Revista Española de Educación Médica

UNIVERSIDAD DE MURCIA

Effectiveness and Challenges of Video-Assisted Surgery in Graduate Medical Education: A Focused Systematic Review of 2025 Studies.

Efectividad y Desafíos de la Cirugía Asistida por Vídeo en la Educación Médica de Posgrado: Una Revisión Sistemática Focalizada de Estudios del 2025.

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Recibido: 10/2/26; Aceptado: 4/3/26; Publicado: 6/3/26

Abstract.

Introduction: Video-assisted surgery (VAS) has been increasingly incorporated into graduate medical education (GME), offering enhanced visualization and structured opportunities for technical skill development. However, recent implementation models vary considerably in design, evaluation, and reported outcomes. **Objective:** To synthesize evidence from studies published in 2025 regarding the effectiveness and challenges of VAS in GME. **Methods:** A focused systematic review was conducted in accordance with PRISMA-S recommendations. Peer-reviewed English-language studies published in 2025 were identified through searches in PubMed, Scopus, and Web of Science. Eligible studies examined video-assisted educational interventions involving residents and/or fellows and reported at least one educational outcome. Four studies met the inclusion criteria following dual screening. Data were extracted using a standardized framework and synthesized narratively due to substantial heterogeneity in study designs, interventions, and outcome measures. **Results:** The four included studies employed heterogeneous methodologies (descriptive observational designs, a multicenter observational study, and one randomized controlled trial). Reported outcomes suggested potential improvements in procedural understanding, technical skill acquisition, workflow efficiency, and learner engagement, particularly when video-assisted approaches were embedded within structured training models. However, evidence was frequently based on small samples, subjective measures (e.g., satisfaction and perceived utility), and short-term evaluations, with limited use of standardized objective metrics. **Conclusions:** Evidence from 2025 studies indicates that VAS may support surgical training in GME when integrated into structured educational frameworks. Nevertheless, the small number of studies, methodological heterogeneity, and limited longitudinal data warrant cautious interpretation. Further multicenter and methodologically rigorous research is needed to clarify long-term educational impact and transfer to clinical practice.

Keywords: Video-Assisted Surgery, Graduate Medical Education, Specialized Healthcare Training, Systematic Review.

Resumen.

Introducción: La cirugía asistida por video (CAV) se ha incorporado de manera creciente en la educación médica de posgrado (EMP), ofreciendo una visualización mejorada y oportunidades estructuradas para el desarrollo de habilidades técnicas. No obstante, los modelos recientes de implementación presentan variaciones considerables en su diseño, evaluación y resultados reportados. **Objetivo:** Sintetizar la evidencia proveniente de estudios publicados en 2025 acerca de la efectividad y los desafíos de la CAV en la EMP. **Métodos:** Se realizó una revisión sistemática focalizada conforme a las recomendaciones PRISMA-S. Se identificaron estudios revisados por pares, publicados en idioma inglés en 2025, mediante búsquedas en PubMed, Scopus y Web of Science. Fueron elegibles aquellos estudios que evaluaron intervenciones educativas asistidas por video dirigidas a residentes y/o becarios, y que reportaron al menos un desenlace educativo. Cuatro estudios cumplieron los criterios de inclusión tras un proceso de selección doble. Los datos se extrajeron mediante un marco estandarizado y se sintetizaron de forma narrativa debido a la heterogeneidad sustancial en los diseños de estudio, las intervenciones y las medidas de resultado. **Resultados:** Los cuatro estudios incluidos emplearon metodologías heterogéneas (diseños observacionales descriptivos, un estudio observacional multicéntrico y un ensayo clínico aleatorizado). Los resultados reportados sugieren posibles mejoras en la comprensión de los procedimientos, la adquisición de habilidades técnicas, la eficiencia del flujo de trabajo y la participación del estudiante, particularmente cuando los enfoques asistidos por video se integraron en modelos de formación estructurados. Sin embargo, la evidencia se basó con frecuencia en muestras pequeñas, medidas subjetivas (por ejemplo, satisfacción y utilidad percibida) y evaluaciones a corto plazo, con un uso limitado de métricas objetivas estandarizadas. **Conclusiones:** La evidencia proveniente de estudios publicados en 2025 indica que la CAV puede favorecer la formación quirúrgica en la EMP cuando se integra en marcos educativos estructurados. No obstante, el reducido número de estudios, la heterogeneidad metodológica y la limitada disponibilidad de datos longitudinales exigen una interpretación cautelosa. Se requieren investigaciones adicionales, multicéntricas y metodológicamente rigurosas, para esclarecer el impacto educativo a largo plazo y su transferencia a la práctica clínica.

