Digital Pathology and Artificial Intelligence for Prostate Cancer Diagnosis, Grading and Prognostication

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Background: In 2017, the FDA allowed marketing the first whole slide imaging system for diagnostic pathology. In 2018, the FDA permitted the first medical device using artificial intelligence for diagnosis and risk stratification through analysis of digital images. We took advantage of these FDA approved technologies and new developments in AI to develop algorithms for analysis of prostate cancer in H&E slides. The algorithms we developed can (i) map and grade cancer in whole digital slides from radical prostatectomies; (ii) predict disease stage from analysis of prostate needle biopsies; (iii) determine the risk of metastatic disease based on nuclear morphology and tissue architecture. (iv) provide a rank list and interpretation of histomorphometric features and (v) be integrated with genomic and clinical outcomes data.
Methods: We develop algorithms using machine learning and AI frameworks that include targeted features in feature libraries, autoencoder features and semantic segmentation using convolutional neural networks. Prediction models include linear and non-linear and parametric and non-parametric models. The algorithms are first trained on deeply annotated images and then tested for accuracy and speed using independent cohorts.
Results: (1) Accuracies for mapping low and high-grade cancer are greater than 80% at a speed of less than one minute per prostatectomy tissue section. (2) The digital feature signature for staging using prostate needle biopsies consists of targeted/handcrafted elements that overlap with hidden morphologic features in neuroendocrine/small cell prostate cancer. (3) The staging signature predicts progression to metastatic disease with an area under the receiver operating curve (AUC) of 0.75.
Conclusions: Digital image analysis (i) is a useful tool in research pathology to map cancer for generation of tissue microarrays, (ii) improves the efficiency of pathology diagnoses by pointing to the region with the highest grade, (iii) provides a non-tissue destructive, fast and cheap method for staging and risk prediction in a point of care setting. As a next step, the algorithms are developed into a user interface to stratify patients with high-grade prostate cancer at diagnosis into a group who requires and a group who does not require a metastatic workup.