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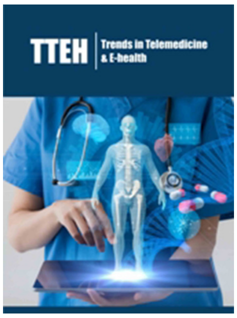

Tele-Robotic and Magnetic-Guided Neurovascular Interventions: Recent Advances and Clinical Implications

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Opinion

Recent advances in robotic and magnetically guided technologies have transformed the landscape of neurovascular intervention, offering novel solutions to longstanding limitations in precision, access, and safety. Tele-robotic systems enable remote manipulation of neurovascular devices, potentially expanding access to specialized care beyond tertiary centers while minimizing occupational radiation exposure for interventionalists. Concurrently, magnetic steering of guidewires and microcatheters is emerging as a key facilitator of distal vessel access in complex cerebrovascular anatomy [1]. Tele-robotic neurointerventional has been shown to be feasible in preclinical models with successful robotic navigation to target arteries under remote control. A recent experimental study demonstrated that operators could control steerable catheters and guidewires to reach the Middle Cerebral Artery (MCA) in a vascular model with high first-attempt success rates and minimal vessel wall contact, highlighting the potential for remote robotic navigation in neurovascular procedures [2].

Historically, the complexity of cerebral vasculature has limited the adoption of robotic platforms designed for coronary and peripheral systems. However, new platforms based on magnetic manipulation integrate a magnetically steerable guidewire with motorized linear drives and remote consoles to navigate narrow and tortuous cerebral arteries under real-time fluoroscopic imaging. These systems have been validated both *in vitro* with realistic neurovascular phantoms and *in vivo* in animal models, and have demonstrated capability for therapeutic procedures such as coil embolization and mechanical thrombectomy [3]. Despite these advances, key challenges remain. Telerobotic systems require robust low-latency network connectivity and optimized interfaces to ensure safe remote operation, especially for time-critical procedures like acute stroke intervention. Studies evaluating communication latency thresholds emphasize that delays beyond certain limits can significantly impact operator performance and procedural safety [4].

Additionally, loss of tactile feedback inherent to robotic platforms is a recognized limitation; however, current evidence suggests that structured visual feedback and advanced imaging integration can partially compensate for this deficit, and research into novel haptic feedback systems (e.g., ferrofluid-based designs) is underway to address this gap [5]. Magnetic guidance of soft guidewires and microcatheters represents a promising adjunct to robotic intervention by actively steering devices into target branches without excessive reliance on manual torque transmission. Magnetically responsive soft guidewires have shown improved navigation in tortuous vessels by leveraging external fields, potentially reducing the risk of vessel perforation and enhancing access to distal obstructions. Moreover, remote magnetic micro-robots and microfiber systems capable of precise embolic delivery are being developed, offering innovative approaches for super selective embolization in aneurysms and tumor vasculature, though clinical translation still faces material biocompatibility and tracking challenges [6]. Clinical evidence for robotic neurovascular interventions is expanding. Recent trials comparing robotic-assisted versus manual cerebral angiography report reduced operator radiation exposure with robotic systems, albeit with ongoing needs for workflow optimization [2]. With high technical success rates across a range of procedures including diagnostic angiography, aneurysm coiling, and carotid stenting, while acknowledging that manual assistance is still required in certain complex maneuvers [7].

In summary, tele-robotic and magnetically guided neurointerventional represents a significant evolution in endovascular therapy. These systems promise improved precision, expanded access to expert care, and enhanced safety for operators and patients alike. Future work should focus on clinical trials, advanced feedback integration, network optimization, and standardized training protocols before these technologies can be fully integrated into routine neurovascular practice.

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