

Abstract

Minimally invasive surgery (MIS) speeds recovery and lowers infection risk, but traditional tools struggle to move precisely through the body’s tight spaces. Magnetically Actuated Surgical Instruments (MASI) solve this by using outside magnets to steer small, wireless tools with high precision. This research examined 8 studies (2010–2025) on MASI used in abdominal, brain, blood-vessel, and MRI-guided surgery. Findings show MASI improve precision and safety, most strongly in abdominal surgery, while cost and tracking accuracy remain key challenges to wider clinical use.

Introduction

- Traditional MIS tools are rigid and struggle to navigate the body’s tight spaces.
- Magnetically Actuated Surgical Instruments (MASI) use external magnets to steer small, wireless tools with precision.
- Hypothesis: MASI improve surgical precision and safety over rigid tools, with electromagnetic systems trading higher cost for greater control than permanent magnets.
- Early designs relied on simple permanent magnets; newer systems add programmable electromagnetic control and real-time imaging.
- Precision matters most in high-risk areas like the heart, brain, and abdomen.
- This research compares MASI across four surgical domains to map where the technology stands.

Methods

- Systematic Literature review: Searched PubMed, IEEE Xplore, Scopus, and Google Scholar for studies published 2010–2025.
- 65 records identified → 8 studies met inclusion criteria (Figure 1).
- Each study reviewed for tool type, control method, target area, and safety/accuracy outcomes.
- Studies grouped into four surgical domains: gastrointestinal, neurosurgical, vascular, and MRI-guided.
- Common challenges noted: limited localization accuracy, tissue interference, and scarce real-world clinical evidence.

Results

- Gastrointestinal: a 50-patient trial showed a magnetic clip safely retracted the gallbladder; patients returned to work within 5 days.
- Neurosurgery: magnetic tools under 3.2mm performed brain biopsies in animals; no human trials yet.
- Vascular: needle-tracking accuracy as fine as 0.73mm was achieved.
- MRI-guided: electromagnetic motors operated safely inside a 3-Tesla scanner during live imaging (Figure 2).

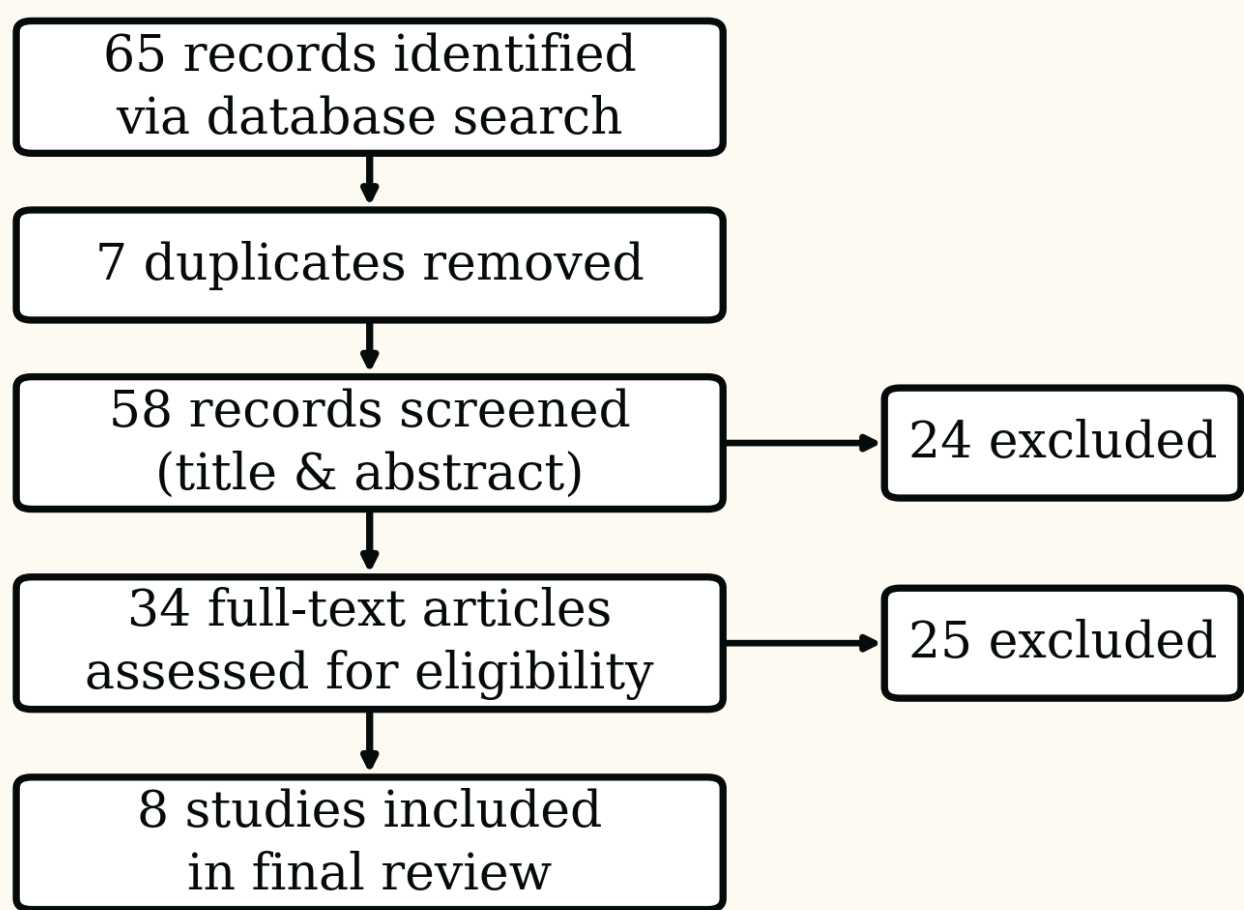


Figure 1. Study selection process (PRISMA-style flow).

