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Transforming Surgical Training through Competency-Based Progression

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ABSTRACT

The traditional Halstedian model of surgical education, built on fixed training periods and apprenticeship-style learning, is increasingly insufficient for modern surgical practice. As techniques such as laparoscopy, robotics, and Artificial Intelligence (AI)-assisted procedures advance, rigid time-based training often fails to produce uniformly competent surgeons, raising concerns about patient safety and workforce readiness. Competency-Based Medical Education (CBME) offers a more effective framework by focusing on demonstrated mastery rather than time spent in training. Using structured assessment tools, such as Entrustable Professional Activities (EPA) and Objective Structured Assessment of Technical Skills (OSATS), CBME establishes clear, objective performance standards. Simulation-based training further supports skill development in a controlled environment, reinforcing outcome-driven learning. By prioritising competence, CBME enables individualised progression, more reliable assessment, and greater global alignment in surgical education. This modern approach is poised to improve patient outcomes, trainee satisfaction, and system efficiency.

Keywords: *Competency-based medical education, Simulation-based learning, Surgical education reform, Technology in medical training, Patient safety*

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INTRODUCTION

For more than a century, surgical education has been anchored in the Halstedian apprenticeship model—the enduring "see one, do one, teach one" approach (1). While revolutionary in its era, this time-bound system now struggles to meet the demands of modern surgery. It assumes that time spent in training equates to competence, an assumption increasingly untenable in an era of technological complexity, global workforce mobility, and heightened accountability (2). By tying progression to duration rather than demonstrated skill, it allows variability in outcomes: some trainees advance without sufficient mastery, while others capable of independent practice are constrained by rigid timelines (3).

This misalignment poses not only an educational challenge, but also an ethical one—patient safety depends on competence, not the time served. Today's surgeons must navigate open, laparoscopic, robotic, and artificial intelligence (AI)-assisted environments alongside complex decision making and interprofessional collaboration (4). The diversity of skills required and the variability in training opportunities have exposed the inflexibility of traditional models. These realities call for a system that prizes verified competence over chronological milestones. Competency-Based Medical Education (CBME) represents that necessary evolution—linking training outcomes directly to performance, not presence (5).

The Case for Competency-Based Progression

CBME redefines advancement by linking it to observable performance across cognitive, psychomotor, and affective domains. Competence is no longer inferred from time or case logs but is demonstrated through structured assessment of defined outcomes. This shift promises several benefits—improved efficiency, enhanced safety, and fairer access to surgical education.

Efficiency and patient safety

Competency-based progression introduces flexibility; trainees demonstrating early mastery can progress faster, while those needing more time receive individualised remediation (6). This approach eliminates the stigma of variable pacing and ensures that readiness, not time, determines independence. Importantly, it safeguards patients by preventing premature advancement—addressing a long-standing flaw in time-based models where variability in supervision and feedback often compromises safety.

Equity and global impact

In low- and middle-income countries (LMICs), where exposure to complex cases and mentorship is inconsistent, CBME offers an adaptable structure for equitable learning (7). Simulation and tele-assessment bridge the geographic and resource gaps, ensuring standardised evaluation even in decentralised systems (8). Thus, CBME is not merely an educational reform, but a strategy for global health equity—reshaping surgical training into a system that is personalised, data driven, and globally scalable.

However, flexibility also demands robust governance. Without consistent standards, variable pacing may introduce disparities between institutions or create perceptions of inequity among trainees. Implementing CBME requires balancing individual progression with collective accountability, ensuring that ‘faster’ does not become ‘superficial.’ Sustainable reform thus relies on shared frameworks, institutional readiness, and faculty commitment—factors that are often underestimated.

Establishing Objective Benchmarks for Competence

A cornerstone of CBME is establishing clear, measurable outcomes that define surgical readiness. Traditional evaluations often rely on subjective impressions. CBME replaces this with structured, transparent benchmarks using Entrustable Professional Activities (EPAs) and tools like the Objective Structured Assessment of Technical Skills (OSATS) (9).

OSATS uses standardised checklists and behaviourally anchored rating scales to evaluate procedural performance, minimise bias, and promote fairness. In contrast, EPAs define real-world professional tasks—such as performing a laparoscopic cholecystectomy or managing postoperative bleeding—that trainees must perform independently. Progress is tracked in digital portfolios, integrating feedback, reflection, and supervisor validation. The 2023 adoption of 18 EPAs by the American Board of Surgery marked a milestone in nationwide standardisation and accountability (10).

Despite their strengths, these tools can foster a 'checklist mentality' if used mechanistically. When competence becomes synonymous with completing tasks, the deeper cognitive and ethical dimensions of surgery—judgement, adaptability, and empathy—risk being sidelined. True CBME must integrate both measurable technical skills and the more nuanced 'invisible curriculum' of professionalism, resilience, and reflective practice. Moreover, assessment reliability depends on faculty calibration; without investment in assessor training, objectivity remains aspirational rather than achieved.

