reflect life-long risk of disease in the mother and infant. Correct identification of placental regions (region ID) is foundational for diagnosis – observations have differing significance based on their location. For example, thick-walled arterioles (TWA) in the decidua are evidence of pathologic failure to remodel maternal vessels and are characteristic in diseases such as preeclampsia. Conversely, TWA arterioles in fetal stem villi are the norm. We sought to develop models that use region ID to correctly differentiate normal from abnormal blood vessels.

Methods:
We trained a region identification (ID) network using 200 whole-slide images of placental disc and membrane rolls on TensorFlow2 and Keras. Placental regions, including terminal villi, stem villi, decidua, fibrin, amnion, and background were rectangularly annotated, extracted, and 128x128 pixel regions were classified using a ResNet50-derived classifier.

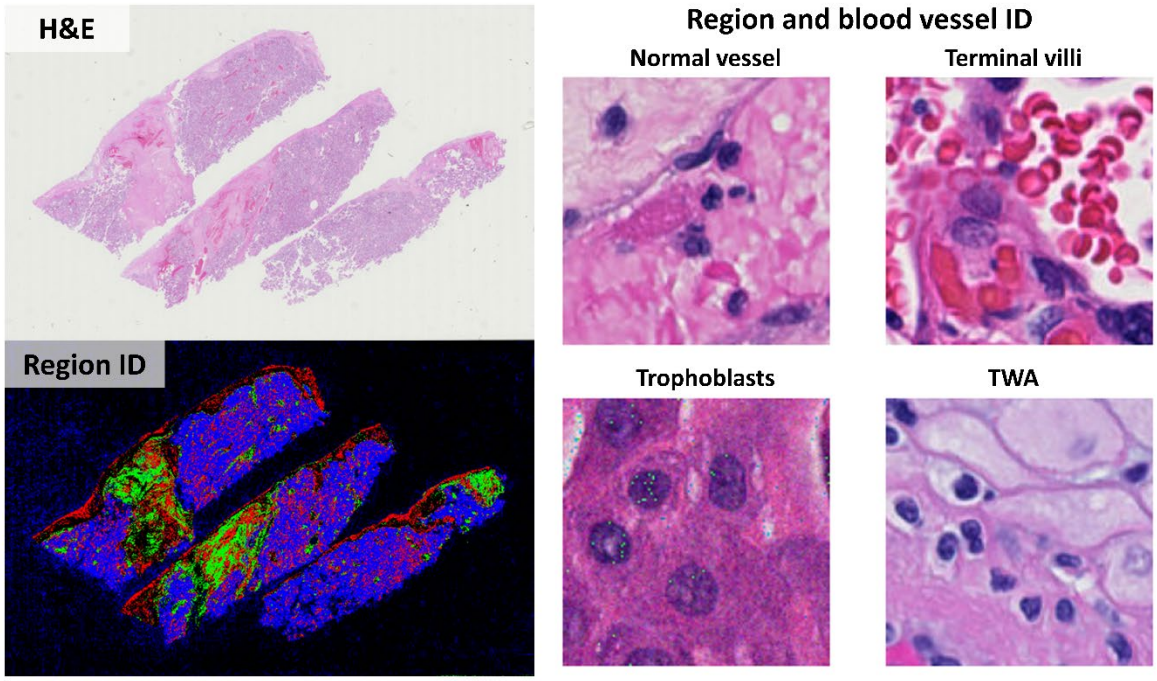
We compared a series of blood vessel segmentation and/or classification networks, including a MobileNetV2-derived U-Net, active learning based on 32x32 pixel micropatches, simple patch classification with a VGG16-derived classifier and combined region ID/blood vessel classification network.

For whole-slide region identification, 160x160 pixel fields with 32 pixel overlaps were generated across whole slides. Fields were classified by averaging the logits of 4 128x128. IRB approval was obtained, STU00211333.

Results:
Region ID showed a categorical accuracy of 0.98 in a balanced test set, with accuracy ranging from 1 for terminal villi and glass to 0.96 for fibrin. Whole-slide image classification shows plausible classification from non-bespoke fields (**Figure, left panels**).

Among vessel identification networks, a U-Net showed reasonable segmentation of blood vessels from background. For combined detection/classification, it showed high nominal accuracy >0.95, driven by the large number of background pixels, while actual detection was poor. Micropatch active learning was unsuccessful. Simple classification showed an accuracy of 0.86. Integrating vessel classification with region ID gave an overall accuracy of 0.9 with accuracies of 0.68 and 0.66 for normal vessels and TWA, respectively (**Figure, right panels**). Normal vessels were liable to misclassification as decidua (12%) – reasonable given this is their normal location or TWA (10%). TWA were misclassified as stem villi (10%) – exactly the problem we are trying to avoid or as normal vessels (16%).

Conclusion:
These results demonstrate that placental microanatomy is readily machine-recognizable. We report findings from several strategies for vessel recognition and classification, using region ID as a basis.


H&E
Region ID
Region and blood vessel ID
Normal vessel
Terminal villi
Trophoblasts
TWA