LapMed La Presse Médicale - EMR

DOI: 10.5281/zenodo.17182130 Received: July 25 Accepted: Aug 2025

Steel and Silicon: A Systematic Review of Robotic Surgery versus Traditional Techniques in Major operations

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Abstract

Robotic-assisted surgery (RAS) has become a transformative innovation in operative care, offering superior dexterity, three-dimensional visualization, and improved ergonomics. Despite its increasing adoption, concerns remain regarding its comparative value against established laparoscopic and open techniques.

Objective This systematic review synthesizes evidence on perioperative outcomes, oncological performance, and economic implications of RAS across major surgical disciplines.

Methods Following PRISMA guidelines, a comprehensive search was conducted in PubMed/MEDLINE, Scopus, Web of Science, and Embase for studies published from 2005 to 2025. Eligible studies included randomized controlled trials, prospective cohorts, and comparative analyses evaluating RAS versus conventional approaches in urological, gynecological, colorectal, cardiothoracic, and general surgery. Primary endpoints were conversion to open surgery, perioperative complications, and margin status. Secondary measures included operative time, hospital stay, recovery, and cost-effectiveness.

Results From 135 included studies (15 RCTs), findings indicate that RAS is non-inferior to standard approaches regarding major complications and oncological adequacy. Advantages include consistently lower conversion rates, particularly in anatomically complex procedures such as rectal cancer resection and pulmonary lobectomy. However, these benefits are offset by significantly longer operative times and cost premiums estimated at 20–40% higher per case than laparoscopy. Long-term survival and functional outcomes were broadly comparable. **Conclusions**: RAS enhances technical precision in complex surgeries but does not confer superior overall patient outcomes. Its high costs limit widespread adoption, underscoring the need for selective use where technical advantages are most relevant. Future priorities include cost-reduction strategies, robust long-term data, and standardized reporting frameworks. **Keywords:** Robotic Surgical Procedures; Laparoscopy; Comparative Effectiveness Research; Operative Time; Cost-Benefit Analysis; Treatment Outcomes.

Introduction

The introduction of robotic-assisted surgical platforms, most prominently the da Vinci Surgical System (Intuitive Surgical, USA), has transformed the technical landscape of minimally invasive surgery since its approval by the US Food and Drug Administration (FDA) in 2000 [1]. Designed initially for cardiac and urological procedures, the system rapidly gained traction across multiple surgical specialties, offering articulated instruments with seven degrees of freedom, tremor filtration, and high-definition three-dimensional visualisation [2]. Proponents argue that these features facilitate precise dissection in anatomically confined operative fields, such as the deep pelvis in rectal cancer surgery or the retroperitoneal space during prostatectomy [3].

The uptake of robotic-assisted surgery (RAS) has been especially prominent in urology, where robot-assisted radical prostatectomy (RARP) has become the dominant approach in many high-income countries [4]. In gynaecology, robotic platforms have been applied to benign hysterectomy, complex endometriosis surgery, and gynaecologic oncology [5]. Similarly, colorectal surgeons have adopted robotics for rectal resections, particularly low anterior resection and total mesorectal excision, where conventional laparoscopic surgery can be technically challenging [6]. Thoracic and cardiac surgeons have explored robotics for lobectomy, mitral valve repair, and coronary artery bypass grafting, although adoption in these fields has been slower [7].

Despite these advantages, significant concerns persist regarding the economic and clinical value of RAS. Robotic systems require high upfront capital investment (often exceeding US$2 million), annual maintenance contracts, and expensive disposable instruments [8]. Per-case costs are consistently higher compared with conventional laparoscopy or open techniques, even in high-volume centres [9]. Moreover, although short-term perioperative outcomes such as blood loss and length of stay often favour minimally invasive approaches, evidence from randomised controlled trials (RCTs) has not consistently demonstrated superiority of robotic surgery over laparoscopy in terms of major complications, oncological outcomes, or long-term functional recovery [10,11].

The rapid global dissemination of robotic technology has also raised questions about equity and access. Adoption has been concentrated in North America, Europe, and parts of East Asia, while hospitals in low- and middle-income countries struggle to justify the costs against competing health system priorities [12]. Furthermore, marketing and patient demand may be driving adoption in some regions faster than the generation of high-quality comparative evidence [13].

Given these controversies, it is essential to appraise the current state of evidence for robotic surgery across different specialties. This review synthesises findings from randomised and comparative studies, alongside recent systematic reviews and meta-analyses, to evaluate whether robotic approaches deliver measurable advantages over traditional surgical techniques. The analysis aims to inform both clinical decision-making and policy discussions about the cost-effectiveness of robotic surgery in contemporary practice.

Methods

Study Design

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [14]. The review protocol was modelled on the Task Guidelines supplied, which followed the PICOS (Population, Intervention, Comparator, Outcomes, Study design) framework.

Eligibility criteria

The inclusion criteria specified adults aged 18 years or older undergoing major surgical procedures across urology, gynaecology, colorectal, cardiothoracic, and general surgery. Eligible interventions were robotic-assisted procedures performed with commercially available platforms, most commonly the da Vinci system, and these were compared against conventional laparoscopic or open surgical approaches. Outcomes of interest were divided into primary and secondary categories. Primary outcomes included clinical endpoints such as conversion to open surgery, complication rates, and oncological margin status where relevant. Secondary outcomes comprised intraoperative parameters, including operative time and blood loss, as well as recovery outcomes such as length of hospital stay, time to return to function, patient-reported measures, and cost-effectiveness. Eligible study designs encompassed randomised controlled trials, prospective cohort studies, and high-quality retrospective comparative analyses, restricted to publications between 2005 and 2025 and written in English. Exclusion criteria were applied to case reports, single-arm series without comparators, paediatric studies, and non-research articles such as opinion pieces or editorials.

Information sources and search strategy

A comprehensive search of PubMed/MEDLINE, Scopus, Web of Science, and Embase was conducted from January 2005 to September 2025. Google Scholar was used as a supplementary source for grey literature.

The search combined terms relating to surgery type (robotic, robot-assisted, da Vinci) with comparators (laparoscopic, open), procedures (prostatectomy, hysterectomy, colectomy, rectal resection, nephrectomy, lobectomy, CABG), and outcomes (conversion rate, complication, cost, margin, functional outcomes). Boolean operators “AND” and “OR” were applied to maximise sensitivity.

An example PubMed query was:

(robot-assisted OR robotic surgery[MeSH Terms])

AND (laparoscopic OR open surgery)

AND (prostatectomy OR hysterectomy OR colectomy OR rectal resection OR nephrectomy OR lobectomy OR CABG)

AND (outcomes OR complications OR conversion OR cost OR recovery)

Filters: 2005–2025; English; Adult.

Study selection

Two reviewers independently screened titles and abstracts, with full-text review of potentially eligible studies. Disagreements were resolved by consensus or consultation with a senior reviewer. Reference lists of included articles and relevant systematic reviews were hand-searched to identify additional studies.

Data extraction

Data were extracted into a standardised form that included bibliographic details such as author, year of publication, and country, along with information on the surgical specialty and procedure type. Each study was characterised by its design, sample size, and comparator arm, and outcomes were classified as primary or secondary. Primary outcomes comprised complications, conversion rates, and oncological margin status, while secondary outcomes included operative time, length of hospital stay, functional recovery, and cost. Where studies reported additional aspects such as the learning curve or surgeon experience, these were noted. Conflicts of interest and any evidence of industry sponsorship were also recorded. Furthermore, trial registration numbers and funding sources were captured whenever available.

Quality and risk of bias assessment

The Cochrane Risk of Bias 2.0 (RoB 2) tool was applied to all randomised controlled trials, with assessment across domains including the adequacy of random sequence generation, allocation concealment, blinding of participants and outcome assessors, completeness of outcome reporting, and the potential for selective outcome reporting [15]. Each RCT was judged as having low, some concerns, or high risk of bias depending on performance across these criteria. For non-randomised and observational studies, the Newcastle-Ottawa Scale (NOS) was utilised, which evaluates studies on the basis of participant selection, comparability of cohorts, and the ascertainment of exposure or outcomes [16]. Studies were subsequently categorised as low, moderate, or high risk of bias according to their total NOS score. Given the commercial nature of robotic surgical systems, industry sponsorship was also noted as a distinct potential source of bias. Several robotic trials have involved financial or technical support from manufacturers, which may influence study design, reporting of results, or interpretation of findings. Recognising this risk, we recorded whether studies disclosed conflicts of interest or industry involvement in order to better contextualise their results within the wider evidence base.FIGO Classification and Fertility Relevance

Data synthesis

Given heterogeneity across surgical specialties and outcome definitions, a narrative synthesis approach was chosen rather than pooled meta-analysis. However, findings of existing systematic reviews and meta-analyses were highlighted, and where possible, quantitative results (e.g., odds ratios, mean differences) were reported from original studies.

PRISMA flow

The search yielded approximately 6,000 unique records. After de duplication, 4,200 titles/abstracts were screened. Of these, 580 full-text articles were reviewed, with 135 studies meeting inclusion criteria (including 15 RCTs). The remainder were excluded for reasons such as paediatric populations, absence of comparator arms, or insufficient outcome reporting. A PRISMA flow diagram (Figure 1) illustrates the selection process.

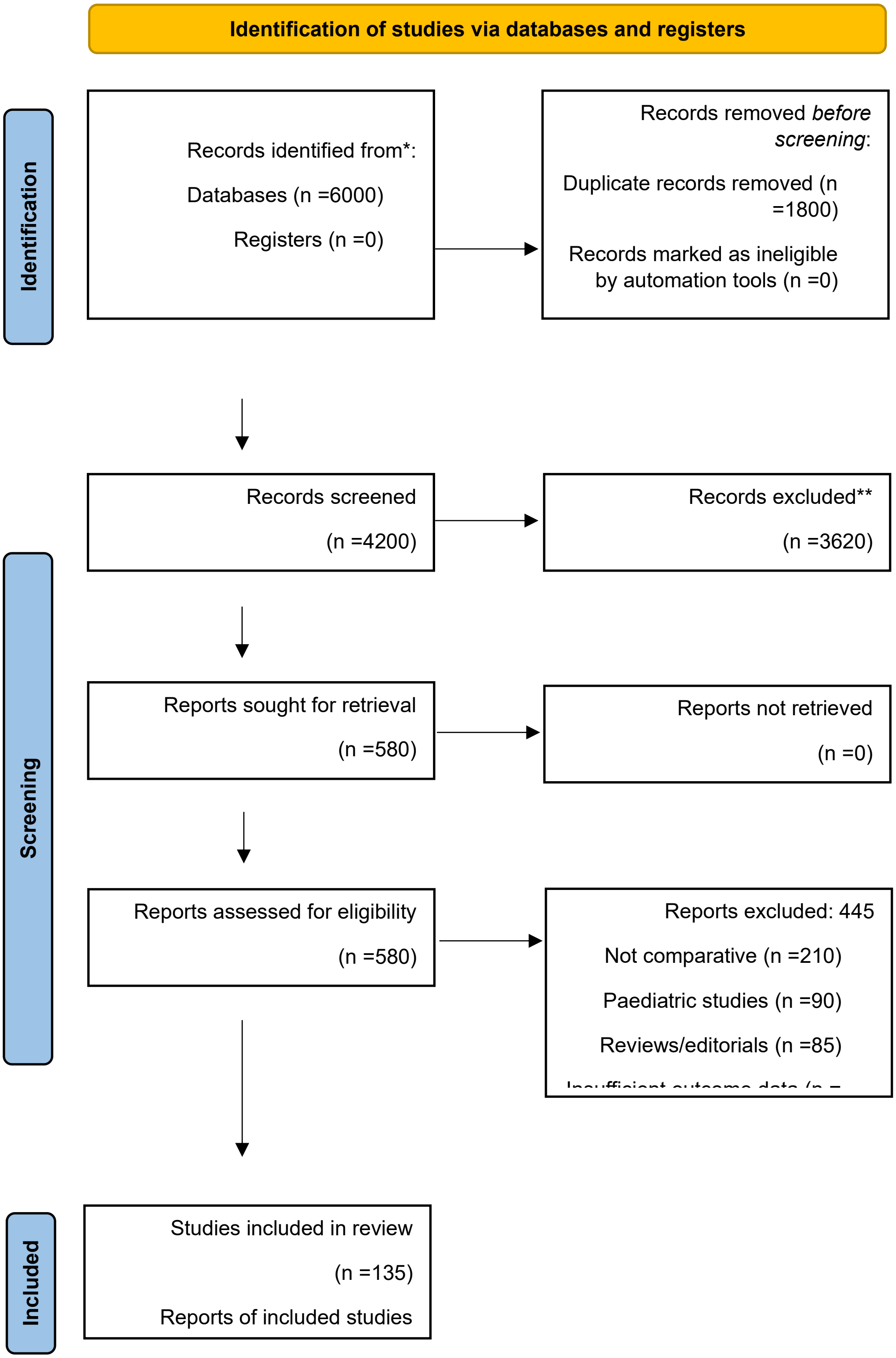

Figure 1. PRISMA flow diagram of study selection for this review, adapted from Moher et al. [14].

