

Virtual Immunohistochemical Staining of Label-free Breast Tissue Using Deep Learning

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Introduction: The immunohistochemical (IHC) staining of tissue is not widely accessible due to its high cost and tedious staining procedures that demand an advanced histology lab infrastructure. Here, we present a virtual IHC staining method using autofluorescence images of unlabeled tissue sections [1]. Our method employs deep learning to digitally predict the IHC HER2 staining of unlabeled breast tissue sections and accurately matches the bright-field microscopic images of the same tissue fields of view (FOVs) captured after the standard IHC HER2 staining (Figure 1a). Besides visual comparison, the efficacy of our virtual staining method of label-free tissue was validated through quantitative blind studies performed by three board-certified pathologists.

Materials and Methods: The virtual staining deep neural network was trained using PyTorch. The network input autofluorescence images were captured with a wide-field fluorescence microscope using standard filter sets (DAPI, FITC, TxRed, Cy5) [1]. The ground truth images were captured with a bright-field microscope after standard IHC staining and were accurately co-registered to match the corresponding autofluorescence FOVs. Network models were trained to generate 12 independent virtually stained whole slide images (WSIs), not included in the training.

Results and Discussion: The success of our method was validated by two quantitative blind studies with evaluations from three board-certified breast pathologists. In the first study, the pathologists blindly graded the HER2 scores of 12 virtually and 12 immunohistochemically stained WSIs. It was demonstrated that the HER2 scores graded based on the virtually and immunohistochemically stained WSIs were statistically equivalent when compared to the ground truth scores provided by the patient health record (see Figure 1b). In the second quantitative blind study, the same group of pathologists inspected the staining quality of 240 virtually and immunohistochemically stained breast tissue image tiles. The results revealed that the virtually and immunohistochemically stained images have statistically equivalent image quality concerning nuclear detail, membrane clearness, and the absence of staining artifacts [1].

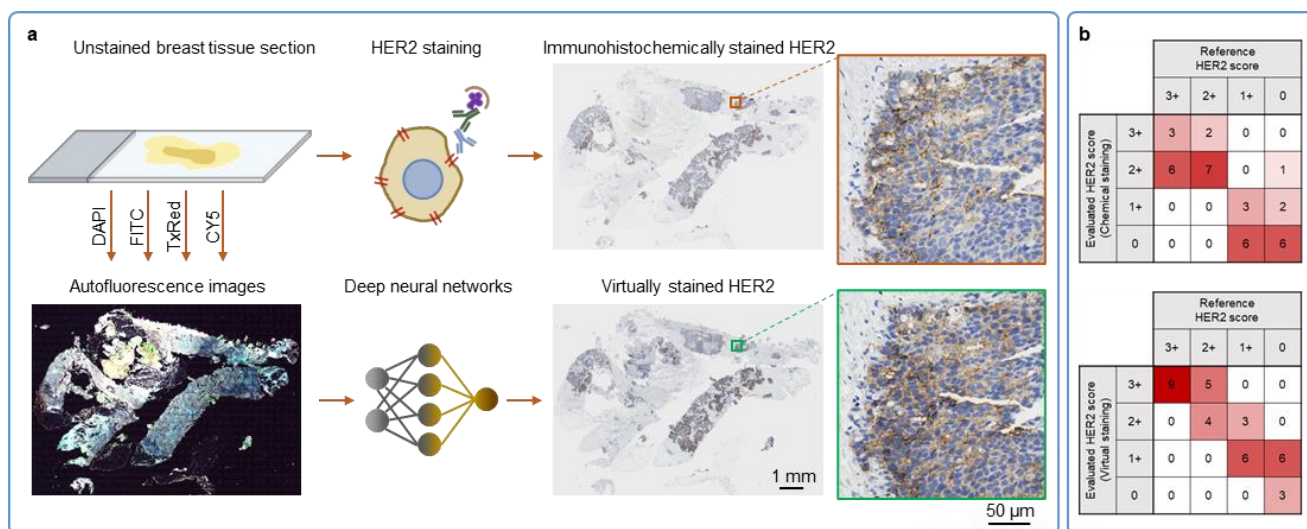


Figure 1. Virtual IHC HER2 staining of label-free breast tissue sections via deep learning. (a) The standard IHC HER2 staining requires laborious tissue treatment procedures (top). A virtual staining deep neural network infers the HER2 staining of unlabeled tissue sections (bottom). (b) Confusion matrices of HER2 scores evaluated based on IHC (top) and virtual (bottom) HER2 staining, compared to the reference (ground truth) HER2 scores provided by UCLA Health.

Conclusions: The presented virtual HER2 IHC staining method provides a label-free, cost-effective, and accurate alternative to the standard IHC staining with comparable image quality and diagnostic value.

References: [1] Bai, et al., *arXiv:2112.05240* (2022). DOI: 10.48550/arXiv.2112.05240