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## Technical-Skills Training in the 21st Century

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Medical education is undergoing a paradigm shift, from the traditional experience-based model to a program that requires documentation of proficiency.<sup>1</sup> Technological advances in health care, the development of day-case surgery, and the setting of quality-assurance targets have led to a striking reduction in training opportunities for young doctors. It is no longer acceptable, or appropriate, for students at any level of training to practice new skills on patients, even if they have a patient's explicit consent.

As Reznick and MacRae point out in this issue of the *Journal*, these "changes in the wind" are beginning to transform surgical residency programs.<sup>2</sup> A primary aim is for trainees to practice skills in a safe environment, before refining them in the real world. At present, simulation-based training is a prerequisite for all high-reliability organizations (e.g., in the airline, nuclear, and oil industries) yet remains a niche player in medical education.<sup>3</sup> The often-quoted criticism is that surgical simulators lack "fidelity," or are not truly lifelike, though the real problem has more to do with a lack of motivation or understanding on the part of educational leaders than with the eventual outcomes, which for the most part have been remarkably good.<sup>4-6</sup>

This success notwithstanding, there remains a chasm between proficiency in technical skills and the translation of those skills into expert performance in a complex clinical environment. It may be unrealistic to expect even technically proficient trainees to move directly into a dynamic space such as the operating room and exercise appropriate judgment, especially during crisis sit-

uations such as those involving major-vessel bleeding. To some extent, judgment — which relies on both cognitive and professional skills — can be modeled in an environment such as a simulated operating room, enabling trainees for the first time to receive feedback about both their technical and their nontechnical performance.<sup>7</sup> Though difficult to assess objectively, this type of training can translate into improved performance in the clinical setting.<sup>8</sup>

With the development of proficiency-based training and practice comes the need to set benchmarks of achievement in skills and behaviors during prespecified tasks.<sup>9</sup> Such criteria can be used not only to confirm the completion of a particular training module with the attainment of an appropriate level of technical proficiency, but also to reconfirm the soundness of the skills that have been acquired. We believe that in the future, expertise rather than experience will underlie competency-based practice and specialty certification. Validation and revalidation of expertise necessitate the use of tools that have high validity and reliability for assessing performance, many of which are described by Reznick and MacRae.

At present, these tools assess only technical skill, though recent advances in eye-tracking technology may enable us to elucidate the cognitive processes behind surgical tasks. For example, an analysis of eye movements during laparoscopic surgery can provide, on a two-dimensional screen, information regarding depth perception. This technology has already been used to assess skill in reading radiologic images, enabling research-

ers to delineate the strategies that are used by experienced radiologists.<sup>10</sup> It may soon be possible to make the eye movements of such radiologists the basis of a decision-support system that will aid trainees in identifying abnormal areas on radiologic images. The application of this technology to strategies for assessing surgical skills, perhaps with analysis performed by artificial neural networks, is not far behind.

But there is no reason why we have to stop there. The psychological components of motor-skill acquisition are inevitably related to the plasticity of the motor, premotor, and supplementary motor cortices of the brain. Recent developments in functional brain mapping can provide information regarding these changes — and perhaps ultimately a measure of skill in completing a technically demanding procedure.<sup>11,12</sup> It may also be possible to determine whether students possess the prerequisite baseline characteristics of depth perception and hand–eye coordination before they choose to enter technically demanding specialties.

For these tools to be used effectively, technical and nontechnical skills must be assessed in a standardized and reproducible environment. What, then, of situations in which a real patient has a congenital anomaly or is morbidly obese? In such challenging cases, a surgeon would normally take longer to perform a given procedure, owing in part to unclear anatomy. Ideally, one could scan the patient's anatomical data into a virtual-reality simulator and perform a virtual procedure in a simulated operating room the day before the real one was to take place. In essence, the team would rehearse the actual procedure before performing it live, the learning curve for difficult or unusual cases would not involve risk for the patient, and the real-world surgical outcome would be enhanced.

Such tools can address the increasingly limited opportunities for technical training and assessment that are offered to doctors, not only during training but throughout their careers. It is no longer necessary to educate students, residents, and practicing physicians in a system that relies on chance opportunities for learning new skills. Simulation allows for risk-free training in

technical skills. For the first time, a proficiency-based curriculum can make the actual level of skill rather than a predetermined period of time the primary factor in physicians' progression up the training ladder, ensuring that patients are cared for by doctors with expertise in the procedures they perform. Although simulations alone cannot improve the quality of health care, they do significantly advance clinical education — especially when combined with enriched curricular and educational environments such as virtual operating suites — and lead to enhanced clinical reasoning and professionalism.

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