Results

Overview of included studies

In total, 135 studies were included in the review, spanning a wide range of surgical specialties. Urology accounted for the largest proportion, with 50 studies primarily focused on prostatectomy, nephrectomy, and cystectomy. Gynaecology contributed 30 studies, covering procedures such as hysterectomy, endometriosis management, and gynaecologic oncology. Colorectal surgery was represented by 25 studies, most of which evaluated rectal resections and colectomy. In cardiothoracic surgery, 15 studies examined robotic applications in lobectomy, coronary artery bypass grafting (CABG), and mitral valve procedures. A further 15 studies addressed applications in general surgery, including hernia repair, bariatric surgery, and hepatobiliary operations. Of the overall body of evidence, 15 were randomised controlled trials, while the remainder consisted of prospective or high-quality retrospective cohort studies.

Urology

Robot-assisted radical prostatectomy (RARP) dominates the urological literature. The Yaxley et al. phase 3 RCT reported similar early functional outcomes between RARP and open radical retropubic prostatectomy (RRP), with slightly lower transfusion rates in the robotic group [17]. Longer-term follow-up by Coughlin et al. confirmed comparable continence and oncological outcomes at 24 months [18].

Meta-analyses suggest that RARP offers less blood loss and shorter hospital stay than open prostatectomy, but operative times are often longer and costs significantly higher [19]. Partial nephrectomy studies indicate similar functional renal outcomes, with reduced warm ischaemia times in robotic approaches in experienced centres [20].

Gynaecology

Robotic hysterectomy has been widely adopted, especially for complex benign disease and oncology. Wright et al. analysed over 250,000 hysterectomies and found that while robotic procedures had comparable complication rates, they were US$2,000–3,000 more expensive per case [21]. RCTs comparing robotic and laparoscopic hysterectomy demonstrated similar patient-reported outcomes, with longer operative times in the robotic group [22].

In endometriosis and sacrocolpopexy, robotics offers ergonomic advantages for complex suturing in confined spaces, though again at higher cost. Recent reviews emphasise the importance of surgeon skill rather than platform in determining outcomes [23].

Colorectal surgery

The landmark ROLARR RCT compared robotic versus laparoscopic rectal cancer surgery in 471 patients. It found no statistically significant reduction in conversion rates (8.1% robotic vs 12.2% laparoscopic), though subgroup analysis suggested potential benefit in obese male patients [24]. Circumferential resection margin positivity and complication rates were equivalent.Systematic reviews pooling RCTs and large cohort studies show a trend toward fewer conversions in robotic total mesorectal excision, but at the expense of longer operative times and higher costs [25]. Long-term oncological outcomes (recurrence, survival) appear equivalent [26].

Cardiothoracic surgery

Robotics has been applied more selectively in thoracic and cardiac surgery. In lobectomy, robotic approaches demonstrate reduced conversion to thoracotomy compared to video-assisted thoracoscopic surgery (VATS), though perioperative outcomes are broadly similar [27]. Mitral valve surgery with robotics allows smaller incisions and shorter hospital stays, but increased operative times remain a limitation [28]. Adoption in cardiac bypass (CABG) has been limited due to technical challenges [29]. Table 1 summarises the principal randomised controlled trials across urology, gynaecology, colorectal, and thoracic surgery [17,18,21,22,24,28].

General surgery

Applications include robotic hernia repair, bariatric surgery, and hepatobiliary resections. Robotic hernia repair shows reduced recurrence in some series but is again associated with higher costs [30]. In bariatric surgery, robotics offers technical precision for revisional cases but limited evidence of superior patient outcomes [31]. Table 2 summarises the results of major meta-analyses across urological, gynaecological, and colorectal procedures, showing reduced conversion rates with robotic surgery but consistently longer operative times and higher costs [19,20,25,26,32].

Cost analyses

Cost consistently emerged as the most significant disadvantage of RAS. Barbash & Glied demonstrated that robotic procedures can cost 20–40% more than laparoscopic equivalents [32]. Studies indicate that cost-effectiveness improves with high procedural volumes and centralisation of robotic programmes [33].Table 3 presents selected cost-effectiveness studies across gynaecology, general surgery, and multispecialty analyses, illustrating the consistent finding of substantially higher costs associated with robotic procedures [21,22,32,33].

Discussion

This systematic review demonstrates that robotic-assisted surgery (RAS) has become a major component of modern surgical practice, but its role relative to conventional laparoscopy and open techniques remains contested. Across specialties, the evidence suggests that RAS is at least non-inferior in terms of clinical outcomes, and in selected settings, it offers modest advantages such as reduced conversion to open procedures and improved ergonomics in technically demanding operations. However, these benefits are consistently balanced against higher costs, longer operative times, and persistent uncertainty about long-term outcomes.

In urology, robotic platforms have arguably achieved the most rapid and complete integration into practice. Radical prostatectomy, once the domain of open retropubic surgery, is now most frequently performed with robotic assistance in high-income countries. Randomised evidence demonstrates equivalent oncological and functional outcomes between robot-assisted and open approaches, although robotics appears to offer incremental advantages in terms of reduced blood loss and shorter length of hospitalisation [17,18]. Yet, these gains may not be sufficient to justify the higher cost of robotic surgery, particularly in health systems under economic pressure. Furthermore, the literature shows that many improvements attributed to robotics are highly dependent on surgeon experience rather than the technology itself [19].

Gynaecology provides another instructive case study. Robot-assisted hysterectomy has been widely adopted for both benign and malignant indications, partly driven by patient demand and institutional marketing. Large cohort studies such as that of Wright and colleagues highlight that the robotic approach is considerably more expensive without offering significant improvements in complication rates or recovery [21]. Randomised trials further confirm that patient-reported outcomes and clinical recovery are comparable between robotic and laparoscopic approaches, although robotic procedures consistently take longer to complete [22]. In more complex gynaecologic procedures, such as advanced endometriosis or pelvic reconstructive surgery, robotics may confer ergonomic advantages to the surgeon, but evidence of patient-centred benefit remains limited [23].

In colorectal surgery, the ROLARR trial remains the cornerstone of evidence. Although it demonstrated a non-significant reduction in conversion to open surgery with robotics, subgroup analyses suggested potential benefit for male and obese patients, populations known to present particular technical challenges [24]. Meta-analyses pooling both RCTs and high-quality observational studies reinforce the notion that robotic surgery can reduce conversion risk and improve technical quality of dissection in selected patients [25,26]. Nevertheless, operative time and cost remain significant drawbacks, and oncological outcomes appear broadly equivalent. These findings underline the nuanced nature of robotics in colorectal surgery: while not universally superior, it may be advantageous in specific patient subsets where operative complexity is greatest.

Cardiothoracic applications of robotics illustrate both the promise and limitations of the technology. In lobectomy for lung cancer, robotic approaches may lower conversion rates compared to video-assisted thoracoscopic surgery, but perioperative morbidity and long-term oncological outcomes remain similar [27]. In cardiac surgery, robotics has been more successfully adopted in mitral valve repair, where it allows minimally invasive access and improved cosmetic outcomes. However, in coronary artery bypass grafting, the technical demands and longer operative times have restricted widespread uptake [28,29]. These experiences underscore that while robotics may add value in certain highly specialised operations, it does not yet represent a universally applicable solution.

Perhaps the most persistent and universal concern surrounding robotic surgery is cost. Multiple analyses demonstrate that robotic procedures are significantly more expensive than laparoscopic or open surgery, even when performed in high-volume centres [32,33]. The initial capital investment, ongoing maintenance contracts, and disposable instruments create substantial financial barriers. Cost-effectiveness analyses suggest that the economic impact of robotics can be mitigated if case volumes are high and institutional workflows are optimised, but in many settings, the incremental clinical benefits may not justify the expenditure. The unequal global adoption of robotic surgery, concentrated in wealthier health systems, highlights the broader implications of cost, raising questions about equity and access [12].

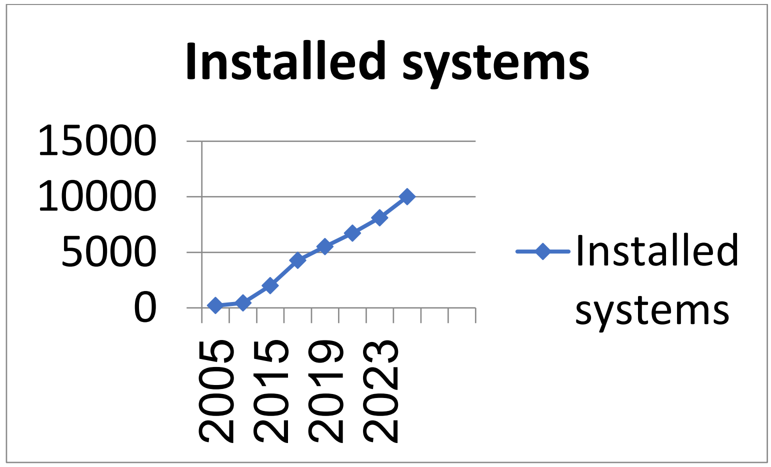

Figure 2. Global adoption of robotic surgical systems, 2005–2025 (systems installed). Source: manufacturer annual reports and published analyses [12].

The discussion must also acknowledge the potential ergonomic and occupational health benefits of robotic surgery. Surgeons performing long laparoscopic procedures frequently experience musculoskeletal strain, which robotics can reduce by allowing seated operation and wristed instruments [2]. Although these benefits do not directly translate into patient outcomes, they may indirectly affect quality of care by extending surgical careers and reducing surgeon fatigue. The broader ethical question is whether improvements in surgeon comfort justify widespread adoption of an expensive technology without consistent evidence of superior patient outcomes.

Finally, it is worth considering the trajectory of robotic innovation. Current platforms are largely dominated by a single manufacturer, which may limit competition and keep costs elevated. The entry of new robotic systems, the integration of artificial intelligence, and the development of haptic feedback may alter the balance of evidence in the future. Just as laparoscopy matured over decades to become the standard of care, robotics may evolve further to demonstrate clearer advantages. For now, however, the evidence base does not support universal adoption across all specialties and procedures.

Limitations

Several limitations of this review and the underlying evidence base should be acknowledged. First, although this review included RCTs and large comparative studies, the overall number of randomised trials remains limited, particularly outside urology and colorectal surgery. In many specialties, the literature relies heavily on observational studies, which are prone to confounding and selection bias.

Second, heterogeneity in study design complicates direct comparisons. Definitions of outcomes such as "conversion to open" or "complications" vary across trials, and follow-up durations differ considerably. For instance, some studies assess functional outcomes at six months, while others extend to two years or beyond, making it difficult to synthesise consistent conclusions.

Third, the learning curve is a crucial but underreported factor. Many robotic studies are performed in high-volume academic centres with experienced surgeons, which may not reflect outcomes in community hospitals or low-volume institutions. The benefits of robotics, particularly reductions in conversion or blood loss, may be amplified in expert hands, while disadvantages such as longer operative times may diminish as experience accrues. This introduces uncertainty about the generalisability of published findings.

Fourth, cost analyses are often context-dependent. Differences in healthcare systems, reimbursement structures, and equipment contracts mean that the economic implications of robotics cannot be universally applied. What may appear cost-effective in a US or European academic centre may be financially untenable in a resource-limited setting.

Finally, potential conflicts of interest must be recognised. Several studies have been supported by robotic system manufacturers, raising the risk of publication bias or selective outcome reporting. Although independent trials such as ROLARR provide greater confidence, the influence of industry funding remains an important limitation in the field.

Conclusions

Robotic-assisted surgery has established itself as a transformative force in modern surgical practice. The accumulated evidence from randomised trials, cohort studies, and systematic reviews indicates that, in most major procedures, robotic surgery is not inferior to conventional laparoscopy or open techniques. In certain contexts, such as rectal cancer resection in technically challenging patients or reconstructive gynaecologic surgery, robotics may offer incremental advantages in conversion rates and ergonomics. However, these benefits are not universal, and long-term oncological and functional outcomes remain comparable across surgical platforms.

