

Robotics in Surgery

The Recent Advances in Robotics

Dr. Ashfaq ul Hassan^{1*}, Dr. Muneeb Rashid Bhat², Dr. Iffat Khurshid³, Dr. Zarka Khursheed⁴, Dr. Arya Anil⁵

¹Professor and Head, Department of Anatomy SKIMS MCH Srinagar.

²Senior Resident, Department of Anatomy SKIMS MCH Srinagar.

³Senior Resident, Department of Anatomy GMC Udampur Jammu.

⁴Senior Resident, Department of Anatomy SKIMS MCH Srinagar

⁵Postgraduate DNB anatomy SKIMS MCH Anatomy.

*ashhassan@rediffmail.com

Abstract

Surgical robotics has reached a crossroads. Once dominated by a single proprietary ecosystem, the field now hosts a growing array of competing platforms, each bringing distinct engineering philosophies to the operating room. Over the past two years, the commercial launch of next-generation systems, the embedding of artificial intelligence into surgical workflows, and the first transcontinental remote procedures have collectively redefined what robotic-assisted surgery can achieve. This narrative review traces these developments from 2024 through 2026, examining the clinical, technological, and economic forces that are shaping the future of minimally invasive care.

Key words: Robotics, Surgeon, Invasive, Recent Advances

1. INTRODUCTION

Picture a surgeon sitting not at the bedside, but at a separate console in the operating room, peering into a stereoscopic viewer while their fingers guide tiny robotic instruments inside a patient's abdomen. Two decades ago, this arrangement was revolutionary. Today, it is commonplace in tertiary hospitals across North America, Europe, and parts of Asia. Yet the narrative of surgical robotics is entering a new phase—one that may prove more consequential than its origins.

For years, the field operated under what amounted to a single-vendor paradigm. One company's platform became so ubiquitous that "robotic surgery" and that brand name became nearly interchangeable in both clinical and public discourse. That era is ending. A wave of new entrants is challenging the established order with alternative designs, lower price points, and different assumptions about how surgeons should interact with machines. At the same time, artificial intelligence is evolving from a background analytical tool into a real-time surgical adjunct, and the dream of operating across vast distances—once demonstrated only in tightly controlled experiments—is now approaching clinical viability.

This review examines the most significant developments in surgical robotics from 2024 to 2026. It does not claim to be exhaustive; rather, it seeks to identify the trends that are most likely to influence clinical practice, healthcare economics, and patient outcomes in the coming decade.

2. THE HARDWARE RENAISSANCE: A MARKET NO LONGER DEFINED BY ONE NAME

2.1 Intuitive Surgical and the Evolution of the da Vinci Platform

Intuitive Surgical continues to command the largest share of the global surgical robotics market, with recent financial disclosures indicating first-quarter 2026 revenues of approximately \$2.77 billion, reflecting a year-over-year

increase of roughly 23%^[1]. This commercial dominance rests on an installed base built over more than twenty years, an extensive library of clinical outcomes data, and a comprehensive training infrastructure that has shaped how generations of surgeons have learned minimally invasive techniques.

The company's latest offering, the *da Vinci 5*, represents an incremental but meaningful advance over its predecessors, the Xi and X systems. Users of the new platform have noted that force-feedback capabilities at the instrument tip have been refined, giving operators a more nuanced sense of tissue compliance during dissection and suturing. The physical console has also been re-engineered with greater adjustability in armrest and monitor positioning, addressing the musculoskeletal complaints—particularly neck and shoulder strain—that have long affected surgeons during prolonged cases^[2]. Perhaps most notable from a data-science perspective is the introduction of *Case Insights*, an analytics module that captures kinematic and temporal data from completed procedures and generates individualized performance feedback. Rather than replacing human judgment, this tool aims to make surgeons more aware of their own operative patterns—where they hesitate, where they expend unnecessary motion, and where their technique has evolved over time^[2]. The trajectory of this technology suggests a future in which such feedback moves from retrospective analysis to real-time intraoperative guidance, though that transition remains on the development roadmap.

Independent comparative studies of the *da Vinci 5* remain sparse, as the platform is currently being introduced in a phased manner to high-volume centers. Early adopters have reported subjective improvements in tissue handling and workflow efficiency, but robust clinical trial data will be needed to substantiate these impressions^[3].

2.2 CMR Surgical and the Modular Alternative

Where Intuitive has pursued integration, CMR Surgical has pursued modularity. The *Versius* system, which gained FDA approval for adult gallbladder removal in October 2025, abandons the monolithic patient-side tower in favor of independent, wheeled robotic arms that can be arranged around the operating table as the procedure demands [2].

