Evaluation of Objective Performance Indicators to Measure Skill and Drive Personalized Recommendations in the Early Robotic Surgery Learning Curve

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Introduction: In robotic surgery, objective performance indicators (OPIs) can be calculated automatically from system events, instrument usage, and kinematic data. OPIs can distinguish novice from expert surgeons and predict clinical outcomes. The best OPIs for measuring performance and driving personalized recommendations in the early learning curve are not known. The objectives of this study were to propose criteria for selection of OPIs and evaluate candidate metrics.

Methods: To inform personalized training recommendations for new robotic surgeons across specialties, OPIs should be procedure agnostic, sensitive to skill at a case level, have an experienced-driven, monotonic trajectory with greater surgeon-to-surgeon than within-surgeon variability to achieve sensitivity and specificity in targeting skill deficits, and be actionable and modifiable OPIs to realize improvement from recommendations. We evaluated the following metrics as procedure-agnostic, case-level, actionable, and modifiable: camera control frequency, velocity, and duration; master clutch frequency and duration; instrument exchange number and frequency, number and frequency of moving an instrument from one port to another; number and frequency of endoscope installs; number and frequency of energy use events; and total energy delivered. All metrics except camera and clutch measures were normalized by procedure type. Deidentified da Vinci Surgical System data were analyzed for 2020 surgeons whose first robotic case was in 2020 or later and who completed their 200th case before the end of February 2025.

Results: Camera control duration, camera control velocity, clutch duration, and clutch frequency met above criteria for OPIs to drive early training recommendations. Figure 1 shows distributions of OPI averages with increasing case experience. Clutch frequency did not demonstrate monotonic distribution, and other OPIs had greater intra-surgeon than inter-surgeon variation.

Conclusions: An understanding of surgical data science principles and OPI characteristics, distributions, and changes during the learning curve are important for their use in informing surgical training and practice.

Camera Control Duration — Average Camera Control Duration (s) vs Previously Completed da Vinci Cases

MTM Clutch Duration — Average MTM Clutch Duration (s) vs Previously Completed da Vinci Cases

Camera Control Frequency — Camera Controls per Minute vs Previously Completed da Vinci Cases

MTM Clutch Frequency — MTM Clutches per Minute vs Previously Completed da Vinci Cases

Camera Movement Speed — Average Camera Control Speed (mm/s) vs Previously Completed da Vinci Cases