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Applications for Machine Learning in Mohs Micrographic Surgery: Increased Efficiency and Accuracy

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Mohs micrographic surgery (MMS) is a precise method of skin cancer treatment via removal in stages for complete resection of malignancy.[1] Machine learning (ML) offers multiple potential applications to the procedure, some of which are discussed here.

The first step in MMS is identifying patients who meet criteria for referral, which often is completed via the histologic confirmation of skin cancer. ML may accelerate referral to a Moh's surgeon by automatically categorizing histologic findings. For example, an image classification system was developed using a cascade of three independently-trained convolutional neural networks (CNN) to sort digitized dermatopathology slides into categories of basaloid, squamous, melanocytic, and other; this system demonstrated an accuracy of up to 98%.[2] A system such as this would allow a dermatologist who interprets biopsies to review cases of a certain category (i.e., basaloid or squamous) and refer other cases.[2] Clinical dermatologists may identify patients who meet criteria for MMS and direct them to Mohs surgeons in a timelier manner with the assistance of ML.

Furthermore, patients and staff can benefit from estimations of the length and complexity of a given Mohs procedure. The total time and wound reconstruction are determined by how many stages are necessary for tumor clearance, which can be difficult to predict. As demonstrated by Shoham et al.,[3] ML models constructed using XGBoost (marginal contribution feature importance [MCI] and gradient boosting decision tree [GDBT]) were applied to a dataset of MMS procedures to preoperatively predict complexity. The first GDBT classification model demonstrated an area under the receiver operating curve (AUROC) of 0.84 for predicting the complexity of wound reconstruction; the second model displayed an AUROC of 0.79 for predicting the number of stages required.[3] ML may analyze preoperative data, such as characteristics of the tumor, to provide estimates on the length and complexity of MMS. Thereby, patients and staff may prepare with accurate expectations.

In addition, the extent of skin cancer often is not fully appreciable before MMS, and ML can evaluate affected areas prior to procedure. One technique utilizes optical coherence tomography (OCT), which is a clinical instrument used for in vivo skin imaging and prediction of tumor boundaries.[4] However, the interpretation of OCT results can be technically challenging and require a qualified professional onsite. A deep CNN with a U-Net architecture was trained to interpret OCT data and automatically detect skin cancer in a MMS clinic; this ML algorithm demonstrated accurate detection of abnormal skin tissue prior to procedure, with an AUROC of 0.88.[4] Results were validated by histologic examination.[4] Assessment of the tumor boundary before MMS via ML-supported OCT would allow for tumor mapping and efficient excision.

During MMS, the decision to continue stage resections or begin closure is dependent on whether histologic examination demonstrates complete clearance of cancer. ML models which analyze the histologic slides of a MMS procedure will facilitate accurate decision making. A pretrained ResNet34 convolutional network evaluated whole slide images for the presence of basal cell carcinoma and was compared with Mohs surgeons interpreting the same slides.[5] The algorithm performed comparably to the Mohs surgeons, with an AUROC of 0.997.[5] A similar model utilized ML (2D ResNet2 pretrained with ImageNet) to detect basal cell carcinoma in MMS frozen sections at a different institution, with an AUROC of 0.753.[6] The authors of both studies recognized that Mohs surgeons and ML models examine histologic slides in fundamentally different ways.[5,6] However, algorithms trained by ML can be a supplemental tool to the Mohs surgeon, as discrepancies between the two may prompt the surgeon to reevaluate the slide for residual carcinoma.

MMS is an effective procedure for the treatment of non-melanoma skin cancer. As ML and new technologies are integrated, its efficiency and accuracy will increase. Applications of ML include identifying eligible patients, predicting procedural complexity, estimating tumor boundaries, and assisting the Mohs surgeon with histologic evaluation.

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