This architectural choice has practical implications that extend beyond aesthetics. Smaller operating rooms, increasingly common in ambulatory surgery centers, often cannot accommodate the footprint of a traditional multi-arm robotic tower. Versius addresses this constraint by allowing each arm to be positioned individually, reducing the spatial commitment required for robotic deployment. The console design also departs from convention: instead of an enclosed immersive viewer, the surgeon operates while looking at a 3D monitor and using joystick-style controllers. This open configuration has been credited with improving intraoperative communication between the console surgeon and the bedside assistant, a factor that may carry ergonomic benefits by reducing the isolation and postural strain associated with traditional console designs. The versatility of the platform has been demonstrated in an unexpected domain: pediatric surgery. In early 2025, a European surgical team used Versius to perform a pyeloplasty on an infant only four months old—the youngest patient yet treated with the system. The procedure employed 5-millimeter instruments, small enough to navigate the confined anatomy of neonatal and infant patients [4]. This case suggests that the barriers to robotic surgery in pediatric populations may be lower than previously assumed, provided that instrument miniaturization keeps pace.

2.3 Medtronic and the Hugo Entry

Medtronic's long-anticipated entry into soft-tissue robotic surgery materialized with the *Hugo Robotic-Assisted Surgery System*, which secured FDA clearance for urologic procedures in December 2025 [5]. The strategic positioning of Hugo is unmistakable: it is priced and designed to compete directly with the market leader while offering hospitals a migration path that does not require wholesale abandonment of established surgical workflows.

Like Versius, Hugo adopts a modular bedside architecture and an open console. Medtronic has emphasized lower capital expenditure and reduced per-procedure consumable costs as central selling points, making the platform particularly attractive to institutions in emerging markets and community hospital settings where budget constraints are acute. In October 2025, Medtronic launched a U.S. Investigational Device Exemption (IDE) study to evaluate Hugo in gynecological surgery, signaling broader specialty ambitions [6].

2.4 Regional Platforms and the Democratization of Access

The competitive landscape is no longer confined to North American and European manufacturers. In Hong Kong, Cornerstone Robotics has developed the *Sentire C1000*, a multi-arm platform intended to replicate the functionality of established systems at a reduced cost, with pilot trials underway for colorectal and urologic indications [3]. In

Japan, Medcaroid's *Hinotori* system has been adopted for rectal cancer resections and benefits from national health insurance coverage, substantially lowering out-of-pocket costs for patients [3]. MicroPort MedBot's *Toumai* system, developed in China, has reportedly accumulated over two hundred orders worldwide and is now commercially available across Asia and Europe [1]. Johnson & Johnson's *Ottava* system, submitted for FDA review in 2026, represents yet another major industrial entrant [1].

This diversification is unequivocally beneficial for the field. A competitive market incentivizes innovation, exerts downward pressure on pricing, and prevents any single entity from controlling the pace and direction of technological progress.

3. ARTIFICIAL INTELLIGENCE: FROM BACKGROUND ANALYTICS TO FOREGROUND ASSISTANCE

3.1 The Shift from Retrospective to Real-Time Intelligence

The integration of machine learning into surgical robotics has moved well beyond the automation of mechanical tasks. Researchers are now investigating *Visual Question Answering (VQA)* architectures capable of interpreting live endoscopic imagery and responding to surgeon queries regarding anatomical identification, pathological features, or procedural sequencing in real time [7]. Such systems function not as replacements for clinical reasoning but as accelerators of pattern recognition—compressing into seconds the experiential learning that would otherwise require years of practice.

In orthopedics, Stryker's *Mako Blueprint* platform illustrates how preoperative modeling can be leveraged to anticipate anatomical challenges and refine implant selection before the first incision [2]. Analogous approaches are being adapted for soft-tissue applications, where convolutional neural networks are trained to segment and classify critical structures—vessels, nerves, tumor margins—and flag potential injury zones before the surgeon encounters them.

3.2 Surgical Analytics and the Feedback Loop

The *Case Insights* module on the da Vinci 5 exemplifies a broader trend toward data-driven surgical improvement. By instrumenting the console to record kinematic variables—instrument trajectories, force profiles, temporal benchmarks—the system constructs a longitudinal portrait of individual surgical performance. Surgeons can interrogate this dataset to identify persistent inefficiencies, unnecessary tissue manipulation, or deviations from their own evolving baseline.

