EDITORIAL

Are We Training Surgeons or Supervisors? Artificial Intelligence, Automation, and the Future of Surgical Expertise in Orthopedics

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Orthopedic surgery isn't exactly "magic," but it absolutely demands mastery. It isn't just knowing what to do it's being able to do it reliably, safely, and under pressure.

For decades, our training model has been built on progressive responsibility: observation, assistance, performance under supervision, and finally independent performance. That pathway assumes a relatively stable environment, where the key variables evolve predictably along a developmental scale.

But artificial intelligence, computer vision, next-generation robotics, mixed reality, and new generative tools are poised to reshape the training environment we've relied on for decades. Sometimes the shift is subtle almost invisible but it's already happening.

The essential question is no longer whether these technologies are coming. It's whether we are unintentionally shifting residency training from developing future surgeons to producing future supervisors of automated systems and whether our curricula, assessment methods, and professional identity are prepared for that transition.[1,2]

The "Supervisor Drift" in Surgical Training

If you listen closely to the modern OR, you can hear the drift. Trainees now spend a meaningful part of their day interacting with technology planning platforms, navigation dashboards, robotic consoles, imaging overlays, and simulation tools often even before they scrub in.

At the same time, the attending's role is evolving. Instead of being purely a hands-on operator and teacher, the surgeon increasingly becomes the coordinator of a hybrid human–machine team: verifying system accuracy, interpreting digital feedback, and working alongside reps and technicians to keep the technology aligned with the surgical plan. In many cases, supervising the "tech stack" has become as central to the workflow as supervising the resident.

And with more devices, screens, cables, and people moving in and out of the room, there's a new, very practical layer of vigilance: integrating these tools without compromising sterility, disciplined traffic patterns, and sterile-field awareness while the digital infrastructure expands around the patient.

Personalized AI Coaching for Orthopedic Residents

One of AI's biggest educational advantages is that it can map a resident's performance knowledge and skills; identify specific gaps, and translate them into targeted learning goals and practice plans. AI-driven chatbots and tutoring tools are already moving into medical education, including orthopedics.

That matters because traditional orthopedic training is still heavily based on exposure and repetition, and a standard rotation may never guarantee contact with uncommon procedures or high-complexity scenarios. AI can help close that gap by generating realistic case vignettes ranging from straightforward to challenging that "simulate" missing experiences and support stepwise progression. Early studies suggest both trainees and practicing orthopedic surgeons are generally receptive to this approach.[3]

AR/VR and mixed-reality simulation can give residents high-fidelity, three-dimensional details of bone, joints, ligaments, and soft tissue, while allowing them to rehearse decision-making and technical steps without putting patients at risk. In parallel, AI-powered templating and preoperative planning (especially in hip and knee arthroplasty) can improve implant sizing accuracy, streamline workflow, and support more consistent limb-length restoration.[4] These tools that translate across orthopedic subspecialties and help trainees learn the plan before they ever touch the patient.

The barriers are real; cost, complexity, and cultural resistance from teams accustomed to traditional techniques. That's why some medical schools in United States are now

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introducing early AI literacy courses to teach future clinicians how to use these systems intelligently and communicate effectively with engineers, reps, and technicians.[5]

AI also supports training in imaging interpretation (X-ray, CT, MRI), helping residents and students sharpen pattern recognition and clinical reasoning alongside their operative education. [6,7]

The Convenience Trap: When AI Makes Surgeons Less Ready

Why struggle through decision-making when an AI can propose a plan in seconds? Why read papers deeply when a summary feels good enough? Why learn the slow craft of operative documentation if a system can generate a polished note?

That convenience can become a subtle form of laziness, and the real cost is cognitive. Trainees may stop doing the hard work of surgical thinking. Recognizing when a plan is wrong even if it looks reasonable, prioritizing under uncertainty, and spotting pitfalls before they become complications.[6]

Recommendations for the Future

The future will demand both skill sets. We still need surgeons with manual excellence, sound judgment, complication management, and independent decision-making. But we'll also need a new layer of capability: supervision of complex systems, validating AI outputs, understanding failure modes, human factors, and accountability, and knowing which AR/VR data actually matters for patient care.

These technologies can generate an overwhelming volume of measurements, angles, distances, alignment metrics, soft-tissue parameters, and implant positioning data. More data does not automatically mean better decisions. Not every metric is clinically meaningful, and not every deviation from the plan should override what we see and feel intraoperatively. A core expertise will be learning how to filter signals from noise and teaching residents and fellows when to trust the technology, when to question it, and when to ignore it.

Rather than resisting the shift, residency programs can formalize it with a practical framework: dual-competency milestones (technical + supervisory), clear documentation of AI use, training in bias and error recognition. We can have protected low-tech cases where residents must demonstrate they can perform safely with minimal augmentation to maintain the fundamental skills.

AI should be treated like a junior colleague; fast, helpful, and occasionally wrong, requiring oversight, skepticism, and verification.

Finally, we have to update assessment and governance. When AI contributes to an error, responsibility does not disappear into the algorithm. Ethical clarity, transparent policies, and accountability structures will become essential in academic surgery and today's trainees need to be prepared to practice within that reality.

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