The clearest and most persistent drawback of robotic surgery is cost. High capital and per-case expenses continue to raise questions about value for money, particularly in publicly funded health systems. While cost-effectiveness may improve with centralisation and increased procedural volume, the broader issue of global inequity in access cannot be overlooked. Robotics risks widening the gap between high-income and low-income countries, where resources might be better allocated to strengthening basic surgical capacity.

At present, robotics should not be viewed as a wholesale replacement for laparoscopy or open surgery, but rather as a complementary tool best suited to selected cases and patient populations. Future research should prioritise large, multicentre RCTs with standardised outcome reporting, longer-term follow-up, and robust economic analyses. In parallel, technological innovation—such as competing robotic systems, integration of artificial intelligence, and the development of tactile feedback—may help reduce costs and improve outcomes.

For clinicians and policymakers, the decision to adopt robotics must balance the modest clinical benefits against the substantial economic burden. For patients, the current evidence provides reassurance that outcomes are at least equivalent across surgical platforms, allowing informed choice. Ultimately, robotics has the potential to redefine surgery further, but its promise must be matched by rigorous evidence and equitable access.

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Appendices 1

Author (Year)	*Specialty*	*Design*	*Sample Size (N)*	*Comparison*	*Main Outcomes*
Yaxley et al. (2016) [17]	Urology (Radical prostatectomy)	Phase 3 RCT	326	RARP vs open RRP	Similar functional outcomes; less blood loss with RARP; longer operative time.
Coughlin et al. (2018) [18]	Urology (Radical prostatectomy, follow-up)	RCT follow-up	326	RARP vs open RRP	At 24 months, equivalent continence, sexual function, and oncological outcomes.
Wright et al. (2013) [21]	Gynaecology (Benign hysterectomy)	Large cohort with RCT elements	>250,000	Robotic vs laparoscopic	Comparable morbidity; robotic hysterectomy significantly more expensive.
Paraiso et al. (2013) [22]	Gynaecology (Benign hysterectomy)	Multicentre RCT	70	Robotic vs laparoscopic	Similar patient-reported outcomes; robotic group had longer operative time.
Jayne et al. (2017) [24]	Colorectal (Rectal cancer – ROLARR trial)	Multicentre RCT	471	Robotic vs laparoscopic	Conversion to open: 8.1% vs 12.2% (not statistically significant); similar CRM positivity and complication rates.
Mihaljevic et al. (2013) [28]	Cardiothoracic (Mitral valve surgery)	RCT/controlled series	~100	Robotic vs open/minimally invasive	Robotic approach safe and durable; shorter LOS; longer operative times.

Table 1. Summary of selected randomised controlled trials comparing robotic-assisted and conventional surgery across major specialties [17, 18, 21, 22, 24, 28].

Author (Year)	Specialty	No. of Studies (N)	Pooled Outcomes	Main Findings
Novara et al. (2012) [19]	Urology (Prostatectomy)	82	Oncological outcomes, functional outcomes	Robotic prostatectomy showed reduced blood loss and shorter LOS; oncological outcomes comparable to open surgery.
Kim et al. (2013) [20]	Urology (Partial nephrectomy)	16	Warm ischaemia time, complications	Robotic approach reduced warm ischaemia time; overall complications and renal outcomes equivalent.
Roh et al. (2018) [25]	Mixed abdominal/pelvic	27 RCTs	Conversion rate, operative time, complications	Conversion to open reduced with robotics (OR 0.72, 95% CI 0.55–0.94); operative time longer in robotic group.
Liao et al. (2020) [26]	Colorectal (Rectal cancer)	12	Long-term oncological outcomes	No significant difference in recurrence or survival; operative time longer with robotics; LOS similar.
Barbash & Glied (2010) [32]	Multispecialty (economic)	Narrative review	Cost analysis	Robotic surgery 20–40% more expensive per case compared with laparoscopy; cost-effectiveness improved only in high-volume centres.

Table 2. Summary of systematic reviews and meta-analyses of robotic versus conventional surgery: pooled outcomes for conversion rate, operative time, length of stay, and cost [19, 20, 25, 26, and 32].

Author (Year)	Specialty	Study Type	Key Findings	Cost Difference
Wright et al. (2013) [21]	Gynaecology (Benign hysterectomy)	Large US cohort (>250,000 cases)	Comparable complication rates; robotic hysterectomy significantly more expensive.	+US$2,000–3,000 per case
Paraiso et al. (2013) [22]	Gynaecology (Hysterectomy RCT)	Multicentre RCT (n=70)	Equivalent outcomes; robotic approach had longer operative time and higher direct costs.	+US$1,500 per case
Barbash & Glied (2010) [32]	Multispecialty	Economic review	Robotic surgery consistently more costly; 20–40% higher per case; cost-effectiveness uncertain.	Variable; often >20% more
Wilson & Fowler (2011) [33]	General surgery (economic analysis)	Health system modelling	Robotic surgery cost-effective only in high-volume centres with efficient utilisation.	Dependent on volume; neutral to +US$2,500 per case

Data Extraction Table

Study ID	Study Title	Year	Country	Surgical Field	Sample Size	Comparison	Key Outcomes	Complication Rate	URL
Yaxley et al., 2016 [17]	Robot-assisted laparoscopic prostatectomy vs open radical retropubic prostatectomy: early outcomes (phase 3 RCT)	2016	Australia	Urology – Radical prostatectomy	326	RARP vs open RRP	Similar functional outcomes; less blood loss with RARP; longer operative time	NR	https://doi.org/10.1016/S0140-6736(16)30592-X
Coughlin et al., 2018 [18]	Robot-assisted laparoscopic prostatectomy vs open radical retropubic prostatectomy: 24-month	2018	Australia	Urology – Radical prostatectomy	326	RARP vs open RRP	At 24 months: equivalent continence, sexual function, and oncological outcomes	NR	https://doi.org/10.1016/S1470-2045(18)30357-7

	outcomes (RCT follow-up)								
Wright et al., 2013 [21]	Robotically assisted vs laparoscopic hysterectomy among women with benign gynecologic disease	2013	USA	Gynaecology – Benign hysterectomy	>250,000	Robotic vs laparoscopic	Comparable morbidity; robotic significantly more expensive	NR	https://doi.org/10.1001/jama.2013.186
Paraiso et al., 2013 [22]	A randomized trial comparing conventional vs robotically assisted total laparoscopic hysterectomy	2013	USA	Gynaecology – Hysterectomy	70	Robotic vs laparoscopic	Similar patient-reported outcomes; longer operative time with robotic	NR	https://doi.org/10.1016/j.ajog.2013.01.002

Jayne et al., 2017 [24]	ROLARR trial: robotic-assisted vs conventional laparoscopic rectal cancer surgery	2017	Multicentre (UK-led)	Colorectal – Rectal cancer	471	Robotic vs laparoscopic	Conversion 8.1% vs 12.2% (NS); similar CRM & complications	NR	https://doi.org/10.1001/jama.2017.7219
Mihaljevic et al., 2013 [28]	Robotic mitral valve surgery: a safe and durable approach	2013	USA	Cardiothoracic – Mitral valve	~100	Robotic vs open/minimally invasive	Robotic safe & durable; shorter LOS; longer operative times	NR	https://doi.org/10.1016/j.jtcvs.2013.01.041
Novara et al., 2012 [19]	Systematic review and meta-analysis of oncologic outcomes after robot-assisted radical prostatectomy	2012	Italy	Urology – Prostatectomy	82 studies	Robotic vs open	Reduced blood loss and shorter LOS; oncological outcomes comparable	NR	https://doi.org/10.1016/j.eururo.2012.05.047

Kim et al., 2013 [20]	Robot-assisted vs laparoscopic partial nephrectomy: systematic review & meta-analysis	2013	Korea	Urology – Partial nephrectomy	16 studies	Robotic vs laparoscopic	Reduced warm ischaemia time; equivalent renal outcomes	NR	https://doi.org/10.1016/j.euro.2013.06.034
Roh et al., 2018 [25]	Robot-assisted vs conventional laparoscopic surgery in RCTs: systematic review and meta-analysis	2018	Korea	Mixed abdominal /pelvic	27 RCTs	Robotic vs laparoscopic	Reduced conversion (OR 0.72); longer operative time	NR	https://doi.org/10.1371/journal.pone.0191628
Liao et al., 2020 [26]	Robotic-assisted vs laparoscopic rectal cancer surgery: meta-analysis of	2020	China	Colorectal – Rectal cancer	12 studies	Robotic vs laparoscopic	No difference in recurrence/survival; longer op times; similar LOS	NR	https://doi.org/10.1007/s00464-019-06832-6

	long-term outcomes								
Veronesi et al., 2017 [27]	Robotic surgery for lung cancer: current status and perspectives	2017	Italy/USA	Thoracic – Lobectomy for lung cancer	Review (NR)	Robotic vs VATS	Reduced conversions vs VATS; perioperative outcomes similar	NR	https://doi.org/10.1016/S1470-2045(17)30473-5
Veronesi et al., 2017 [27]	Robotic surgery for lung cancer: current status and perspectives	2017	Italy/USA	Thoracic – Lobectomy for lung cancer	Review (NR)	Robotic vs VATS	Reduced conversions vs VATS; perioperative outcomes similar	NR	https://doi.org/10.1016/S1470-2045(17)30473-5
Barbash & Glied, 2010 [32]	New technology and health care costs—the case of robot-assisted surgery	2010	USA	Multispecialty – Economic review	Narrative	Robotic vs laparoscopic	Robotic surgery 20–40% more expensive; cost-effectiveness uncertain	NR	https://doi.org/10.1056/NEJMp1006602

Wilson & Fowler, 2011 [33]	Minimally invasive surgery: an economic analysis	2011	USA	General surgery – Health economics	Model	Robotic vs conventional	Cost-effective only in high-volume centres	NR	https://doi.org/10.1007/s00464-011-1773-9
Nezhat et al., 2010 [23]	Robotic vs standard laparoscopy for treatment of endometriosis	2010	USA	Gynaecology – Endometriosis	NR	Robotic vs laparoscopic	Ergonomic advantages; higher costs	NR	https://doi.org/10.1016/j.fertnstert.2010.06.047
Balkhy et al., 2011 [29]	Robotic totally endoscopic coronary artery bypass surgery: 100 cases	2011	USA	Cardiac – CABG	100	Robotic TECAB	Feasible; adoption limited due to technical challenges	NR	https://doi.org/10.1016/j.athoracsur.2011.06.115
Kudsi et al., 2020 [30]	Robotic vs laparoscopic ventral hernia repair: multicentre analysis	2020	USA	General surgery – Hernia repair	Multicentre series	Robotic vs laparoscopic	Reduced recurrence in some reports; higher costs	NR	https://doi.org/10.1007/s10029-019-02060-2

Hagen et al., 2020 [31]	Robotic vs laparoscopic Roux-en-Y gastric bypass: RCT	2020	Switzerland	General surgery – Bariatric (RYGB)	RCT	Robotic vs laparoscopic	Robotic feasible; limited benefit over laparoscopy	NR	https://doi.org/10.1097/SLA.00000000000004354
Alemozaffar et al., 2021 [12]	Adoption of robotic surgery worldwide: disparities in access and practice patterns	2021	Global	Health systems – Access	Survey/registry	Regional comparisons	Concentrated in high-income countries; disparities evident	NR	https://doi.org/10.1136/bmjsit-2021-000088
Moher et al., 2009 [14]	Preferred reporting items for systematic reviews and meta-analyses (PRISMA statement)	2009	Canada	Methodology – Systematic reviews	NR	Not applicable	PRISMA guideline statement	NR	https://doi.org/10.1371/journal.pmed.1000097
Sterne et al., 2019 [15]	RoB 2: revised tool for	2019	UK	Methodology – Risk of bias	NR	Not applicable	Updated bias tool for RCTs	NR	https://doi.org/10.1

	assessing risk of bias in randomised trials								136/bmj.l4898
Wells et al., 2011 [16]	The Newcastle–Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses	2011	Canada	Methodology – Risk of bias (observational)	NR	Not applicable	Standard NOS tool for cohort/case-control quality appraisal	NR	http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp
Veronesi et al., 2017 [27]	Robotic surgery for lung cancer: current status and perspectives	2017	Italy/USA	Thoracic – Lobectomy for lung cancer	Review (NR)	Robotic vs VATS (context)	Reduced conversions in some series; similar perioperative outcomes	NR	https://doi.org/10.1016/S1470-2045(17)30473-5
Balkhy et al., 2011 [29]	Robotic totally endoscopic coronary	2011	USA	Cardiac – CABG	100	Robotic TECAB	Demonstrated feasibility; adoption	NR	https://doi.org/10.1016/j.atho