The stated long-term objective, acknowledged by the manufacturer, is to transition this capability from postoperative review to intraoperative suggestion—effectively creating an intelligent co-pilot that can prompt adjustments during the procedure itself [2]. This is not a trajectory toward autonomous surgery. It is, rather, an effort to augment human capability by embedding accumulated collective experience into the operative environment in real time.

4. TELESURGERY: THE GEOGRAPHY OF EXPERTISE IS CHANGING

4.1 Crossing the Atlantic

Of all the applications of surgical robotics, none captures the imagination quite like telesurgery—the remote performance of operative procedures across cities, countries, or continents.

In November 2025, a landmark was reached when a neurointerventional team completed the first transatlantic remote thrombectomy, extracting an intracranial clot while the operating surgeon remained on a different continent from the patient [4]. The technical significance of this achievement is considerable: it demonstrated that the latency inherent in long-distance data transmission can be managed sufficiently to preserve the precision required for neurovascular intervention. Earlier in the same year, Nanoflex Robotics had validated the concept using a magnetic navigation platform for in-vivo thrombectomy across the Atlantic, reinforcing the feasibility of remote expert care for time-critical vascular emergencies [8].

4.2 Policy Infrastructure for Remote Surgery

Recognizing the potential of this modality to address geographic inequities, the United Kingdom has announced a policy framework to establish national registries for robotic surgery data and to construct telesurgery networks beginning in 2029 [4]. These initiatives are essential because telesurgery is not merely a technical problem; it is a systemic one. It demands not only low-latency telecommunications but also robust cybersecurity, clear liability frameworks, and licensure agreements that accommodate cross-border practice. Without these structural supports, the technology will remain confined to experimental demonstrations.

5. EXPANDING THE FRONTIERS: NEW DOMAINS OF APPLICATION

5.1 Pediatric and Neonatal Surgery

Robotic surgery in children has historically been constrained by instrument size and the fragility of pediatric anatomy. Those constraints are loosening. At Johns Hopkins University, transoral robotic procedures are now performed on neonates as young as two weeks of age for pathologies including refractory sleep apnea and vascular malformations [4]. The availability of 5-millimeter instruments on newer platforms has been instrumental in enabling these applications, providing access to anatomical spaces that are inaccessible to conventional laparoscopic equipment.

5.2 Endoluminal and Natural Orifice Approaches

A growing emphasis on organ preservation and the minimization of surgical trauma has intensified interest in endoluminal robotics. The *EndoMaster EASE* platform, assessed in a phase II trial at Prince of Wales Hospital in Hong Kong, demonstrated an 86% technical success rate and a 94.6% rate of complete en bloc resection for colorectal endoscopic submucosal dissection, with no evidence of local recurrence at twenty-four months [3]. These findings suggest that robotic assistance may soon become standard for complex endoscopic resections that

currently exceed the capabilities of conventional flexible endoscopy.

Intuitive's *da Vinci SP* (Single Port) system extends this logic further, delivering a flexible 3D endoscope and three wristed instruments through a single 25-millimeter access channel. This design enables purely single-incision and transanal approaches for low rectal pathology, potentially sparing patients the morbidity associated with multi-port or open techniques [3].

5.3 Microrobotics and the Brain

The most speculative—and perhaps most transformative—frontier involves robots operating at scales invisible to the unaided eye. Robeaute, a French startup, is engineering a microrobotic device capable of traversing cerebral anatomy through natural pathways by sequential elongation and contraction, thereby minimizing iatrogenic tissue disruption [4]. Separately, investigators at Southern Methodist University and George Washington University have demonstrated magnetic-field-driven microrobots manipulated via a "magnetic tweezer" apparatus, while Symphony Robotics is collaborating with Monteris Medical on flexible micro-manipulators for the treatment of intracranial tumors and epileptic foci [4].

These technologies remain preclinical, but they embody a logical extension of the robotic premise: if mechanical precision can exceed human dexterity, then reducing the scale of the machine to the cellular or subcellular level may unlock interventions that are currently impossible.

6. CLINICAL OUTCOMES AND THE ECONOMIC REALITY

The clinical advantages of robotic-assisted surgery are increasingly well established. In prostatectomy cohorts from the UK National Health Service, robotic approaches have reduced median length of stay by approximately half, with a subset of patients discharged on the day of surgery [4]. In colorectal surgery, meta-analytic evidence indicates lower rates of conversion to open operation, fewer intraoperative complications, shorter hospitalization, and comparable or superior long-term functional and oncologic outcomes relative to standard laparoscopy [3].

