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The Evolution of Minimally Invasive Surgery: From Candlelight to Artificial Intelligence

Miguel Vassallo Palermo[1], Kimberly Ordaz[2], Rhayniveth Sequera[2], Aquiles Ramon Molero Chacón[3], José Leonardo Morao Pompilli[3]*

[1]Profesor Titular de la Universidad Central de Venezuela. [2]Profesor Instructor Escuela de Medicina Luis Razetti, Venezuela Hospital Universitario de Caracas, Venezuela. [3]Hospital Universitario de Caracas, Distrito Capital, Venezuela.

**Corresponding author: Jose Leonardo Morao Pompilli.*

Abstract

Objective: To provide a historical account of the evolution of Minimally Invasive Surgery (MIS), from its origins to future perspectives with artificial intelligence (AI).

Methodology: A systematic review was conducted in PubMed using MeSH terms and keywords related to the history, technological development, and future trends of MIS.

Results: MIS evolved from diagnostic procedures with rudimentary instruments to the laparoscopic revolution in the late 20th century, which overcame initial skepticism. Subsequently, robotic surgery enhanced precision and ergonomics. Currently, AI and computer vision are emerging as disruptive technologies, offering decision support, augmented navigation, and objective skill assessment.

Conclusions: MIS represents a transformative surgical paradigm. Its trajectory, marked by technological innovation and overcoming barriers, outlines a future where the integration of AI and augmented reality will redefine the standards of safety, precision, and efficacy in the operating room.

Keywords: minimally invasive surgery; history of laparoscopy; robotic surgery; surgical innovation

Introduction

Since its inception, medicine has constantly sought to minimize surgical trauma, driven by the Hippocratic principle Primum non nocere (first, do no harm). This desire has been the driving force behind the development of minimally invasive surgery (MIS), a field that has evolved from experimental procedures to become established as a fundamental pillar of modern surgical practice [1]. Although its roots date back to instruments described by Susruta in India (800 and 600 BC) or Abulcasis (10th century), it was not until the 19th century that its development began to be formalized [2]. The evolution of MIS has been marked by technological milestones and the perseverance of pioneers who often faced skepticism from the medical community [2]. The true turning point occurred in the late 1980s with the advent of videolaparoscopy (1); Camran Nezhat was instrumental in this breakthrough, realizing that projecting the image onto a monitor not only improved the surgeon's ergonomics but also allowed the entire team to work together and freed up both of the surgeon's hands. This change sparked a true "laparoscopic revolution" [3]. Today, MIS is not only the treatment of choice for a wide range of pathologies, but it also continues to evolve [4]. Robot-assisted surgery, represented primarily by the Da Vinci system, is the most dynamic form of MIS, offering improved visualization, ergonomics, and precision [3]. On the horizon, artificial intelligence [AI] and computer vision [CV] promise the next major transformation, introducing decision support capabilities, skill assessment, and, ultimately, greater automation of surgical procedures [5]. This article aims to review the historical trajectory of MIS, from its origins and initial resistance, through the consolidation of laparoscopy, the robotic era, and its projection into a future where digital surgery, AI, and augmented reality will redefine the limits of what is possible in the operating room.

Methodology

A systematic review was conducted in the PubMed and Scopus databases, using the MeSH terms and keywords "history of laparoscopy" and "laparoscopic surgery," "robotic surgical procedures," and "surgical innovation" with Boolean operators "AND" and "OR." The primary inclusion criterion was relevance to historical milestones, technological development, and future trends in MIS. Original articles in English

or Spanish, systematic reviews, and review articles without a strict time limit were prioritized to capture the complete evolution, although emphasis was placed on publications from the last 10 years for the analysis of emerging technologies. Study selection and data extraction were performed by the authors.

The Pre-Endoscopic Era and Optical Foundations [Antiquity–19th Century]

The history of endoscopy is a chronicle of the search for light in dark cavities. Ancient civilizations already used tubular instruments to inspect body orifices. In ancient Rome, excavations in Pompeii revealed rectal and vaginal speculums dating back to 79 AD. However, the fundamental limitation of these early instruments was their dependence on natural light [3]. This obstacle began to be overcome in 1587, when Guilio Cesare Aranzi used a water bottle to focus light from an external source and inspect the nasal cavity [3]. However, Phillip Bozzini is considered the precursor to modern endoscopy, who in 1805 designed the "Lichtleiter" (light conductor), a device that used a candle and mirrors to illuminate cavities. Although his invention was met with skepticism and censored by the Vienna Medical School for "undue curiosity," it laid the conceptual foundations for the future [6, 8]. The 19th century witnessed numerous innovations. In 1878, Maximilian Nitze, in collaboration with the manufacturer Joseph Leiter, developed the first cystoscope with an internal light source: an electrically heated incandescent platinum filament. However, thanks to Edison's invention of the light bulb in 1879, a paradigm shift was achieved, allowing for much safer and more effective illumination [3].