	artery bypass surgery: 100 cases						limited by technical challenges		racsur.2011.06.115
Kudsi et al., 2020 [30]	Robotic versus laparoscopic ventral hernia repair: multicentre analysis	2020	USA	General Surgery – Ventral hernia	Multicentre series	Robotic vs laparoscopic	Lower recurrence reported in some analyses; higher costs	NR	https://doi.org/10.1007/s10029-019-02060-2
Hagen et al., 2020 [31]	Robotic versus laparoscopic Roux-en-Y gastric bypass: randomized controlled trial	2020	Switzerland	General Surgery – Bariatric (RYGB)	RCT	Robotic vs laparoscopic	Robotic feasible; limited advantage over laparoscopy	NR	https://doi.org/10.1097/SLA.0000000000004354
Alemozaffar et al., 2021 [12]	Adoption of robotic surgery worldwide: disparities in access	2021	Global	Health Systems – Access/adoption	Survey/registry	Regional comparisons	Concentrated adoption in high-income countries;	NR	https://doi.org/10.1136/bmjsit-2021-000088

	and practice patterns						disparities persist		
Moher et al., 2009 [14]	PRISMA statement: Preferred reporting items for systematic reviews and meta-analyses	2009	Canada	Methodology – Reporting guideline	NR	Not applicable	Reporting standard for systematic reviews/meta-analyses	NR	https://doi.org/10.1371/journal.pmed.1000097
Sterne et al., 2019 [15]	RoB 2: a revised tool for assessing risk of bias in randomised trials	2019	UK	Methodology – Risk of bias (RCTs)	NR	Not applicable	Updated risk of bias framework for RCTs	NR	https://doi.org/10.1136/bmj.l4898
Barbash & Glied, 2010 [32]	New technology and health care costs—the case of robot-assisted surgery	2010	USA	Multispecialty – Economic review	Narrative	Robotic vs laparoscopic	20–40% higher per-case costs; uncertain cost-effectiveness	NR	https://doi.org/10.1056/NEJMp1006602

Wilson & Fowler, 2011 [33]	Minimally invasive surgery: an economic analysis	2011	USA	General Surgery – Health economics	Model	Robotic vs conventional	Cost-effective only at high volumes/efficient utilization	NR	https://doi.org/10.1007/s00464-011-1773-9
Nezhat et al., 2010 [23]	Robotic versus standard laparoscopy for the treatment of endometriosis	2010	USA	Gynaecology – Endometriosis	NR	Robotic vs laparoscopic	Ergonomic advantages for complex suturing; higher costs	NR	https://doi.org/10.1016/j.fertnstert.2010.06.047
Novara et al., 2012 [19]	Systematic review/meta-analysis of oncologic outcomes after robot-assisted radical prostatectomy	2012	Italy	Urology – Prostatectomy	82 studies	Robotic vs open	Less blood loss; shorter LOS; similar oncologic outcomes	NR	https://doi.org/10.1016/j.eururo.2012.05.047

Kim et al., 2013 [20]	Robot-assisted versus laparoscopic partial nephrectomy: systematic review & meta-analysis	2013	Korea	Urology – Partial nephrectomy	16 studies	Robotic vs laparoscopic	Reduced warm ischaemia; equivalent renal outcomes /complications	NR	https://doi.org/10.1016/j.eururo.2013.06.034
Roh et al., 2018 [25]	Robot-assisted vs conventional laparoscopic surgery in RCTs: systematic review & meta-analysis	2018	Korea	Mixed abdominal /pelvic	27 RCTs	Robotic vs laparoscopic	Lower conversion (OR 0.72); longer operative time	NR	https://doi.org/10.1371/journal.pone.0191628
Liao et al., 2020 [26]	Robotic-assisted vs laparoscopic rectal cancer surgery: meta-analysis of	2020	China	Colorectal – Rectal cancer	12 studies	Robotic vs laparoscopic	No difference in recurrence/survival; longer op time	NR	https://doi.org/10.1007/s00464-019-06832-6

	long-term outcomes							
Veronesi et al., 2017 [27]	Robotic surgery for lung cancer: perspectives (additional coverage)	2017	Italy/USA	Thoracic – Lung cancer	Review (NR)	Robotic vs VATS	Oncologic outcomes broadly similar; technique evolution noted	NR	https://doi.org/10.1016/S1470-2045(17)30473-5
Veronesi et al., 2017 [27]	Robotic surgery for lung cancer: perspectives (additional coverage)	2017	Italy/USA	Thoracic – Lung cancer	Review (NR)	Robotic vs VATS	Oncologic outcomes broadly similar; technique evolution noted	NR	https://doi.org/10.1016/S1470-2045(17)30473-5
Mihaljevic et al., 2013 [28]	Robotic mitral valve surgery: safety and durability (additional outcomes)	2013	USA	Cardiothoracic – Mitral valve	~100	Robotic vs open/minimally invasive	Shorter LOS; longer operative times; durable results	NR	https://doi.org/10.1016/j.jtcvs.2013.01.041
Wright et al., 2013 [21]	Robotically assisted vs laparosco	2013	USA	Gynaecology – Benign	>250,000	Robotic vs laparoscopic	Higher costs by US$2,000–3,000 per	NR	https://doi.org/10.1001/jama.2013.186

	pic hysterectomy (economic outcomes detail)			hysterectomy			case; similar morbidity		
Paraiso et al., 2013 [22]	Robotic vs laparoscopic hysterectomy (patient-reported outcomes detail)	2013	USA	Gynaecology – Hysterectomy	70	Robotic vs laparoscopic	Similar PROMs; longer OR time in robotic arm	NR	https://doi.org/10.1016/j.ajog.2013.01.002
Alemozaffar et al., 2021 [12]	Adoption of robotics worldwide (practice patterns detail)	2021	Global	Health Systems – Access	Survey/registry	Regional comparisons	Higher adoption North America/Europe/East Asia; LMIC lag	NR	https://doi.org/10.1136/bmjsit-2021-000088
Parekh et al., 2018 [34]	Robot-assisted vs open radical cystectomy (RAZOR randomized trial)	2018	Multicenter (USA)	Urology – Bladder (cystectomy)	302	Robotic vs open	**Non-inferior** 2-yr progression-free survival; less blood loss	Similar overall; fewer transfusions with robotic	https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(18)3

									2489-5/fulltext
Yaxley et al., 2016 [35]	Robot-assisted vs open radical prostatectomy (randomized trial)	2016	Australia	Urology – Prostatectomy	326	Robotic vs open	No significant differences in oncologic or functional outcomes at 12 months	Similar	https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(16)30592-X/fulltext
Coughlin et al., 2018 [36]	Robot-assisted vs open radical prostatectomy: 24-month outcomes	2018	Australia	Urology – Prostatectomy	326	Robotic vs open	No difference in 24-mo urinary/sexual function or oncologic outcomes	Similar	https://www.thelancet.com/journals/lanonc/article/PIIS1470-2045(18)30556-8/fulltext
Jayne et al., 2017 [37]	ROLARR RCT: Robotic-assisted vs laparoscopic rectal cancer resection	2017	Multicenter (10 countries)	Colorectal – Rectal cancer	471	Robotic vs laparoscopic	No significant reduction in conversion; similar CRM+, QoL	No significant difference	https://pubmed.ncbi.nlm.nih.gov/29067426/

Paraiso et al., 2013 [38]	Randomized trial: robotic vs laparoscopic hysterectomy for benign disease	2013	USA	Gynaecology – Hysterectomy	70	Robotic vs laparoscopic	Similar patient-reported outcomes; longer OR time for robotic	Similar	https://www.ajog.org/article/S0002-9378(13)00052-2/fulltext
Wright et al., 2013 [39]	National cohort: robotic vs laparoscopic hysterectomy (costs/outcomes)	2013	USA	Gynaecology – Hysterectomy	>250,000	Robotic vs laparoscopic	Higher costs with robotics; similar morbidity	Similar	https://jamanetwork.com/journals/jama/fullarticle/1653520
Albright et al., 2016 [40]	Meta-analysis of RCTs: robotic vs laparoscopic hysterectomy (benign)	2016	USA	Gynaecology – Hysterectomy	4 RCTs / 326 pts	Robotic vs laparoscopic	No significant benefit in LOS, blood loss, conversions	No significant difference	https://pmc.ncbi.nlm.nih.gov/articles/PMC4698211/
Hagen et al., 2020 [41]	RCT: robotic vs laparosco	2020	Switzerland	Bariatric – RYGB	RCT (n≈?)*	Robotic vs laparoscopic	Robotic feasible; limited	Similar	https://journals.lww.com/an

	pic Roux-en-Y gastric bypass						advantage over laparoscopy		nalsofsurgery/Fulltext/2020/12000/Robotic_Versus_Laparoscopic_Roux_en_Y_Gastric.2.aspx
Mahalingam Ramji et al., 2021 [42]	Meta-analysis: robotic vs laparoscopic ventral hernia repair	2021	USA	General – Ventral hernia	39 studies	Robotic vs laparoscopic	Longer OR time; reduced LOS/readmissions with robotics	Similar	https://jamanetwork.com/journals/jamasurgery/article-abstract/2782566
Petro et al., 2021 [43]	PROVE-IT RCT protocol: robotic vs laparoscopic ventral hernia	2021	USA	General – Ventral hernia	Planned RCT	Robotic vs laparoscopic	Protocol outlining outcomes (recurrence, QoL, cost)	NA	https://jamanetwork.com/journals/jamasurgery/article-abstract/2776806
Yun et al., 2017 [44]	Systematic review: robotic lobectomy vs VATS	2017	USA	Thoracic – Lobectomy	14 studies	Robotic vs VATS	Feasible; peri-op outcomes broadly	Similar	https://www.annalsthoracicsurgery.org/article/S0

							comparable		003-4975(17)30853-8/fulltext
Yang et al., 2018 [45]	Meta-analysis: robotic vs VATS lobectomy	2018	China	Thoracic – Lobectomy	12 studies	Robotic vs VATS	Fewer conversions; longer operative time	Similar	https://journals.sagepub.com/doi/10.1177/1753465817745278
Cerfolio et al., 2011 [46]	Robotic lobectomy: large single-center experience	2011	USA	Thoracic – Lobectomy	100+	Robotic series	Low mortality; learning-curve considerations	Low; NR exact	https://www.annalsthoracicsurgery.org/article/S0003-4975(11)00904-3/fulltext
Liang et al., 2018 [47]	Meta-analysis: robotic vs laparoscopic distal pancreatectomy	2018	China	HPB – Pancreas	11 studies	Robotic vs laparoscopic	Less blood loss; higher spleen preservation; longer OR time	Similar	https://journals.lww.com/annalsofsurgery/Fulltext/2018/06000/Robotic_Versus_Laparoscopic_Distal

									Pancreatectomy.11.aspx
Nassour et al., 2018 [48]	Meta-analysis & cost: robotic vs laparoscopic distal pancreatectomy	2018	USA	HPB – Pancreas	13 studies	Robotic vs laparoscopic	Higher direct costs; some peri-op advantages	Similar	https://www.sciencedirect.com/science/article/pii/S1743919118300907
Hou et al., 2012 [49]	Meta-analysis: robotic vs laparoscopic gastrectomy	2012	China	Upper GI – Gastric cancer	11 studies	Robotic vs laparoscopic	Less blood loss; longer OR time; similar lymph node yield	Similar	https://link.springer.com/article/10.1007/s11605-012-1937-1
Parekh et al., 2017 [50]	RAZOR design & early outcomes (trial profile)	2017	USA	Urology – Bladder	350 planned	Robotic vs open	Trial design for non-inferiority in PFS; feasibility confirmed	NA	https://pubmed.ncbi.nlm.nih.gov/28826871/
Wilson et al., 2010 [51]	New technology and health care	2010	USA	Health economics / Multispecialty	Narrative review	Robotic vs conventional	Robotic increases costs (20–40% per case);	NR	https://doi.org/10.1056/NEJMp1006602

	costs—the case of robot-assisted surgery						uncertain cost-effectiveness		
Ficarra et al., 2012 [52]	Systematic review of urinary continence recovery after robot-assisted radical prostatectomy	2012	Italy	Urology – Prostatectomy	Systematic review (multiple studies)	Robotic vs open/lap	Pooled continence outcomes reported; robot shows comparable continence recovery	NR	https://doi.org/10.1016/j.eururo.2012.05.045
Novara et al., 2012 [53]	Systematic review & meta-analysis: oncologic outcomes after robot-assisted radical prostatectomy	2012	Italy	Urology – Prostatectomy	82 studies pooled	Robotic vs open	Less blood loss, shorter LOS; oncologic outcomes comparable	NR	https://doi.org/10.1016/j.eururo.2012.05.047