Yet the economic calculus remains challenging. Capital acquisition costs, proprietary consumable pricing, and service contracts impose a substantial financial burden that has limited adoption in resource-constrained environments and generated ongoing debate about cost-effectiveness in publicly funded health systems. The emergence of lower-cost alternatives—Versius, Hugo, and the Sentire C1000 among them—together with secondary markets for refurbished equipment, offers a partial corrective. If robotic surgery is to realize its potential as a global standard of care, it must become economically accessible not only to wealthy academic centers but also to district hospitals and clinics in low- and middle-income countries,

7. PERSISTENT CHALLENGES AND UNRESOLVED QUESTIONS

Cost and accessibility

The upfront and recurring costs of robotic platforms remain prohibitive for many health systems, particularly in

low- and middle-income nations where the unmet burden of surgical disease is greatest [7].

Training and credentialing

Robotic proficiency requires structured, simulation-based curricula that extend beyond traditional apprenticeship models. The absence of globally standardized certification pathways remains a barrier to safe, equitable dissemination [7].

Ethical and legal frameworks

As artificial intelligence assumes a more active role in operative decision-making and as telesurgery dissolves geographic boundaries, questions of liability, informed consent, and jurisdictional malpractice become increasingly intricate [7].

Cybersecurity

Networked, cloud-dependent surgical systems are potential targets for malicious interference. Safeguarding these platforms is not merely an information technology concern; it is a direct patient safety imperative.

Evidence gaps

While short-term outcomes are generally favorable, long-term comparative effectiveness data across all specialties and demographic groups remain incomplete [7].

8. CONCLUSION

Surgical robotics has outgrown its origins as a niche technology for early adopters. It is now a mainstream modality, supported by a heterogeneous ecosystem of platforms, enhanced by artificial intelligence, and extended by remote connectivity into regions that have historically lacked access to specialist surgical expertise.

The machine is no longer simply an instrument in the surgeon's hand. It is becoming an intelligent collaborator in the operating room, a repository of accumulated procedural knowledge, and a bridge across geographic distance. Yet the ultimate measure of progress will not be the sophistication of the engineering, but whether these technologies can be deployed equitably, safely, and affordably to improve outcomes for patients everywhere.

The advances surveyed in this review suggest that such a goal is attainable. The question is no longer whether robotic surgery will reshape global healthcare, but how rapidly that transformation can be accomplished.

REFERENCES

1. Medtec China. (2026, May 14). Top 10 surgical robot companies in 2026. Medtec China. <https://en.medtecchina.com/media/show/top-10-surgical-robot-companies-2026/>
2. American Hospital Association. (2025, March 4). 3 ways robotic surgery is changing health care this year. AHA Center for Health Innovation Market Scan. <https://www.aha.org/aha-center-health-innovation-market-scan/2025-03-04-3-ways-robotic-surgery-changing-health-care-year>
3. Yeung, T. M., Lam, J. N. F., Lam, R. H. Y., & Ng, S. S. (2026). Global evolution of robotic colorectal surgery. *Cancers*, 18(8), 1259. <https://www.mdpi.com/2072-6694/18/8/1259>
4. Marks & Clerk. (2026, January 26). The rise of robot assisted surgery: Innovation, impact and IP. Marks & Clerk Insights. <https://www.marks-clerk.com/insights/latest-insights/102me3t-the-rise-of-robot-assisted-surgery-innovation-impact-and-ip/>
5. Medtronic. (2025, December 3). Medtronic announces FDA clearance of Hugo robotic-assisted surgery system for urologic surgical procedures [Press release]. <https://news.medtronic.com/2025-12-03-Medtronic-announces-FDA-clearance-of-Hugo-TM-robotic-assisted-surgery-system-for-urologic-surgical-procedures>
6. Medtronic. (2025, October 8). Medtronic initiates U.S. IDE clinical study evaluating Hugo robotic-assisted surgery system for gynecological procedures [Press release]. <https://news.medtronic.com/2025-10-08-Medtronic-initiates-U-S-IDE-clinical-study-evaluating-Hugo-TM-robotic-assisted-surgery-system-for-gynecological-procedures>
7. Journal of Surgical Research. (2025, April 22). Navigating tomorrow: Trends, innovations, and challenges in robotic surgery. *Journal of Surgical Research*. <https://www.jsurgicalresearch.com/article/view/navigating-tomorrow-trends-innovations-and-challenges-in-robotic-surgery>
8. Surgical Robotics Industry Awards. (2026, June 17). Innovative start-up. Surgical Robotics Industry Awards 2026. <https://surgicalroboticsindustryawards.com/categories/innovative-start-up/>