

Neurosurgery and Artificial Intelligence: Considerations About Defensive Medicine

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Introduction

Defensive medicine has long been a pervasive reality in surgical specialties, and perhaps nowhere more so than in neurosurgery [1]. The extraordinarily high stakes of our discipline—where millimeters can separate recovery from disability or death—are compounded by a medico-legal climate that amplifies surgeon vulnerability [1]. Ordering additional imaging, prolonging hospital stays, avoiding high-risk yet potentially beneficial procedures, and maintaining exhaustive documentation have all become characteristic defensive behaviors. While intended to shield against litigation, these practices often drive overtreatment, inefficiency, and escalating costs, without necessarily improving patient outcomes [2].

Today, the rise of artificial intelligence (AI) promises to redefine this landscape [3]. AI-powered diagnostic tools, predictive models, and intraoperative guidance systems suggest a future in which human error may be reduced, uncertainty minimized, and defensive medicine rendered obsolete. Yet paradoxically, AI may also inaugurate new forms of defensiveness—born not of fear of human fallibility, but of medico-legal entanglements in a world where clinicians and algorithms share responsibility for decisions. Neurosurgery, with its combination of complex decision-making and high medico-legal exposure, sits at the forefront of this tension.

The promise of AI is compelling. In radiology, a study show that AI can reduce perceptual errors, assist with triage, and increase diagnostic accuracy [4]. In neurosurgery, early applications range from automated imaging interpretation to intraoperative navigation, predictive analytics for aneurysm rupture or traumatic brain injury, and outcome modeling for spinal procedures [3]. These innovations raise

the possibility that AI could reduce litigation by preventing misdiagnosis, shortening time to treatment, and improving surgical precision.

Yet evidence from related fields warns of a paradox. When radiologists in a recent study were presented with AI-generated outputs, their diagnostic accuracy improved overall—but when the AI was wrong, it misled them into errors they would not otherwise have made. Even more tellingly, radiologists were especially reluctant to contradict AI recommendations when they believed that the AI output would be permanently stored in the medical record and potentially discoverable in court. Such findings highlight a new kind of defensive medicine: one driven not by distrust of technology, but by fear of being accused of negligence for overriding it [4,5].

In neurosurgery, this paradox may manifest as “defensive conformity”—the inclination to align with AI recommendations regardless of one’s own clinical judgment. If an AI system recommends conservative management of an incidental aneurysm, is the surgeon at risk of litigation if they disagree and operate? Conversely, if the surgeon follows AI advice to operate and a complication occurs, could they be accused of recklessly abdicating judgment to a machine? Both paths carry liability, and both may reinforce a defensive instinct to follow AI uncritically.

As AI systems advance, legal scholars have argued that they may come to define the medical standard of care, particularly if they consistently outperform average clinicians. Should that threshold be reached, neurosurgeons could face an expectation to defer to AI recommendations, with deviation interpreted as negligence. Such a scenario raises profound ethical and legal questions: Is the surgeon’s duty to exercise independent judgment diminished in the presence of a superior algorithm? Or does accountability remain unchanged, with AI viewed as merely advisory?

The opacity of many AI models—the so-called “black box” problem—compounds this dilemma. A neurosurgeon can explain their reasoning in court; an algorithm often cannot. Without explainability, surgeons may struggle to justify why they agreed or disagreed with AI outputs, leaving them legally vulnerable. Conversely, explainable AI models—those that cite clinical features, prior cases, or rel-

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evant literature—may offer surgeons both a cognitive aid and a medico-legal defense, enabling them to articulate why a particular recommendation was or was not followed.

Some have proposed contractual arrangements among hospitals, vendors, and insurers to clarify liability, shifting responsibility toward manufacturers when AI systems act autonomously. Others advocate legislative reform, including liability shields when clinicians reasonably rely on Food and Drug Administration (FDA)-approved or certified AI systems. Yet until such frameworks are established, neurosurgeons will likely operate in a gray zone where defensive conformity prevails.

Interestingly, defensive behaviors may oscillate between two extremes: automation bias and black-box mistrust. On one hand, automation bias drives clinicians to over-trust algorithms, particularly when accountability pressures loom. On the other, mistrust of opaque “black box” models may push surgeons toward duplicative testing, second opinions, or unnecessary procedures—classic defensive medicine in a new guise.

Both tendencies risk distorting clinical judgment. Neurosurgeons, for instance, may over-rely on AI-derived imaging interpretations of spinal instability, even when their own assessment suggests otherwise. Alternatively, they may order redundant imaging to “double-check” an algorithm’s findings, not out of genuine diagnostic uncertainty, but as a legal safeguard. Thus, the very technology intended to reduce defensive medicine may instead reconfigure and perpetuate it.

Several scenarios can be envisioned for the future of defensive medicine in neurosurgery:

- **Optimistic trajectory:** AI integration reduces errors, enhances decision-making, and standardizes care. Malpractice claims decline, insurance premiums drop, and defensive practices become less necessary.
 - **Pessimistic trajectory:** Fear of liability in the AI era fuels defensive conformity and redundant testing. Surgeons abdicate judgment to avoid litigation, eroding patient-centered care.
 - **Intermediate trajectory:** AI becomes a confirmatory tool rather than a replacement for judgment. Legal frameworks evolve to protect reasonable reliance on AI while preserving surgeon accountability. Defensive medicine does not disappear but is reshaped into new patterns.
- The trajectory we follow will depend on choices made now. Several steps are critical:
- **AI literacy:** Neurosurgeons must acquire not only technical familiarity but also legal and ethical awareness of AI systems. Blind reliance and reflexive mistrust are equally dangerous.
 - **Explainable AI:** Professional societies should advocate for transparent algorithms capable of providing rationales comprehensible to clinicians, patients, and courts.
 - **Shared decision-making:** In cases of AI-clinician disagreement, involving patients in deliberation may

strengthen informed consent and reduce claims of nondisclosure. At present, there is little evidence regarding patients’ perspectives on the use and potential role of AI in medicine; this dimension warrants further investigation.

- **Policy engagement:** Neurosurgical associations must engage legislators and regulators to clarify liability distribution, ensuring that surgeons are not unfairly penalized for reasonable decisions in complex AI-mediated contexts.
- **Cultural leadership:** Neurosurgeons should frame AI as an adjunct to human expertise, not a replacement. Trust, empathy, and accountability remain irreducibly human dimensions of care.

Conclusions

Defensive medicine is unlikely to vanish with the advent of artificial intelligence. More plausibly, it will evolve, reshaped by the medico-legal ambiguities of algorithmic decision support. For neurosurgeons, the challenge lies in ensuring that AI integration enhances—rather than constrains—clinical judgment. The profession must resist a drift toward defensive conformity, in which surgeons follow algorithms out of fear rather than conviction. Instead, we should advocate for explainable systems, fair liability frameworks, and a culture that values the irreplaceable human elements of neurosurgical care.

If defensive medicine in the past was a struggle between physicians and the law, the future risks becoming a struggle between physicians and algorithms. It is incumbent upon us to ensure that AI becomes a partner in care rather than a new source of defensive anxiety. The decisions we make now—regarding technology, policy, and professional culture—will determine whether AI helps liberate neurosurgery from defensive medicine, or merely changes its face.

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Author Contributions

IZ and AC contributed equally in the design and preparation of the manuscript. IZ wrote the manuscript. Both authors have been involved in revising the manuscript critically for important intellectual content. Both authors gave final approval of the version to be published. Both authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

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Conflict of Interest

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