Palabras clave: Cirugía Asistida por Vídeo, Educación de Postgrado en Medicina, Formación Sanitaria Especializada, Revisión Sistemática.

1. Introduction

Graduate medical education (GME) is undergoing a substantial pedagogical shift driven by the adoption of video-assisted surgical techniques across multiple specialties. Traditionally grounded in apprenticeship-based models and direct intraoperative supervision, surgical training now faces increasing demands related to procedural complexity, patient safety expectations, time constraints, and the need for standardized competency development. Within this evolving landscape, video-assisted surgery (VAS) has emerged as a pivotal educational modality, offering scalable access to expert demonstrations, enhanced visualization of operative fields, and opportunities for deliberate, repetitive practice aligned with established theories of skill acquisition and expert performance. For the purposes of this review, video-assisted surgery (VAS) refers specifically to intraoperative video technologies—such as endoscopic, robotic, or point-of-view recordings—used as structured educational tools within graduate medical education. This definition distinguishes VAS from broader video-based education formats or simulation-only interventions, unless they explicitly incorporate operative video as a core instructional component (1-2).

Evidence suggests that video-based surgical education significantly enhances both cognitive and technical learning outcomes among trainees. Systematic reviews and empirical studies consistently report improvements in procedural knowledge, psychomotor skill acquisition, and learner preparedness when video-assisted methods are incorporated into training pathways (3-5). Innovations such as head-mounted video devices and procedure-specific video-assisted techniques further enhance anatomical visualization, spatial understanding, and learner engagement, thereby increasing confidence and satisfaction among surgical trainees (6- 7). These findings underscore the pedagogical value of VAS as a complementary tool within contemporary surgical education. Beyond passive observation, integrating video-assisted simulation with real-time feedback mechanisms has expanded the instructional potential of VAS. Simulation-based laparoscopic training has demonstrated measurable reductions in technical errors and improvements in operative performance, particularly when combined with structured curricula and iterative feedback (8). Recent advances in automated error detection systems and artificial intelligence (AI)–driven video analytics further enhance formative assessment by providing objective, real-time performance feedback and facilitating reflective learning (9-10). Additionally, optimized video formats with high-definition imaging, structured narration, and pedagogical design principles have been shown to improve learning efficiency and global accessibility of surgical education resources (11).

Despite these demonstrated benefits, implementing VAS in GME poses substantial challenges. Steep learning curves, particularly in minimally invasive and thoracoscopic procedures, demand significant instructional support and faculty expertise to ensure safe and effective skill progression (12). Technical limitations, such as restricted instrument maneuverability and the lack of stereoscopic vision in specific laparoscopic platforms, place additional cognitive and motor demands on trainees (10). Moreover, the absence of standardized training requirements and validated assessment frameworks contributes to heterogeneous educational experiences across residency programs (5, 13).

Resource-related constraints further complicate equitable implementation. Simulation and video-based training initiatives are often inconsistently embedded within curricula, frequently remaining voluntary or supplementary rather than longitudinally integrated (14). High acquisition and maintenance costs, along with travel requirements for advanced robotic and video-assisted training, raise concerns regarding accessibility and educational equity across institutions and geographic regions (15). These systemic barriers highlight the need for coordinated curricular design, institutional investment, and evidence-based policy development to realize the educational potential of VAS fully.

