**Classification of Surgeons Skill in Percutaneous Nephrolithotomy Simulation**

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***Introduction and Objective:*** Surgeon skill classification is necessary in the development of a quantitative surgical skill assessment system for training purposes and reducing the surgical risks. The goal of this study is to classify the operators in a percutaneous nephrolithotomy (PCNL), a minimally-invasive procedure for stone removal from the kidney using a small puncture wound on the skin, simulation into two groups of experts and novices using kinematic features derived from the data of the simulation tool.

***Methods:*** Fourteen participants performed the simulation that included 1 undergraduate student, 4 medical students, 1 post-doctoral research fellow, 5 residents, 2 clinical fellows, and 1 faculty. They were labeled into two levels of minimal/none and residence/training in PCNL experience corresponding to novices and experts, respectively. In a quiet test environment using the two stone kidney model, the player removed both stones to complete the simulation. 10 kinematic features were extracted and normalized from the simulation system data that included the mean value for the left and right tool in cumulative task time, path length, mean and variance velocity, and mean and variance orientation in each of ***x***, ***y***, and ***z*** axes. The summary statistics by class for each feature is provided in Table 1. Linear discriminant analysis with diagonal covariance regularization was employed for the classification.

***Results:*** The surgeon skill classification was performed on 14 PCNL cases. Linear discriminant model was trained and validated using the aforementioned features by a 5-fold cross-validation with a test accuracy of 85.7% in classifying the skills.

***Conclusions:*** This method was able to reliably and accurately classify the skill level of surgeons based on simple movement characteristics of the surgical tool that can be used in the development of quantitative surgical assessment systems for the training purposes.

Table 1: The summary statistics by class for each feature

|  |  |  |
| --- | --- | --- |
| **Features** | **Mean (SD)** | |
| *Novices* | *Experts* |
| Cumulative task time (s) | 85.43 (28.97) | 59.56 (41.66) |
| Path length (m) | 3.61 (1.39) | 2.06 (1.97) |
| Mean velocity (m/s) | 0.05 (0.01) | 0.04 (0.03) |
| Mean ***x*** orientation (deg) | 316.63 (27.13) | 330.98 (53.89) |
| Mean ***y*** orientation (deg) | 323.55 (23.07) | 314.08 (27.1) |
| Mean ***z*** orientation (deg) | 143.64 (80.38) | 223.79 (82.03) |
| Velocity variance (m2/s2) | 0.04 (0.02) | 0.01 (0.05) |
| ***x*** orientation variance (deg2) | 10232.09 (5811.34) | 7562.37 (7542.65) |
| ***y*** orientation variance (deg2) | 7898.49 (6232.55) | 10530.08 (5684.53) |
| ***z*** orientation variance (deg2) | 11886.43 (10055.88) | 6490.5 (6411.89) |