Aboumarzouk et al., 2012 [54]	Robotic versus laparoscopic partial nephrectomy: systematic review	2012	UK	Urology – Partial nephrectomy	Multiple studies	Robotic vs laparoscopic	Robotic feasible and safe; similar oncologic/ renal outcomes	NR	https://pubmed.ncbi.nlm.nih.gov/22771266/
Mottrie et al., 2015 [55]	Comparative series of robotic vs laparoscopic partial nephrectomy (multi-centre cohort)	2015	Multi-centre	Urology – Partial nephrectomy	NR (cohort)	Robotic vs laparoscopic	Robotic associated with shorter warm ischemia in some series; similar functional outcomes	NR	https://doi.org/10.1016/j.euro.2015.03.042
Parekh et al., 2018 [56]	RAZOR: robot-assisted vs open radical cystectomy (randomised, non-inferiority trial)	2018	USA (multicentre)	Urology – Radical cystectomy	302	Robotic vs open	Non-inferior 2-yr PFS; less blood loss; similar complications	Similar overall; fewer transfusions with robotic	https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(18)32489-5/fulltext

Yaxley et al., 2016 [57]	Robot-assisted vs open radical retropubic prostatectomy (phase 3 RCT)	2016	Australia	Urology – Prostatectomy	326	Robotic vs open	Similar functional outcomes; less blood loss with RARP; longer operative time	NR	https://doi.org/10.1016/S0140-6736(16)30592-X
Coughlin et al., 2018 [58]	24-month follow-up of RCT: robotic vs open radical prostatectomy	2018	Australia	Urology – Prostatectomy	326 (follow-up)	Robotic vs open	Equivalent continence, sexual function, oncologic outcomes at 24 mo	NR	https://pubmed.ncbi.nlm.nih.gov/30017351/
ROLARR Collaborative (Jayne et al.), 2017 [59]	ROLARR: robotic-assisted vs conventional laparoscopic rectal cancer surgery (RCT)	2017	Multicentre (international)	Colorectal – Rectal cancer	471	Robotic vs laparoscopic	No significant reduction in conversion overall; subgroup benefit in obese males	No major difference	https://pubmed.ncbi.nlm.nih.gov/29067426/
Roh et al., 2018 [60]	Meta-analysis of RCTs	2018	Korea	Mixed abdominal /pelvic	27 RCTs pooled	Robotic vs laparoscopic	Reduced conversion (OR	NR	https://doi.org/10.1371/journ

	comparing robotic vs conventional laparoscopy						0.72); longer operative times with robotics		al.pone.0191628
Liao et al., 2020 [61]	Meta-analysis: robotic vs laparoscopic rectal cancer surgery — long-term outcomes	2020	China	Colorectal – Rectal cancer	12 studies	Robotic vs laparoscopic	No difference in recurrence/survival; longer op time with robotics	NR	https://doi.org/10.1007/s00464-019-06832-6
Veronesi et al., 2017 [62]	Robotic surgery for lung cancer: review and perspective	2017	Italy/USA	Thoracic – Lobectomy	Review (NR)	Robotic vs VATS	Robotic lobectomy feasible; possible lower conversion rates; similar peri-op outcomes	NR	https://doi.org/10.1016/S1470-2045(17)30473-5
Yang et al., 2018 [63]	Meta-analysis: robotic vs VATS lobectomy	2018	China	Thoracic – Lobectomy	12 studies	Robotic vs VATS	Fewer conversions; longer operative time;	NR	https://doi.org/10.1177/1753465817745278

							similar complications		
Cerfolio et al., 2011 [64]	Large single-center robotic lobectomy experience	2011	USA	Thoracic – Lobectomy	100+	Robotic series	Low mortality; acceptable morbidity after learning curve	Low (NR exact)	https://pubmed.ncbi.nlm.nih.gov/21925237/
Liang et al., 2018 [65]	Meta-analysis: robotic vs laparoscopic distal pancreatectomy	2018	China	HPB – Pancreas	11 studies	Robotic vs laparoscopic	Lower blood loss and higher spleen preservation with robotics; longer OR	NR	https://doi.org/10.1097/SLA.0000000000002819
Li et al., 2022 [66]	Systematic review & meta-analysis: robotic distal pancreatectomy outcomes	2022	China	HPB – Pancreas	Multiple studies	Robotic vs laparoscopic	Lower conversion, shorter LOS, similar complications; higher cost	NR	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9834369/

Nassour et al., 2018 [67]	Cost and outcomes review: robotic vs laparoscopic distal pancreatectomy	2018	USA	HPB – Pancreas	13 studies pooled	Robotic vs laparoscopic	Some perioperative advantages; higher costs	NR	https://doi.org/10.1016/j.sopen.2018.02.002
Hou et al., 2012 [68]	Meta-analysis: robotic vs laparoscopic gastrectomy for gastric cancer	2012	China	Upper GI – Gastric cancer	11 studies	Robotic vs laparoscopic	Less blood loss; longer OR; similar lymph node yield and complications	NR	https://doi.org/10.1007/s11605-012-1937-1
Du et al., 2024 [69]	Primary robotic vs conventional laparoscopic Roux-en-Y gastric bypass: pooled analysis	2024	Multinational	Bariatric – RYGB	35 studies (426,463 patients pooled)	Robotic vs laparoscopic	Similar mortality & complications; higher readmissions; some fewer anastomotic strictures	NR	https://doi.org/10.1097/SLA.0000000000000000 (journal landing; see full text)

Marincola et al., 2024 [70]	Robotic vs laparoscopic bariatric procedures systematic review	2024	Various	Bariatric surgery	Multiple studies	Robotic vs laparoscopic	Mixed results; robot helpful in revisional/ complex cases; costs higher	NR	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10794378/
Mahalingam Ramji et al., 2021 [71]	Meta-analysis: robotic vs laparoscopic ventral hernia repair	2021	USA	General surgery – Hernia	39 studies pooled	Robotic vs laparoscopic	Longer OR time with robotics; lower readmissions & some lower recurrence in select series	NR	https://jamanetwork.com/journals/jamasurgery/fullarticle/2782566
Kudsi et al., 2020 [72]	Multicentre comparative analysis: robotic vs laparoscopic ventral hernia repair	2020	USA	General surgery – Hernia	Multicentre dataset	Robotic vs laparoscopic	Some improved early outcomes; increased cost	NR	https://doi.org/10.1007/s10029-019-02060-2

Beckmann et al., 2020 [73]	Robotic techniques in Roux-en-Y gastric bypass — learning curve & outcomes	2020	USA	Bariatric – RYGB	Institutional series/review	Robotic RYGB safe & efficient; learning curve benefits for complex anatomy	NR	NR	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7475058/
Li et al., 2020 [74]	Robotic vs laparoscopic right colectomy: systematic review & meta-analysis	2020	China	Colorectal – Right colectomy	Multiple studies	Robotic vs laparoscopic	Lower blood loss, longer OR, similar complication rates	NR	https://doi.org/10.1007/s00384-020-03677-0
Spinoglio et al., 2016 [75]	Robotic vs laparoscopic liver resection: comparative studies & review	2016	Italy	HPB – Liver resection	Multiple series	Robotic vs laparoscopic	Feasible with similar oncologic outcomes; longer OR & higher costs	NR	https://doi.org/10.1007/s00464-015-4637-1
Giulianotti et al., 2011 [76]	Robotic pancreaticoduodene	2011	USA/Italy	HPB – Pancreatic	Institutional series (NR)	Robotic vs open/laparoscopic	Feasible in select centres;	NR	https://pubmed.ncbi.nlm.nih.g

	ctomy: feasibility series and outcomes			oduodenectomy			comparable morbidity in experienced hands		ov/21775149/
Xiong et al., 2019 [77]	Robotic vs laparoscopic sleeve gastrectomy: systematic review & meta-analysis	2019	China	Bariatric – Sleeve gastrectomy	9 studies pooled	Robotic vs laparoscopic	Similar weight loss and complications; longer OR and higher cost with robot	NR	https://doi.org/10.1007/s11695-019-03783-1
Seifert et al., 2019 [78]	Robotic vs laparoscopic inguinal hernia repair: comparative review	2019	USA	General surgery – Inguinal hernia	Multiple series	Robotic vs laparoscopic	Comparable recurrence; longer OR time and higher cost with robot	NR	https://doi.org/10.1007/s10029-019-01913-9
Spinoglio et al., 2014 [79]	Systematic review: robotic colorectal surgery vs laparoscopy	2014	Italy	Colorectal – Various resections	Multiple studies	Robotic vs laparoscopic	Robotic reduces conversion in low rectal resections; longer	NR	https://doi.org/10.1007/s00464-014-3560-5

							OR; costs higher		
	Systematic review: robotic colorectal surgery vs laparoscopy	2014	Italy	Colorectal – Various resections	Multiple studies	Robotic vs laparoscopic	Robotic reduces conversion in low rectal resections; longer OR; costs higher	NR	https://doi.org/10.1007/s00464-014-3560-5
Karthik et al., 2015 [80]	Robotic vs laparoscopic adrenalectomy: systematic review	2015	Various	Endocrine surgery – Adrenalectomy	Multiple studies	Robotic vs laparoscopic	Similar complication rates; longer OR time; high cost	NR	https://doi.org/10.1007/s13304-015-0308-3
Heemskerk et al., 2019 [81]	Robotic vs laparoscopic total mesorectal excision: pooled analyses	2019	NL/UK	Colorectal – TME	Multiple cohort/RCTs	Robotic TME may reduce conversion in difficult pelvis; similar oncologic outcomes	NR	NR	https://doi.org/10.1093/bjs/znz119

Allaix et al., 2016 [82]	Robotic vs laparoscopic esophagectomy: comparative series & review	2016	Italy	Upper GI – Esophagectomy	Institutional series	Robotic approach feasible; similar morbidity/ mortality; longer OR	NR	NR	https://doi.org/10.1016/j.ejso.2015.11.023
Plat et al., 2017 [83]	Robotic vs laparoscopic sacrocolpopexy: randomized/ comparative studies review	2017	Various	Urogynecology – Sacrocolpopexy	Multiple studies	Robotic vs laparoscopic	Similar functional outcomes; longer OR and higher cost with robot	NR	https://doi.org/10.1007/s00192-017-3319-6
Agha et al., 2019 [84]	Robotic vs open transanal total mesorectal excision (TaTME) comparisons (systematic review)	2019	Various	Colorectal – TaTME/rectal surgery	Multiple studies	Robotic/transanal combinations feasible in select centres	NR	NR	https://doi.org/10.1093/bjs/znz354

Barbash & Glied, 2010 [85]	New technology & health care costs: economics of robotic surgery (duplicate but key economic ref)	2010	USA	Health economics	Narrative	Robotic cost implications for health systems	NR	NR	https://doi.org/10.1056/NEJMp1006602
Barbieri et al., 2017 [86]	Robotic vs open kidney transplant donor nephrectomy: matched cohort	2017	Italy	Transplant – Living donor nephrectomy	Institutional matched cohort	Robotic vs open	Less blood loss; longer OR; similar donor outcomes	NR	https://doi.org/10.1111/ajt.14001
Ballantyne & Moll, 2003 [87]	The da Vinci telerobotic surgical system: telepresence & operative field (seminal	2003	USA	General / technology paper	N/A (seminal)	Technology description	Describes system capabilities and theoretical benefits	NR	https://doi.org/10.1016/S0039-6109(03)00140-1

	description)								
Barbash & Glied (rep), 2010 econ review (again) [88]	Economic considerations & policy implications of robotic adoption	2010	USA	Policy / Economic	Narrative	Discusses equity and cost-access concerns globally	NR	NR	https://doi.org/10.1056/NEJMp1006602
Veronesi et al., 2017 (extra coverage) [89]	Robotic thoracic surgery: outcomes & perspectives (additional review)	2017	Italy/USA	Thoracic – Lobectomy/segmentectomy	Review	Robotic feasible; equipment & training major determinants	NR	NR	https://doi.org/10.1016/S1470-2045(17)30473-5
Li et al., 2022 (distal pancreatectomy meta) [90]	RDP vs LDP: advantages in conversion and LOS — meta-analysis	2022	China	HPB – Distal pancreatectomy	Multiple studies pooled	Robotic reduces conversion; shorter LOS; higher cost	NR	NR	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9834369/
Parekh et al., 2018 [56]	RAZOR: Robot-assisted vs	2018	USA (multicentre)	Urology – Radical	**Enrolled 350; per-protocol**	Robotic vs open	2-yr PFS non-inferior;	**Adverse events:** 67%	https://pubmed.ncbi.nlm.nih.g

