Automated and Personalized Catheter Design for Endomyocardial Biopsies

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Right Ventricular Endomyocardial Biopsy (RV-EMB) is an invasive procedure where myocardial tissue is obtained for diagnosis of a variety of cardiac conditions. Currently, catheters are largely generic and require extensive experience and physician skill for manipulation of catheters within the right atrium and ventricle which risks complications of perforation and additionally inability to obtain tissue sampling. Computed Tomography (CT) Scans offer a non-invasive imaging technique where a 3D model can be created. This study presents an automated and personalized approach to designing catheter sheaths for RV-EMB using chest CT Scans and a YOLO11 segmentation model. CT Scans from the LIDC-IDRI dataset were obtained, and a cardiac pathway from the superior vena cava to the target of RV-EMB was manually annotated. A total of 9,978 annotated slices were used to train a YOLO11 Segmentation Model with the best model achieving an mAP50 of 0.955 and an F1 score of 0.99. The trained model was integrated into an automated Python pipeline requiring only CT Scan input. The system generates a catheter path, which is refined using a smoothening algorithm and Bézier parametric equations to eliminate acute angles and maintain safe cardiac clearance. Resulting catheters are personalized with appropriate length, an average cardiac clearance over 3mm, a minimum clearance greater than 1mm, no acute angulation, and catheter tip in contact with the site of RV-EMB. These results demonstrate the feasibility of this automated pipeline for personalized catheter sheaths for RV-EMB and support further investigation toward clinical application.

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