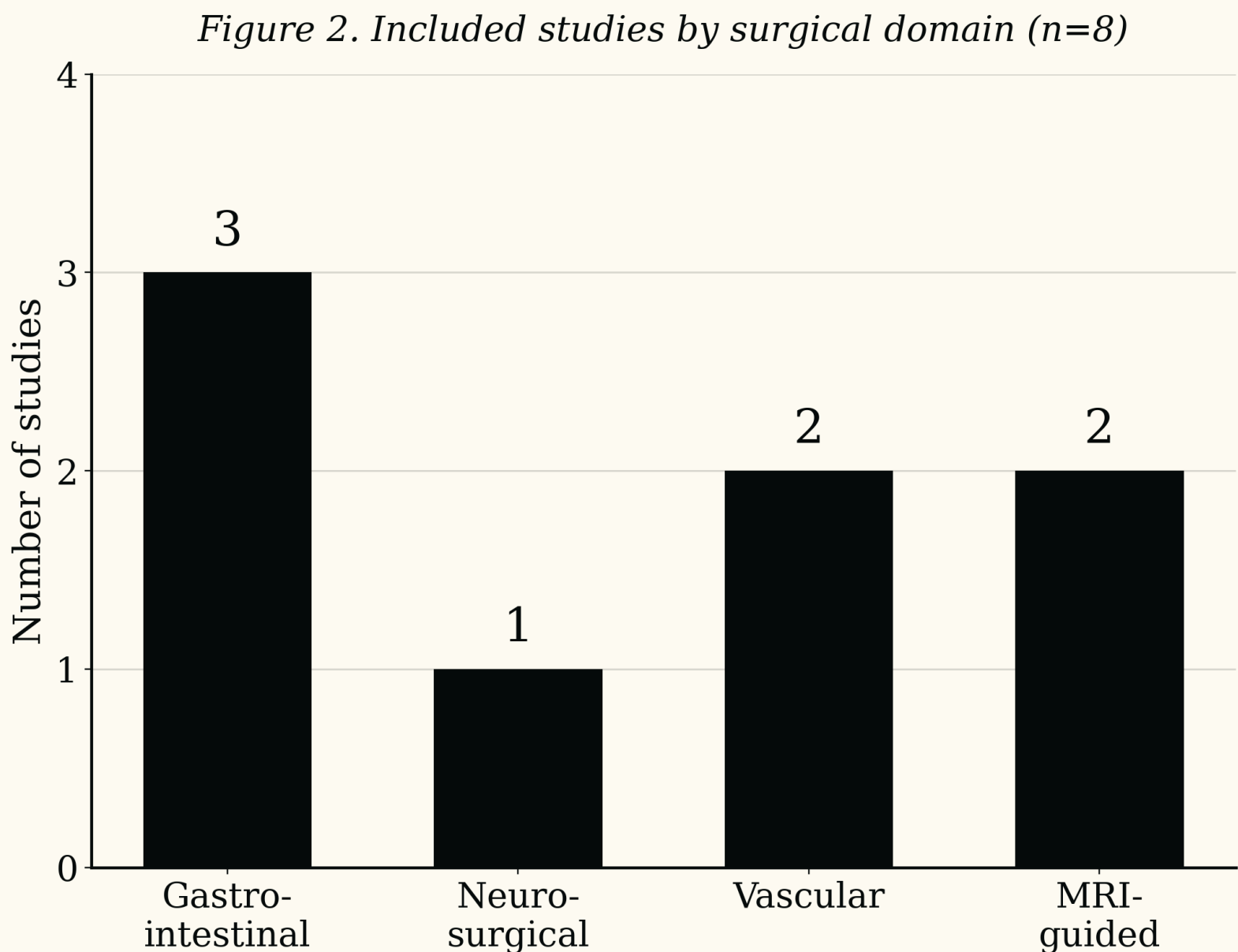


Figure 2. Included studies by surgical domain (n=8)

Discussion

- Permanent-magnet systems reached patients first, with a strong safety record in abdominal surgery.
- Their fixed magnetic strength limits fine, real-time control.
- Electromagnetic systems offer programmable, adjustable fields — better suited to neurosurgery and vascular work.
- Most neurosurgical and vascular tools are still tested only in models or animals.
- High equipment costs and imprecise tool tracking remain key barriers to adoption.
- Validates MASI improve surgical precision and safety over rigid tools, however, high costs continue to be a key challenge to adoption.

Conclusion

- MASI show real progress toward safer, more precise minimally invasive surgery.
- Gains are clearest in abdominal procedures, where clinical trials already exist.
- Electromagnetic systems hold the most promise for neurosurgery and vascular work but need more testing.
- Future work should focus on lower costs and better real-time tracking.
- Potential Future research: Magnetic tools are likely to become a key part of next-generation surgical robotics.

References

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