Simulation-Based Mastery and High-Stake Assessment

Simulation has transformed surgical education by providing a safe, controlled environment for deliberate practice and error correction (12). Trainees can refine psychomotor skills through repeated exposure before entering the operating room—critical for patient safety and the development of confidence.

From low-fidelity box trainers for basic laparoscopic tasks to high-fidelity virtual reality (VR) platforms replicating complex anatomy and dynamic scenarios, simulation supports progressive skill acquisition (13, 14). Cadaveric and animal models remain invaluable for tactile realism, particularly in advanced or emergency procedures (15, 16). Importantly, simulation-trained skills have been shown to transfer effectively to clinical performance, correlating with improved intraoperative outcomes and fewer complications (17).

Despite these advantages, simulation should complement—not replace—real clinical experience. An overemphasis on simulation may create 'artificial competence,' where proficiency in a simulated environment fails to capture the unpredictability and emotional complexity of real surgery. Furthermore, equitable access to high-fidelity simulators remains a challenge, particularly in resource-limited settings. Institutions must therefore balance technological sophistication with inclusivity, ensuring that simulation enhances, rather than stratifies, training. As simulation continues to strengthen technical readiness, emerging digital technologies and AI-driven analytics are reshaping how these competencies are evaluated, setting the stage for a new frontier in surgical assessment.

Technology, AI and the Expanding Frontier of Surgical Assessment

Technological innovation has accelerated the transition to CBME by making assessment more objective, scalable, and data driven. AI-assisted video analysis, for instance, can now evaluate surgical dexterity by measuring metrics, such as instrument trajectory, motion efficiency, and error frequency (19). These systems offer consistent feedback unaffected by fatigue or interpersonal bias while generating valuable analytics for benchmarking performance.

Extended reality

Extended reality (XR), including virtual, augmented, and mixed reality, has shown efficacy comparable to traditional simulation in improving proficiency, especially in minimally invasive and robotic surgery (20). By layering anatomy, providing haptic feedback, and simulating high-pressure scenarios, XR strengthens spatial reasoning and cognitive load management. Moreover, technology enables remote mentorship: Supervisors can review live or recorded procedures, annotate performance, and monitor longitudinal progress (21). Such innovations democratise expertise, expanding the reach of surgical educators beyond geographic boundaries.

However, technology is not a panacea. Digital tools risk reinforcing existing inequalities—institutions with financial and technical capacity surge ahead, while others fall behind. Moreover, data-driven assessments must safeguard privacy, avoid overreliance on metrics, and preserve the humanistic essence of surgery. There is also the danger of 'technological determinism'—believing that innovation alone can reform education. Real transformation demands cultural and institutional change—protected faculty time, structured mentorship, and alignment with accreditation frameworks. Without these, even the most advanced technologies may amplify, rather than alleviate, systemic burdens.

Integrating Human, Institutional and Technological Reform

CBME represents more than an assessment reform—it is a paradigm shift that challenges traditional hierarchies and pedagogical assumptions. Implementing it successfully requires reconfiguring the institutional culture. Faculty development, workload redistribution, and genuine stakeholder engagement are crucial.

Many surgical educators express conceptual support for CBME but struggle with practical barriers, including limited time for observation, inconsistent feedback practices, and bureaucratic reporting demands. The shift from 'time served' to 'competence demonstrated' requires not only new tools but also new mindsets—valuing individualised learning trajectories over uniform progression (22). Institutions must provide incentives and infrastructure that reward formative assessment and mentorship, not just clinical productivity.

Equally important is the need for a longitudinal evaluation of CBME outcomes. While early reports are promising, robust evidence on long-term impacts—on surgeon performance, patient outcomes, and workforce sustainability—remains limited. Without such evidence, CBME risks becoming a fashionable label rather than a substantive reform.

CONCLUSION

The traditional time-based apprenticeship model, though historically significant, no longer meets the demands of contemporary surgical practice. The assumption that time equates to competence jeopardises both learners and patients. CBME offers a more adaptive and accountable alternative—anchored in measurable performance, continuous feedback, and individualised pacing. Simulation, AI, and extended reality have provided technological tools for this transformation, but technology alone cannot deliver reform. The real challenge lies in synchronising human, institutional, and technological evolution—training faculty, aligning accreditation standards, and embedding reflective patient-centred values within every level of the system.

Ultimately, the success of CBME will depend on our collective will to move beyond tradition. The goal is not merely to produce technically skilled surgeons, but to produce thoughtful professionals capable of safe, adaptable and compassionate care. The future of surgical education must be defined not by how long one trains but by how well one performs when it matters most.

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