Advanced Engineering Technology for Measuring Performance

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• Simulation • Technology • Assessment • Sensors • Motion tracking

KEY POINTS

- Many technologies can achieve motion tracking of a surgeon's movements, but limitations in the simulation-based and operating room environments constrain their usage.
- Visual attention can reveal the cognitive processes underlying selection of procedural actions.
- Physiologic stress measurement can discern between experience levels of surgeons based on stress response, but it has multiple limitations.
- Evaluation of physical examination skills can be enhanced with the use of sensors to collect data on palpation force, frequency, location, and duration.
- Video-based data collection paired with qualitative analysis tools can be a valuable supplement to traditional observation methods.
- Application of innovative technology-based assessment tools requires a systematic evaluation of validity evidence using the modern construct validity framework.

INTRODUCTION

Simulation-based clinical skills assessments have become a high priority in helping promote and ensure clinical excellence.[1–5] Trainee competence in the simulated environment can be assessed in numerous ways, including self-assessment measures,[6] observer-generated measures,[7–10] and technology-based performance measures.[2–5] Self-assessment and observer-based scoring are commonly used to assess trainees

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but remain subject to bias. In contrast, technology-based measures can objectively quantify clinical and procedural performance and provide patient-centered metrics.[11]

Current technology allows for the collection of a variety of performance measures based on (1) motion,[12] (2) visual attention,[13] (3) physiologic stress,[14] and (4) palpation.[15] In addition, the use of innovative video capture technology and qualitative assessment measures can aid in the evaluation of data gathered from advanced engineering technology. The performance data generated from technology-based assessment tools (**Table 1**) may provide objective and reliable measures not possible with checklists and global rating scales alone. This article provides an overview of advanced engineering technology used to measure performance and the impact on clinical and surgical skills assessment.

MOTION

A developing field in the assessment of complex surgical skill proficiency is the use of electronic sensors to record movement. Multiple technologies are able to capture the movement of a surgeon's hands and instruments while performing real or simulated procedures. These motion capture technologies record the 3-dimensional (3D) position of a person's body over time, known as kinematics, whereas other sensor technologies focus on recording the forces produced or experienced by a person or object, defined as kinetics.[16]

Various motion measures can be derived from a trace of position over time (**Fig. 1**A). The path length of the hands, straightness of movements, and working volume, defined as the 3D area in which the hands are moving, are obtained from 3D position. Velocity, acceleration (**Fig. 2**B), and motion smoothness profiles can be generated by taking derivatives with respect to time. Time-based measures, such as the number of

Table 1
Examples of data collected from measuring hand movements, visual attention, physiologic responses, and palpation

Measurement	Data Outputs (Units)
Hand movements Motion tracking	• Path length (m) • Time (s) • Velocity (cm/s) • Acceleration (cm/s^2) • Motion smoothness (cm/s^3) • 3D position (m) • Working volume (cm^3)
Visual attention Eye tracking	• Gaze location (m) • Fixation duration (s) • Number of eye movements (#)
Physiologic responses Electrodermal activity Thermal imaging	• Temperature (°C) • Thermal emission (W/m^2) • Skin conductance (S) • Voltage signal (V) • Heart rate (beats/min) • Respiratory rate (breaths/min)
Palpation Force sensors	• Force (N) • Area palpated (cm^2) • Pressure (N/m^2) • Palpation time (s)