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A human in the loop in surgery automation

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Medical robots are expected to improve healthcare delivery and reduce costs. Robots are devoid of human shortcomings such as fatigue or momentary attention lapses, and can enhance practitioners' capabilities in performing tasks, including surgeries. As robots' perception, decision-making, and autonomy increase, the role of humans will change, even decrease, and other issues relating to cybersecurity and privacy will become more significant (1). The complex interplay between increasingly autonomous surgical robots, medical practitioners, and support staff will soon complicate the understanding of how to allocate responsibility if something goes wrong. In this correspondence, we argue that while the role of human performance in medical robot surgeries may decrease as robotic technology increases, the role of human oversight will increase.

Levels of automation define the robot's progressive ability to perform particular functions independently. Yang et al. proposed a generic six-layered model for medical robots' autonomy levels depicting a spectrum ranging from no autonomy (level 0) to full autonomy (level 5) to bridge this gap (1). The effort is a step towards clarity, but the model needs detailing on how it applies to specific types of medical robots. Medical robots' embodiment and capabilities differ vastly across surgical, physically/socially assistive, or serviceable contexts, and the involved human-robot interaction is also distinctive (2). Socially assistive robots, for instance, interact with users socially, performing a task for the user, but physical contact with the user is minimal. In contrast, physically assistive robots (e.g., lower-limb exoskeletons), work towards a seamless integration with the user's movement, and surgical robots are collaborative robots that extend the surgeon's abilities.

Since these elements demand domain-specific concretization, we propose to tailor the model of Yang et al. to surgery automation for further discussion (Fig. 1).

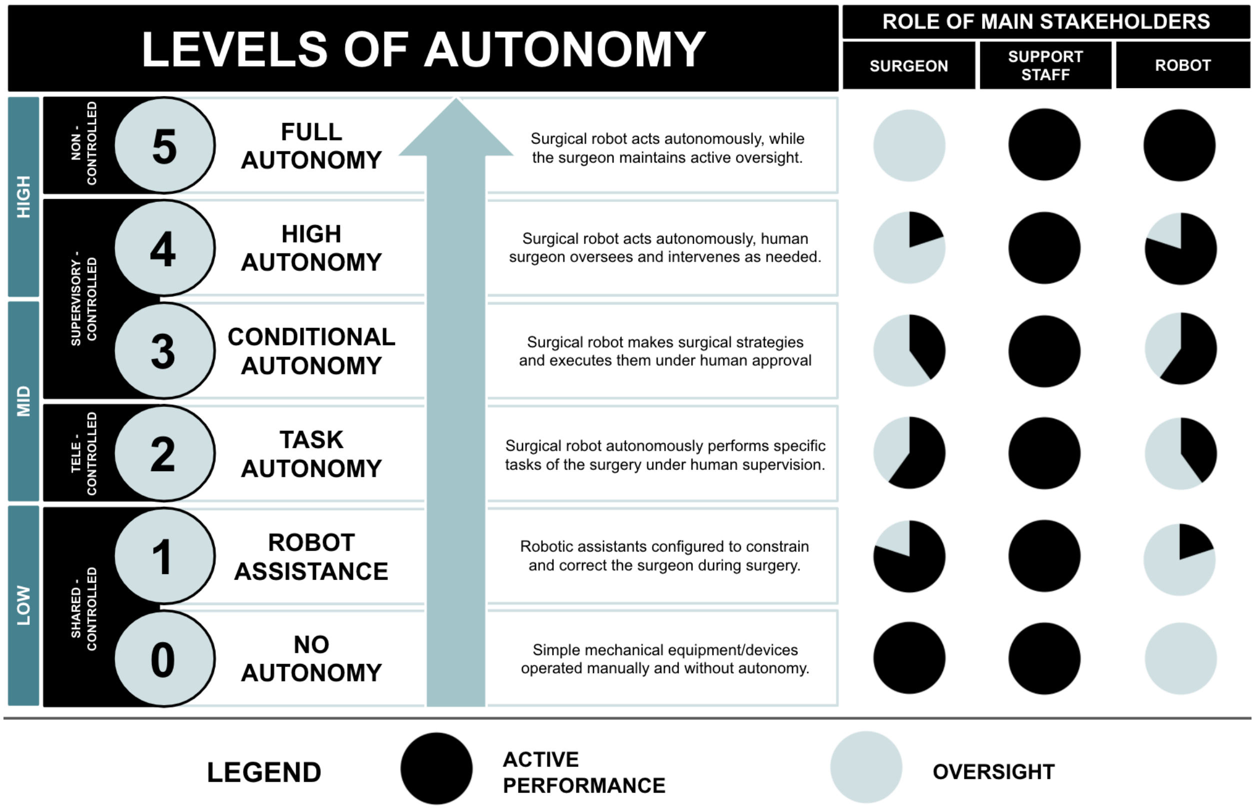

Fig 1. Autonomy levels and the role of humans in robot surgeries

Today, most surgical robots are at level 3 (conditional autonomy). Researchers are working on hands-free robots to conduct soft tissue surgeries on animals such as pigs (3), although fully autonomous surgical robots (level 5) are far from reality. However, it seems that many equipment-related failures reported in surgical procedures can be attributed to humans, including incorrect configuration and settings, encouraging research to remove humans from the surgery equation altogether (4, 5). This brings up the worry that human oversight will decrease if robot autonomy continues to increase (1). However, what decreases is not *human oversight*, if we understand *oversight* as *overseeing*, i.e., 'supervise (a person or their work).' With progressive robot autonomy, the human surgeons' active *performance* decreases while in parallel their *oversight* increases. Moreover, since autonomous robotic platforms rely heavily on sensory data, the medical support staff's role will remain integral and crucial for many functions ranging from patient positioning to port placement. Therefore, humans will not be eliminated in highly automated surgical procedures, but will continue to participate actively in either performance, oversight, or support.

What the future holds for surgery automation is a complex interplay between humans and robots where the roles and responsibilities will blur. In such a complicated ecosystem that involves different actors (including the hospital and the manufacturer), various degrees of robot autonomy, and an adaptive role of humans (human surgeons, support staff) to surgery automation, understanding where faults or errors originated, determining causality, and attributing responsibility will be challenging (6).

This is particularly relevant because, despite the advances and benefits that surgery robots may bring to society, systems that exercise direct control over the physical world can cause harm in a way that humans cannot necessarily anticipate, control, or rectify (7). For instance, safety issues such as injury or death may arise if surgery robots power down mid-operation, operate unintendedly, or if pieces of the surgical tools fall into the patient's body (4). Thus, no matter how efficient a robot is, it is unlikely that human oversight will decrease if safety is meant to be ensured in highly-automated surgeries (8). This nuance is essential to avoid ascribing or extending responsibility to the surgical robot, which the literature has repeatedly highlighted as a legitimate course of action in complex robotic ecosystems (9).

Understanding the role of humans in robotic surgeries is essential to understand better who is responsible if something goes wrong. The iRobotSurgeon project, for instance, surveyed whether society perceives human surgeons as responsible for harms when robots become more autonomous (10). Efforts like this are essential because even in the most advanced surgical environments, surgeons and their teams still perform multiple functions without a clear understanding of who holds responsibility. Therefore, an optimal framework on the use of surgery robots in which clear responsibilities are depicted is necessary to eliminate incongruity in procedural safety and avoid society from ascribing a disproportionate burden of responsibility to one stakeholder.

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