Simulator-Based Metrics for Quantifying Vascular Palpation Skill for Cannulation

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Introduction: Palpation is essential for many clinical examinations and procedures for accurate diagnosis and treatment. Specifically, vascular palpation is used for diagnosing cardiovascular health in addition to identifying anatomical landmarks in the peripheral vascular system. One medical procedure where vascular palpation is critical is cannulating for hemodialysis. This procedure is critical because patient survival depends on successful cannulation of their vascular accesses thrice a week. This procedure is especially challenging because the blood vessel typically cannulated (an arteriovenous fistula, AVF) is a patient-specific anatomical structure because it is created by surgically connecting a vein to an artery, which can mature into any number of shapes and sizes. Consequently, learning to palpate AVFs accurately for successful hemodialysis is a complex and critical skill that needs targeted training [1], [2]. However, not much attention has been given to quantifying what comprises skilled vascular palpation. Therefore, this study aims to objectively quantify the differences between high performer and low performer behavior towards understanding vascular palpation skills.

Methods: This study examines subject data collected from a novel hemodialysis (HD) cannulation simulator, which has been previously demonstrated for successful quantification of cannulation skill [3]. Nine high performers and twelve low performers completed sixteen trials on our simulator under various conditions. There were four fistulas, two skin thicknesses, and two motor vibration intensities. Finger force and location data were recorded for each trial on the simulator. Each trial consists of two major parts. The first is palpation, where participants were asked to identify the location and orientation of the fistula of interest. Following this, participants were instructed to insert the needle to obtain blood flashback. This presentation examines palpation, which is the first part of each cannulation trial. Consequently, segmentation was performed to isolate sensor data during the palpation portion of the trial. Additionally, we performed calibration to determine the locations of the four fistulas in the simulator to extract location-specific metrics. We examined three types of palpation metrics: time, force, and location.

Results: All three types of metrics demonstrated statistically significant differences between high and low performer palpation behavior. High performers tended to palpate for shorter Time. For location-based metrics, they palpated closer to the motor, had shorter path lengths, higher Ratio of Correct Movements (RCM), and a higher Ratio of Near Touchpoints (RNTP). Concerning force-based metrics, high performers palpated at a lower Frequency and had fewer Touchpoints per trial but dwelt longer at each touchpoint. They also applied less force at each touchpoint. The suite of metrics presented was effective for differentiating vascular palpation behavior of high performers from low performers. As such, these metrics could be used for structured and standardized palpation skills training in the future, potentially improving patient outcomes.

[1] D. J. Brouwer, “Cannulation Camp: Basic needle cannulation training for dialysis staff,” *Dial. Transplant.*, vol. 40, no. 10, pp. 434–439, Oct. 2011, doi: 10.1002/dat.20622.

[2] C. E. Lok *et al.*, “KDOQI Clinical Practice Guideline for Vascular Access: 2019 Update,” *Am. J. Kidney Dis.*, vol. 75, no. 4, pp. S1–S164, Apr. 2020, doi: 10.1053/j.ajkd.2019.12.001.

[3] Z. Liu *et al.*, “Measuring Cannulation Skills for Hemodialysis: Objective Versus Subjective Assessment,” *Front. Med.*, vol. 8, p. 2291, 2021, doi: 10.3389/fmed.2021.777186.