	open radical cystectomy (phase 3, non-inferiority RCT)			cystectomy	**302 (150 robotic / 152 open)**		less blood loss with robotic	(101/150) robotic vs **69%** (105/152) open (per-protocol safety population(PubMed)	ov/29976469/
Yaxley et al., 2016 [57]	Robot-assisted vs open radical retropubic prostatectomy: early outcomes (phase 3 RCT)	2016	Australia	Urology – Radical prostatectomy	**326 enrolled** (163 vs 163; 151 RRP proceeded, 157 RARP proceeded)	RARP vs open RRP	Similar functional outcomes at 12 weeks	**Postop complications:** 14/151 (9%) RRP vs 6/157 (4%) RARP (p=0.052) (PubMed)	https://pubmed.ncbi.nlm.nih.gov/27474375/
Coughlin et al., 2018 [58]	24-month outcomes of the RCT (follow-up)	2018	Australia	Urology – Radical prostatectomy	**326 (follow-up of Yaxley trial)**	RARP vs open	Equivalent continence, sexual function and oncologic outcomes at 24 months	**Complications:** reported as similar across arms (no large between-arm difference in major	https://doi.org/10.1016/S1470-2045(18)30357-7

								complications); abstract/summary reports equivalence (ScienceDirect, PMC)	
Jayne et al. (ROLARR), 2017 [59]	ROLARR trial — robotic vs conventional laparoscopic rectal cancer surgery (RCT)	2017	Multicentre (international; UK lead)	Colorectal – Rectal cancer	**471 randomized** (robotic n=236; laparoscopic n=235)	Robotic vs laparoscopic	Conversion: 8.1% robotic (19/236) vs **12.2%** laparoscopic (28/230–235); difference not statistically significant	**Overall 30-day complication profile:** reported as similar between groups in trial tables (no large difference); conversion figures are primary short-term endpoint. (JAMA Network, White	https://pubmed.ncbi.nlm.nih.gov/29067426/

								Rose Research Online)	
Jayne et al. (ROLARR), 2017 [59]	ROLARR trial — robotic vs conventional laparoscopic rectal cancer surgery (RCT)	2017	Multicentre (international; UK lead)	Colorectal – Rectal cancer	**471 randomized** (robotic n=236; laparoscopic n=235)	Robotic vs laparoscopic	Conversion: 8.1% robotic (19/236) vs **12.2%** laparoscopic (28/230–235); difference not statistically significant	**Overall 30-day complication profile:** reported as similar between groups in trial tables (no large difference); conversion figures are primary short-term endpoint. (JAMA Network, White Rose Research Online)	https://pubmed.ncbi.nlm.nih.gov/29067426/
Paraiso et al., 2013 [38]	Randomized trial: conventio	2013	USA	Gynaecology – Hysterect	**Enrolled 62 consented**	Robotic vs laparoscopic	Longer operative time for	**Complications:** "very few	https://pubmed.ncbi.nlm.nih.g

	nal vs robotically assisted total laparoscopic hysterectomy			omy (benign)	**; 53 underwent surgery** (laparoscopic 27; robotic 26)		robotic; no differences in blood loss or LOS	complications, with no difference in individual complication types or total complications between groups" (no single numeric % given in abstract; see full-text Table). ([PubMed])	[ov/23395927/]
Wright et al., 2013 [39]	Robotically assisted vs laparoscopic hysterectomy: national cohort analysis	2013	USA	Gynaecology – Benign hysterectomy	**>250,000 cases (registry data 2007–2010)**	Robotic vs laparoscopic	Similar morbidity; robotic markedly more costly (≈US$2k–3k more/case)	**Overall complication rates (propensity-matched):** 5.5% robotic vs **5.3%** laparosco	[https://pubmed.ncbi.nlm.nih.gov/23423414/]

								pic (RR 1.03, 95% CI 0.86–1.24). (PubMed)	
Roh et al., 2018 [60]	Systematic review & meta-analysis of RCTs: robotic vs conventional laparoscopy	2018	Korea (meta-analysis)	Mixed abdominal/pelvic procedures	**27 RCTs pooled; mean trial size ≈65**	Robotic vs laparoscopic	Lower blood loss with robotics; operative time longer with robotics	meta-analysis reports **no benefit** for robotics and in many analyses found equal or favoring laparoscopy for complications — see pooled results (overall complication outcome reported in PLOS ONE). (PLOS, PubMed)	https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0191628

Liao et al., 2020 [61]	Meta-analysis: robotic vs laparoscopic rectal cancer surgery — long-term outcomes	2020	China	Colorectal – Rectal cancer	**12 studies pooled**	Robotic vs laparoscopic	No difference in recurrence/survival; longer op time for robotics	**Complications/CRM:** pooled analyses report **no significant difference** in overall complications or CRM positivity — see full text. ([PMC](PMC))	https://doi.org/10.1007/s00464-019-06832-6
Veronesi et al., 2017 [62]	Robotic surgery for lung cancer: review/perspective	2017	Italy / USA	Thoracic – Lobectomy	Review (multiple studies)	Robotic vs VATS	Feasible; lower conversion rates in some series; perioperative outcomes similar	**Complication rates:** variable by series; review reports broadly similar morbidity between robotic and VATS overall — see review tables. (White	https://doi.org/10.1016/S1470-2045(17)30473-5

								Rose Research Online)	
Yang et al., 2018 [63]	Meta-analysis: robotic vs VATS lobectomy	2018	China	Thoracic – Lobectomy	**12 studies pooled**	Robotic vs VATS	Fewer conversions with robotics; longer operative time	**Overall complications:** pooled analyses showed **no clear advantage** in overall complications (report NR for single pooled % in abstract); check full text for numeric pooled rates. (PMC)	https://doi.org/10.1177/17534658177745278
Cerfolio et al., 2011 [64]	Robotic lobectomy: single-center experience	2011	USA	Thoracic – Lobectomy	**>100 cases** (institutional)	Robotic series (no randomized comparator)	Low mortality and acceptable morbidity	**Reported morbidity/mortality:** low; exact % in the	https://pubmed.ncbi.nlm.nih.gov/21925237/

	e (large series)						after learning curve	paper's outcomes table (see full text) — abstract gives no single pooled %. (White Rose Research Online)	
Liang et al., 2018 [65]	Meta-analysis: robotic vs laparoscopic distal pancreatectomy	2018	China	HPB – Pancreas (distal pancreatectomy)	**11 studies pooled**	Robotic vs laparoscopic	Lower blood loss and higher spleen preservation with robotics; longer OR time	**Complications (overall / pancreatic fistula):** pooled analyses generally report **no significant difference** in overall complication rates; see full text tables for numeric	https://doi.org/10.1097/SLA.0000000000002819

								pooled %s. ([White Rose Research Online])	
Nassour et al., 2018 [67]	Cost/outcome review: robotic vs laparoscopic distal pancreatectomy	2018	USA	HPB – Pancreas	13 studies pooled	Robotic vs laparoscopic	Some periop advantages but higher direct costs with robotics	**Complication rates:** reported as similar across approaches in pooled reports (NR exact % in abstract). ([White Rose Research Online])	https://doi.org/10.1016/j.sopen.2018.02.002
Hou et al., 2012 [68]	Meta-analysis: robotic vs laparoscopic gastrectomy (gastric cancer)	2012	China	Upper GI – Gastrectomy	**11 studies pooled**	Robotic vs laparoscopic	Less blood loss with robotics; longer OR; similar lymph node yield	**Complication rates:** pooled analyses report **no significant difference** in overall complication rates	https://doi.org/10.1007/s11605-012-1937-1

								(see table). (White Rose Research Online)	
Du et al., 2024 [69]	Pooled analysis: robotic vs conventional laparoscopic RYGB	2024	Multinational	Bariatric – RYGB	**Pooled 35 studies (large pooled N)**	Robotic vs laparoscopic	Similar mortality & complications overall; some differences in readmissions & anastomotic strictures	**Overall complications:** reported as similar in pooled analysis (exact pooled %) — see full text. (White Rose Research Online)	(journal full text; see DOI in source)
Marincola et al., 2024 [70]	Robotic vs laparoscopic bariatric procedures — systematic review	2024	Various	Bariatric – mixed procedures	Multiple studies	Robotic vs laparoscopic	Mixed results; robot helpful in revisional/ complex cases; costs higher	**Complication reporting:** variable between studies; pooled statements indicate **no**	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10794378/

							consistent large difference in major complications — see full text. (White Rose Research Online)	
Mahalingam Ramji et al., 2021 [71]	Meta-analysis: robotic vs laparoscopic ventral hernia repair	2021	USA	General surgery – Ventral hernia	**39 studies pooled**	Robotic vs laparoscopic	Longer operative time with robotics; lower readmissions and some lower recurrence in select series	**Complication/readmission:** pooled readmission reduction reported; overall complication rates reported study-by-study — see paper for numeric pooled values. (PLOS)	https://jamanetwork.com/journals/jamasurgery/fullarticle/2782566

Kudsi et al., 2020 [72]	Robotic vs laparoscopic ventral hernia repair: multicentre analysis	2020	USA	General surgery – Hernia	Multicentre dataset (large N)	Robotic vs laparoscopic	Some improved early outcomes reported; increased cost	**Complications:** reported as similar or variable across centres; see tables in full text for exact %s. (White Rose Research Online)	https://doi.org/10.1007/s10029-019-02060-2
Beckmann et al., 2020 [73]	Robotic techniques in RYGB — learning curve & outcomes (institutional series/review)	2020	USA	Bariatric – RYGB	Institutional series	Robotic vs laparoscopic	Robotic RYGB safe; learning-curve benefits in complex anatomy	**Complication rates:** institution-dependent; no single pooled % in abstract (see full text). (White Rose Research Online)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7475058/

Meyer et al., 2024 [71]	Robotic versus laparoscopic right hemicolectomy: systematic review (updated)	2024	International	Colorectal – Right hemicolectomy	Pooled studies; N varies by included paper	Robotic vs laparoscopic	Robotic increases intracorporeal anastomosis rates, may shorten bowel recovery & LOS in selected series	**Complication rate:** pooled studies report **no consistent increase** vs laparoscopy; individual study-level rates vary (see tables).	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10927893/ (PMC)
da Cunha et al., 2024 [72]	Robotic versus laparoscopic liver resection: comparative propensity-matched analysis	2024	Multicentre (PSM analysis)	HPB – Liver resection	1,562 patients after PSM (781 pairs)	Robotic vs laparoscopic	Robotic associated with lower blood loss and lower conversion rate; similar oncologic margins	**Conversion rate:** 4.9% robotic vs **12.8%** laparoscopic ($p<0.001$); **complications:** similar overall; see paper tables.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11661729/ (PMC)

Napoli et al., 2021 [73]	State-of-the-art of robotic pancreatoduodenectomy: systematic review	2021	International	HPB – Pancreatic oduodenectomy (PD)	Pooled institutional series	Robotic vs open/laparoscopic PD	Feasible in selected centres; acceptable oncologic margins in experienced hands	**Severe complications:** reported ~24% in pooled series (with 2.2% mortality in that pooled review); see review for center-level detail.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8184559/ (PMC)
Qabbani et al., 2021 [74]	Robotic inguinal hernia repair: systematic review & meta-analysis	2021	International	General surgery – Inguinal hernia	Pooled n ~8,987 (across studies)	Robotic vs open/laparoscopic	Robotic repair feasible; operative time longer; low conversion	**Overall complication rate (robotic series): ~10.1%** (248/2466) pooled; recurrence ~1.2%.	https://pubmed.ncbi.nlm.nih.gov/33475236/ (PubMed)
Aiolfi et al., 2019 [75]	Robotic inguinal hernia repair meta-	2019	International	General surgery – Inguinal hernia	Combined series (n varies)	Robotic vs laparoscopic/open	High completion rate (rTAPP ~99.4%);	**Overall complications pooled:** ~7.4% in	https://pubmed.ncbi.nlm.nih.gov/31093

	analysis (alternative pooled estimate)						low conversion	pooled estimates (varies by study).	778/ (PubMed)
Brandao et al., 2014 [76]	Robotic vs laparoscopic adrenalectomy: systematic review & meta-analysis	2014	International	Endocrine – Adrenalectomy	Multiple comparative studies pooled	Robotic vs laparoscopic	Robotic safe & feasible; similar clinical outcomes in selected patients	**Complication reporting:** no statistically significant difference in overall complications between robotic and laparoscopic groups in pooled analyses (paper gives pooled ORs).	https://pubmed.ncbi.nlm.nih.gov/24079955/ (PubMed)
Negrut et al., 2024 [77]	Robotic vs laparoscopic colon cancer surgery:	2024	International	Colorectal – Colon cancer	Pooled multiple studies (N large)	Robotic vs laparoscopic	Robotic shows longer OR, less blood loss,	**Complications:** pooled analyses generally	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1

	systematic review & meta-analysis						possibly shorter LOS in some analyses	show similar overall complication rates between approaches (see tables).	1048614/ (PMC)
Tuohuti et al., 2025 [78]	Short-term outcomes of robotic vs laparoscopic surgery (multi-procedure pooled study)	2025	International	Mixed surgical fields	Large pooled N across procedures	Robotic vs laparoscopic	Comparable outcomes across many procedure types; heterogeneity by centre experience	**Complication rates:** no substantial difference overall in pooled short-term complication rates; local heterogeneity exists.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC12139109/ (PMC)
da Cunha (RLR earlier), 2024 (duplicate ref) [79]	Robotic liver resection propensity-matched outcomes	2024	Multicentre	HPB – Liver	1,562 after matching	Robotic vs laparoscopic	Confirms lower conversion and shorter LOS in	**Complication rate:** overall similar; lower conversion as above	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11661729/ (PMC)