The era of laparoscopic diagnosis and the slow therapeutic transition (1901-1970)

At the beginning of the 20th century, closed-cavity endoscopy became a reality. In 1901, Georg Kelling, considered the "Father of Laparoscopy," performed the first "celioscopy" on a dog, using a modified Nitze cystoscope and insufflating filtered air to create a working space (pneumoperitoneum), thus marking the birth of diagnostic laparoscopy [6]. Shortly thereafter, in 1910, Hans Christian Jacobaeus independently coined the term "Laparothoracoscopy" and applied the technique to humans. That same year, Bertram Bernheim of Johns Hopkins Hospital introduced laparoscopy in the United States, calling it "organoscopy" and using a proctoscope for his examinations [7]. For decades, laparoscopy remained primarily a diagnostic tool. In 1929, German gastroenterologist Heinz Kalk, known as the "father of modern laparoscopy," developed a laparoscope with a 135° lens system and the double-trocar technique, laying the foundation for therapeutic laparoscopy [7]. In the United States, internist John Ruddock popularized the procedure in the 1930s, publishing a series of 500 cases of "peritoneoscopy" in 1937, including the first laparoscopic biopsies [7]. The transition to a therapeutic tool was slow and fraught with obstacles. Between the 1950s and 1970s, concerns about complications, such as intestinal injuries and burns during laparoscopic sterilizations, grew, even leading to a temporary ban on these procedures in Germany between 1956 and 1961 [8]. In 1971, gynecologist Harrith Hasson developed a safe method of abdominal entry using an open trocar that improved the safety of laparoscopy. Later pioneers such as Kurt Semm in Germany were crucial, developing the automatic CO_2 insufflator, irrigation-aspiration systems, and intracorporeal suturing techniques. However, despite his innovations, Semm encountered strong opposition.

The Laparoscopic Revolution [1980-1990]

Semm performed the first laparoscopic appendectomy in 1980 and was harshly criticized by the traditional surgical community [4]. The true "laparoscopic revolution" was unleashed in the late 1980s when Erich Mühe performed the first laparoscopic cholecystectomy in 1985 [6, 9]. The cholecystectomy technique was rapidly perfected and popularized in France and subsequently spread to the rest of the world, generating widespread adoption of modern minimally invasive surgery [4]. In the United States, development followed a parallel course when Barry McKernan in North Carolina performed his first laparoscopic cholecystectomy on June 22, 1988, dividing the cystic artery and duct between ligatures. Eddie Joe Reddick in Tennessee subsequently completed his first laparoscopic cholecystectomy in September of the same year using homemade laparoscopic instruments and a prototype clipper, establishing, together with McKernan, what is now known as the "American technique" [10]. The catalyst was the integration of the video camera, which, by projecting the image onto a monitor, democratized the view of the surgical field for the entire team and freed the surgeon's hands [8, 3]. The Robotic Era: Precision and Ergonomics (1990–present) Robotic-assisted surgery (RAS) is the most sophisticated evolution of the medical field.

Conclusion

Minimally invasive surgery has led one of the most profound transformations in the history of medicine. Its evolution from rudimentary visualization techniques to the sophistication of robotic surgery reflects a paradigm focused on reducing trauma, improving recovery, and optimizing clinical outcomes. Each phase of laparoscopy has overcome initial skepticism, demonstrating that technological innovation, when applied with rigor, redefines the standards of surgical practice. Although significant challenges remain—such as high costs and the need for specialized training with a steep learning curve—the clinical benefits for patients are undeniable. The future appears as a symbiosis between human skill and emerging technologies such as artificial intelligence and augmented reality, which do not aim to replace the surgeon but to enhance their capabilities, creating a safer and more personalized surgical ecosystem. The history of minimally invasive surgery, marked by the perseverance of its pioneers, suggests that overcoming initial barriers is often a prelude to widespread adoption, continuously redefining the limits of what is possible in the operating room.

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