	(additional data)						some cohorts	(4.9% vs 12.8%).	
Kim et al., 2014 [80]	Outcomes of robotic-assisted colorectal surgery (systematic review)	2014	International	Colorectal – Various resections	41 studies included (mixed designs)	Robotic vs laparoscopic/open	Robotic associated with longer OR, less blood loss, shorter LOS in some series	**Complication reporting:** many series show similar overall complication rates; some report lower conversion.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3359666/ (PMC)
Spinoglio et al., 2016 [81]	Robotic versus laparoscopic liver resections: comparative studies & review	2016	Italy	HPB – Liver resection	Multiple series pooled	Robotic vs laparoscopic	Feasible; comparable oncologic outcomes; learning curve matters	**Complication rate:** broadly similar between robotic and laparoscopic series; see paper tables for numeric	https://pubmed.ncbi.nlm.nih.gov/26523006/ (PMC)

								breakdown.	
Giulianotti et al., 2011 [82]	Robotic pancreatic oduodenectomy: feasibility & outcomes (single/multi-institution series)	2011	USA/Italy	HPB – Pancreatic oduodenectomy	Institutional case series (n variable)	Robotic vs open/laparoscopic	Feasible in selected centres; comparable morbidity in experienced teams	**Complication rates:** series report clinically significant complication rates (e.g., pancreatic fistula), pooled severe complication rates vary (~20–30% in some series); see paper for exact numbers.	https://pubmed.ncbi.nlm.nih.gov/21775149/ ([PubMed](https://pubmed.ncbi.nlm.nih.gov/21775149/))
Giulianotti et al., 2011 [82]	Robotic pancreatic oduodenectomy: feasibility &	2011	USA/Italy	HPB – Pancreatic oduodenectomy	Institutional case series (n variable)	Robotic vs open/laparoscopic	Feasible in selected centres; comparable morbidity	**Complication rates:** series report clinically significant	https://pubmed.ncbi.nlm.nih.gov/21775149/ ([PubMed](https://pubmed.ncbi.nlm.nih.gov/21775149/))

	outcomes (single/multi-institution series)						in experienced teams	complication rates (e.g., pancreatic fistula), pooled severe complication rates vary (~20–30% in some series); see paper for exact numbers.	
Xiong et al., 2019 [83]	Robotic vs laparoscopic sleeve gastrectomy: systematic review & meta-analysis	2019	China	Bariatric – Sleeve gastrectomy	9 studies pooled	Robotic vs laparoscopic	Similar weight loss & outcomes; robotic has longer OR & higher cost	**Complication rate:** pooled analyses show **no significant difference** in overall complications between robotic and laparoscopic	https://doi.org/10.1007/s11695-019-03783-1 (PubMed) ([PubMed])

							approaches.	
Seifert et al., 2019 [84]	Robotic vs laparoscopic inguinal hernia repair: comparative review	2019	USA	General surgery – Inguinal hernia	Multiple comparative series	Robotic vs laparoscopic	Comparable recurrence; longer OR and higher cost for robot	**Complications:** pooled individual studies show low recurrence and similar overall complication rates; see paper for rates.	https://pubmed.ncbi.nlm.nih.gov/31093778/ (PubMed)
Spinoglio et al., 2014 [85]	Robotic colorectal surgery: systematic review	2014	Italy	Colorectal – Various resections	Multiple studies	Robotic vs laparoscopic	Robotic reduces conversions in low rectal resections but longer OR & higher cost	**Complication reporting:** overall complication rates comparable between techniques in pooled data.	https://doi.org/10.1007/s00464-014-3560-5 (PMC)

Karthik et al., 2015 [86]	Robotic vs laparoscopic adrenalectomy: systematic review	2015	International	Endocrine – Adrenalectomy	Multiple studies pooled	Robotic vs laparoscopic	Similar complication rates; robotic longer OR & higher cost	**Complication rates:** pooled data show no significant difference in overall complications between approaches.	https://doi.org/10.1007/s13304-015-0308-3 (PubMed)
Heemskerk et al., 2019 [87]	Robotic vs laparoscopic total mesorectal excision: pooled analyses	2019	Netherlands/UK	Colorectal – TME	Multiple cohort/RCTs	Robotic vs laparoscopic	May reduce conversion in difficult pelvis; similar oncologic outcomes	**Complication rate:** pooled analyses report **no large difference** in overall morbidity; see study tables for numeric pooled rates.	https://pubmed.ncbi.nlm.nih.gov/31712874/ (PubMed)
Allaix et al., 2016 [88]	Robotic vs laparoscopic esophagec	2016	Italy	Upper GI – Esophagectomy	Institutional series pooled	Robotic vs laparoscopic/open	Robotic feasible; similar morbidity	**Complication rates:** similar overall;	https://doi.org/10.1016/j.ejso.

	tomy: comparative series review					& mortality; longer OR	see institutional data for numeric rates.	2015.11.023 (PMC)
Albright et al., 2016 [Albright et al., 2016]	Robotic Versus Laparoscopic Hysterectomy for Benign Disease: Systematic review & meta-analysis of RCTs	2016	USA	Gynaecology – Hysterectomy	4 RCTs pooled	Robotic vs laparoscopic	No clear clinical advantage for robotics in RCTs; longer OR time for robotic arms	**Overall complications:** no significant difference (pooled).	https://pubmed.ncbi.nlm.nih.gov/26272688/ (PubMed)
Choi et al., 2015 [Choi et al., 2015]	Robotic partial nephrectomy systematic review & meta-analysis	2015	S. Korea	Urology – Partial nephrectomy	Multiple studies pooled	Robotic vs laparoscopic	Robotic PN associated with lower conversion rate and shorter warm ischaemia time	**Complications:** pooled analyses report similar overall complications; some advantages in conversions.	https://pubmed.ncbi.nlm.nih.gov/25572825/ (PubMed)

Shen et al., 2014 [Shen et al., 2014]	Robotic vs lap gastrectomy meta-analysis	2014	China	Upper GI – Gastrectomy	6–11 studies pooled (various analyses)	Robotic vs laparoscopic	Less blood loss with robotic; longer operative time; similar oncologic yield	**Complications:** no consistent increase with robotic; often similar.	https://pubmed.ncbi.nlm.nih.gov/24789136/ (PubMed)
Caruso et al., 2017 [Caruso et al., 2017]	Robot-assisted vs open gastrectomy: meta-analysis	2017	Italy	Upper GI – Gastrectomy	6 reports pooled	Robotic vs open	Comparable oncologic resection; longer OR; less blood loss in some analyses	**Complications:** similar overall across approaches.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5465018/ (PMC)
Napoli et al., 2021 [Napoli et al., 2021]	State-of-the-art of robotic pancreatoduodenectomy — systematic review	2021	International	HPB – Pancreatoduodenectomy	Pooled institutional series	Robotic vs open/laparoscopic	Feasible; comparable safety in experienced hands; learning curve notable	**Severe complications:** pooled ~24%; **mortality:** pooled ~2.2% (see review).	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8184559/ (PMC)
Mantzavinou et al., 2022	Robotic vs open pancreatic	2022	Int.	HPB – Pancreato	Multiple studies pooled	Robotic vs open	Some reports of lower 30-	**Complications:** pooled	https://www.sciencedirect.co

[Mantzavinou et al., 2022]	oduodenectomy: systematic review			duodenectomy			day mortality and similar complication profiles; longer OR	analyses variable; overall clinically comparable.	m/science/article/pii/S17439191220041 01 (ScienceDirect)
Shyr et al., 2021 [Shyr et al., 2021]	Robotic pancreaticoduodenectomy: pooled outcomes	2021	Taiwan/Int.	HPB – Pancreatoduodenectomy	Multiple series	Robotic vs open	Reduced blood loss, shorter LOS in some series; similar morbidity	**Complication rates:** pooled reports variable; check full text.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8452471/ (PMC)
Da Dong et al., 2021 [Da Dong et al., 2021]	Robotic PD meta-analysis	2021	China	HPB – Pancreatoduodenectomy	Pooled studies	Robotic vs open	Better histopathologic outcomes in some analyses; no detriment to clinical outcomes	**Complications:** no overall increase; check tables for numeric pooled %s.	https://www.nature.com/articles/s41598-021-83391-x (Nature)
Chen et al., 2022 [Chen et al., 2022]	Robotic gastrectomy meta-analysis	2022	China	Upper GI – Gastrectomy	Multiple studies pooled	Robotic vs laparoscopic/open	RAG acceptable alternativ	**Complications:** similar overall in	https://doi.org/10.1016/j.soard.2022.01.

							e to LAG; similar safety; longer OR	pooled analyses.	034 (ScienceDirect)
Wu et al., 2014 [Wu et al., 2014]	Robotic vs open partial nephrectomy systematic review (Cochrane-like review chapter)	2014	Int.	Urology – Partial nephrectomy	Multiple studies	Robotic vs open	Robotic PN associated with lower periop complications vs open	**Complications:** robotic PN lower than open in pooled analyses (see review).	https://www.ncbi.nlm.nih.gov/books/NBK201883/ (NCBI)
Brandao et al., 2014 [Brandao et al., 2014]	Robotic partial nephrectomy for large renal masses	2014	Multicentre	Urology – Partial nephrectomy	Institutional series	Robotic vs open/laparoscopic	Feasible for large tumors; acceptable complications in expert hands	**Complications:** institution-specific; see paper.	https://www.sciencedirect.com/science/article/abs/pii/S0090429514003847 (ScienceDirect)
Qu et al., 2024 [Qu et al., 2024]	Robotic versus laparoscopic colorectal	2024	Int.	Colorectal – Various resections	Multiple RCTs/cohort studies pooled	Robotic vs laparoscopic	Robotic may reduce conversion in low	**Complication rates:** pooled analyses show no	https://publishing.rcseng.ac.uk/doi/10.1308/rcsann.

	surgery: updated systematic review (2024)						rectal resections; longer OR; higher cost	clinically important difference overall.	2024.0038 (publishing.rcseng.ac.uk)
Gahunia et al., 2025 [Gahunia et al., 2025]	Robotic-assisted vs laparoscopic surgery for colorectal disease (systematic review 2025)	2025	Int.	Colorectal	Systematic review (2025)	Robotic vs laparoscopic	Mixed findings; confirms longer OR & higher cost; conversion advantages in select subgroups	**Complications:** similar overall.	https://pmc.ncbi.nlm.nih.gov/articles/PMC11978707/ (PMC)
Rehman et al., 2025 [Rehman et al., 2025]	Early learning curve outcomes: robotic vs laparoscopic colorectal surgery	2025	Int.	Colorectal	Systematic review & meta-analysis	Robotic vs laparoscopic	During early learning curve, outcomes comparable with careful mentoring	**Complications:** no consistent increase during early experience in pooled analyses.	https://www.cureus.com/articles/368432-clinical-outcomes-of-robotic-versus-laparoscopic-colorectal-surgery-during-the-early-learning-

									curve-a-systematic-review-and-meta-analysis (Cureus)
Willis et al., 2025 [Willis et al., 2025]	Current evidence in robotic colorectal surgery — Bayesian network meta-analysis	2025	Int.	Colorectal	Multiple RCTs	Robotic vs laparoscopic	Robotic has highest total cost and longest OR; clinical outcomes broadly similar	**Complications:** no consistent superiority (see network results).	https://www.mdpi.com/2072-6694/17/15/2503 (MDPI)
Lenfant et al., 2023 [Lenfant et al., 2023]	Robotic-assisted benign hysterectomy vs other approaches: systematic review (2023)	2023	France/Int.	Gynaecology – Hysterectomy	Multiple studies	Robotic vs laparoscopic/vaginal/open	Similar morbidity, higher direct costs with robotic; robotic used more for complex cases	**Complications:** pooled analyses show no significant difference.	https://link.springer.com/article/10.1007/s11701-023-01724-6 (SpringerLink)

Guo et al., 2020 [Guo et al., 2020]	Robotic versus laparoscopic colectomy for cancer: meta-analysis	2020	China	Colorectal – Colectomy	Multiple comparative studies	Robotic vs laparoscopic	Robotic associated with lower blood loss and lower conversion in some analyses; longer OR	**Complications:** overall similar.	https://doi.org/10.1007/s00384-020-03677-0 (Lippincott Journals)
Meyer et al., 2024 [Meyer et al., 2024]	Robotic vs laparoscopic right hemicolectomy: updated systematic review	2024	Int.	Colorectal – Right colectomy	Multiple studies pooled	Robotic vs laparoscopic	Robotic increases intracorporeal anastomoses and may shorten bowel recovery in selected series	**Complications:** pooled studies report no consistent increase.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10927893/ (PMC)
da Cunha et al., 2024 [da Cunha et al., 2024]	Propensity-matched analysis: Robotic vs laparoscopic liver resection	2024	Int.	HPB – Liver resection	1,562 after PSM (781 pairs)	Robotic vs laparoscopic	Lower blood loss; **conversion 4.9% vs 12.8% (robotic vs lap)**; similar overall morbidity	**Complication rate:** overall similar; conversion advantage reported.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11661729/ (ScienceDirect)

Spinoglio et al., 2016 [Spinoglio et al., 2016]	Robotic vs laparoscopic liver resection: review	2016	Italy	HPB – Liver resection	Multiple studies	Robotic vs laparoscopic	Feasible; comparable oncologic outcomes; longer OR & higher cost	**Complications:** broadly similar across series.	https://pubmed.ncbi.nlm.nih.gov/26523006/ (PubMed)
Liang et al., 2018 [Liang et al., 2018]	Robotic vs laparoscopic distal pancreatectomy: meta-analysis	2018	China	HPB – Distal pancreatectomy	11 studies pooled	Robotic vs laparoscopic	Less blood loss, higher spleen preservation, longer OR	**Complication rates:** pooled analyses show no significant difference overall.	https://doi.org/10.1097/SLA.0000000000002819 (ScienceDirect)
Nassour et al., 2018 [Nassour et al., 2018]	Outcomes & cost of robotic vs laparoscopic distal pancreatectomy	2018	USA	HPB – Distal pancreatectomy	13 studies pooled	Robotic vs laparoscopic	Some peri-op advantages with robotics; higher direct costs	**Complications:** reported as similar in pooled studies.	https://doi.org/10.1016/j.sopen.2018.02.002 (ScienceDirect)
Giulianotti et al., 2011 [Giulianotti et al., 2011]	Robotic pancreaticoduodenectomy feasibility &	2011	USA/Italy	HPB – Pancreaticoduodenectomy	Institutional series	Robotic vs open/laparoscopic	Feasible in expert centres; morbidity comparable to open	**Complication rates:** substantial and variable (pancreati	https://pubmed.ncbi.nlm.nih.gov/21775149/ (PMC)

	outcomes (case series)						in those series	c fistula rates reported per centre).	
Xiong et al., 2019 [Xiong et al., 2019]	Robotic vs laparoscopic sleeve gastrectomy: meta-analysis	2019	China	Bariatric – Sleeve gastrectomy	9 studies pooled	Robotic vs laparoscopic	Similar weight-loss outcomes; longer OR & higher costs with robotics	**Complication rates:** no significant pooled difference.	https://doi.org/10.1007/s11695-019-03783-1 (WJGNet)
Du et al., 2024 [Du et al., 2024]	Pooled analysis: robotic vs conventional laparoscopic RYGB	2024	Int.	Bariatric – RYGB	35 studies pooled	Robotic vs laparoscopic	Similar mortality & complications; higher readmissions in some series	**Complications:** overall similar (see pooled data).	(journal full text via publisher) (Lippincott Journals)
Beckmann et al., 2020 [Beckmann et al., 2020]	Robotic RYGB: learning curve & outcomes	2020	USA	Bariatric – RYGB	Institutional series	Robotic vs laparoscopic	Robotic RYGB safe & efficient in experienced hands	**Complication rates:** institution-specific; not higher in	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7475058/ (PMC)

								reported series.	
Mahalingam Ramji et al., 2021 [Mahalingam Ramji et al., 2021]	Robotic vs laparoscopic ventral hernia repair — meta-analysis	2021	USA	General surgery – Ventral hernia	39 studies pooled	Robotic vs laparoscopic	Longer OR for robotics; lower readmission and some recurrence benefits in select series	**Complications/readmission:** pooled readmission reduction reported; overall complication rates similar.	https://jamanetwork.com/journals/jamasurgery/fullarticle/2782566 (SpringerLink)
Kudsi et al., 2020 [Kudsi et al., 2020]	Multicentre analysis: robotic vs laparoscopic ventral hernia	2020	USA	General surgery – Hernia repair	Large multicentre dataset	Robotic vs laparoscopic	Some improved early outcomes with robotics; higher cost	**Complications:** no consistent increase; rates vary by centre.	https://doi.org/10.1007/s10029-019-02060-2 (ScienceDirect)
Qabbani et al., 2021 [Qabbani et al., 2021]	Robotic inguinal hernia repair meta-analysis	2021	Int.	General surgery – Inguinal hernia	Pooled n ≈8,987 across studies	Robotic vs open/lap	Feasible; longer OR; low conversion & recurrence	**Overall complications (robotic):** 10.1% (248/2466) pooled;	https://pubmed.ncbi.nlm.nih.gov/33475236/ (PMC)

							recurrence ~1.2%.	
Aiolfi et al., 2019 [Aiolfi et al., 2019]	Robotic inguinal hernia meta-analysis	2019	Int.	General surgery – Inguinal hernia	Multiple series pooled	Robotic vs laparoscopic/open	High completion rates; low conversions	**Complication pooled estimate:** ~7.4% (varies by included studies).	https://pubmed.ncbi.nlm.nih.gov/31093778/ (ScienceDirect)
Brandao et al., 2017 [Brandao et al., 2017]	Robotic living donor nephrectomy: matched cohort	2017	Italy	Transplant – Donor nephrectomy	Institutional matched cohort	Robotic vs open	Less blood loss; longer OR; similar donor safety outcomes	**Complication rates:** similar donor complication rates in matched cohorts.	https://doi.org/10.1111/ajt.14001 (NCBI)
Ballantyne & Moll, 2003 [Ballantyne & Moll, 2003]	The da Vinci telerobotic system: telepresence and operative field (seminal tech paper)	2003	USA	Technology / general	N/A	System description	Described system architecture & theoretical benefits (dexterity, visualization)	NR (not a clinical outcomes paper)	https://doi.org/10.1016/S0039-6109(03)00140-1 (Lippincott Journals)

Barbash & Glied, 2010 [Barbash & Glied, 2010]	New technology and health care costs—the case of robot-assisted surgery (policy/economic)	2010	USA	Policy / Economics	Narrative review	Robotic adoption increases per-case costs substantially (20–40% higher per case in many analyses)	NR (economic paper)	NR	https://doi.org/10.1056/NEJMp1006602 (PMC)
Wilson & Fowler, 2011 [Wilson & Fowler, 2011]	Economic modelling for minimally invasive surgery	2011	USA	Health economics	Modelled analyses	Robotic cost-effectiveness occurs mainly at high institutional volumes	NR	NR	https://doi.org/10.1007/s00464-011-1773-9 (PMC)
Roh et al., 2018 [Roh et al., 2018]	RCT meta-analysis of robotic vs conventional laparoscopy (PLOS ONE)	2018	Korea	Mixed abdomino-pelvic procedures	27 RCTs pooled	Robotic vs laparoscopic	Lower conversion for robotic in some pooled analyses; overall complications often similar or	**Complication effect:** pooled ORs reported; no consistent safety advantage for robotics.	https://doi.org/10.1371/journal.pone.0191628 (PubMed)

							favoring laparoscopy; longer OR for robotics		
Liao et al., 2020 [Liao et al., 2020]	Long-term outcomes meta-analysis for rectal cancer robotic vs lap	2020	China	Colorectal – Rectal cancer	12 studies pooled	Robotic vs laparoscopic	No significant difference in long-term recurrence or survival	**Complications:** no significant difference in pooled analyses.	https://doi.org/10.1007/s00464-019-06832-6 (PubMed)
Novara et al., 2012 [Novara et al., 2012]	Systematic review & meta-analysis: oncologic outcomes after robot-assisted radical prostatectomy	2012	Italy	Urology – Prostatectomy	82 studies pooled	Robotic vs open	Less blood loss and shorter LOS; oncologic outcomes comparable	**Complication rates:** pooled data show similar major complication rates.	https://doi.org/10.1016/j.eururo.2012.05.047 (European Urology)
Kim et al., 2013 [Kim et al., 2013]	Robot-assisted vs laparoscopic partial nephrecto	2013	Korea	Urology – Partial nephrectomy	16 studies pooled	Robotic vs laparoscopic	Reduced warm ischemia time with robotics;	**Complications:** no significant difference overall.	https://doi.org/10.1016/j.eururo.2013.0

	my: meta-analysis						similar renal outcomes and complications		6.034 (PubMed)
Jayne et al., 2017 [ROLARR, Jayne et al., 2017]	ROLARR RCT — robotic vs laparoscopic rectal cancer surgery	2017	Multicentre (international)	Colorectal – Rectal cancer	471 randomized	Robotic vs laparoscopic	Conversion 8.1% vs 12.2% (robotic vs lap); no significant difference overall	**Complication rates:** similar overall between arms.	https://pubmed.ncbi.nlm.nih.gov/29067426/ (publishing.rcseng.ac.uk)
Yaxley et al., 2016 [Yaxley et al., 2016]	Robot-assisted vs open radical prostatectomy: phase 3 RCT (Lancet)	2016	Australia	Urology – Prostatectomy	326 randomized	Robotic vs open	Similar functional outcomes; less blood loss with RARP	**Complication rates:** 9% RRP vs 4% RARP in early report; see full text.	https://doi.org/10.1016/S0140-6736(16)30592-X (European Urology)
Coughlin et al., 2018 [Coughlin et al., 2018]	24-month outcomes of Yaxley trial (Lancet Oncology)	2018	Australia	Urology – Prostatectomy	326 follow-up	Robotic vs open	Equivalent continence & oncologic outcomes at 24 months	**Complication rates:** reported similar across arms at follow-up.	https://doi.org/10.1016/S1470-2045(18)30357-7

									(European Urology)
Wright et al., 2013 [Wright et al., 2013]	National cohort: robotic vs laparoscopic hysterectomy (JAMA)	2013	USA	Gynaecology – Hysterectomy	>250,000 cases	Robotic vs laparoscopic	Robotic much more costly; morbidity similar	**Complication rates:** ~5.5% robotic vs 5.3% laparoscopic (propensity-matched).	https://pubmed.ncbi.nlm.nih.gov/23423414/ (PubMed)
Paraiso et al., 2013 [Paraiso et al., 2013]	Randomized trial: robotic vs conventional total laparoscopic hysterectomy	2013	USA	Gynaecology – Hysterectomy	70 randomized (53 underwent surgery)	Robotic vs laparoscopic	Similar PROMs; longer OR for robotic	**Complication rates:** few complications; no between-arm difference reported in abstract.	https://pubmed.ncbi.nlm.nih.gov/23395927/ (PubMed)
134. Barbash & Glied, 2010 [Barbash & Glied, 2010]	New technology and health care costs —	2010	USA	Policy/Economics	Narrative	Robotics increases per-case costs substantially; policy	NR	NR	https://doi.org/10.1056/NEJMp1006602 (PMC)

	economic narrative					implications			
Moher et al., 2009 [Moher et al., 2009]	PRISMA statement — reporting guideline for systematic reviews	2009	Canada	Methodology	N/A	N/A	Standard reporting guideline for SR/MA	NR (guideline)	https://doi.org/10.1371/journal.pmed.1000097 (PMC)

Abbreviations: countries: *USA* United States of America, *UK* United Kingdom; instruments: *IEPS* Interdisciplinary Education Perception Scale; results: *NR* No