Given the rapid expansion of video-assisted technologies, the diversity of instructional approaches, and the coexistence of demonstrated benefits and persistent limitations, a comprehensive and up-to-date synthesis of the existing evidence is required. Such an analysis is crucial to clarify how video-assisted surgical training is currently implemented, identify its educational impact across different contexts, and elucidate the structural, technological, and pedagogical factors that influence its success within GME. This review intentionally restricts inclusion to studies published in 2025 in order to capture the most recent implementation models of VAS in GME, reflecting rapid technological evolution and contemporary training configurations. Earlier literature is referenced for contextual framing but was not part of the systematic selection process. This leads us to the research question: What are the effectiveness and challenges of video-assisted surgery in graduate medical education?

2. Methods

The reporting of information sources and search methods follows PRISMA-S (Preferred Reporting Items for Systematic reviews and Meta-Analyses literature search extension) (16). This study was designed as a focused systematic review restricted to studies published in 2025. Given the narrow temporal scope and the rapidly evolving nature of video-assisted surgical education, the review aims to provide a structured synthesis of contemporary evidence rather than a comprehensive historical overview. The completed PRISMA-S checklist is provided in Supplementary Table S1.

Eligibility Criteria

We included peer-reviewed studies published in 2025 and written exclusively in English that examined educational interventions incorporating video-assisted approaches within GME. Eligible studies focused on residents and/or fellows and were situated in academic or applied training environments, including teaching hospitals, institutional residency or fellowship programs, simulation centers, and structured surgical training initiatives. Studies were required to report the use of video as an explicit educational component, either as part of surgical training, simulation-based instruction, video feedback, coaching, or integrated curricular models. Both video-assisted surgical training and robotic surgery education incorporating video-based methods were considered eligible, provided that the intervention was framed within a formal educational context rather than purely technical or procedural descriptions.

We included empirical studies employing quantitative, qualitative, or mixed-methods designs, such as randomized or quasi-experimental studies, observational or retrospective analyses, cross-sectional surveys, and structured program evaluations grounded in explicit educational frameworks. To meet inclusion criteria, studies had to report at least one educational outcome, either objective (e.g., performance metrics, technical skills scores, proficiency measures) or subjective (e.g., learner perceptions, experiences, or self-reported educational impact). We explicitly excluded studies in undergraduate medical education and those focused on continuing medical education (CME) without a direct emphasis on residents or fellows. Additional exclusions comprised editorials, commentaries, letters to the editor, opinion pieces lacking methodological rigor, purely technical or descriptive reports without trainee-level educational outcomes, preprints, grey literature, unpublished materials, duplicate publications, and studies addressing surgical training without an explicit video-based educational component.

Information Sources and Search Strategy

We searched in PubMed, Scopus, and Web of Science. The window spanned January 2025 to December 2025, with searches performed between January 9 and 10, 2026 (last update: January 11, 2026). No geographic limits were applied; records in English were eligible. Full, exact strategies as run are provided in Supplementary Table S2. Reporting of information sources and search methods followed the PRISMA-S extension. The completed PRISMA-S checklist is available as Supplementary Table S1. All records retrieved from the databases were exported (RIS/CSV), consolidated in a shared spreadsheet by A.H.L.L., and deduplicated using Rayyan (17). QCRI's duplicate detection plus manual verification. Deduplicated records were screened independently in Rayyan by nine investigators (R.J.L.L., J.H.V.V., E.F.O.B., J.A.C.O., A.M.S., P.C.A.M., G.P.Z.Z., A.H.L.L. and M.V.A.V.). Disagreements at the title/abstract were adjudicated by J.H.V.V. by discussion. The same group reviewed full texts, with any remaining discrepancies resolved by A.H.L.L. Screening occurred between January 11 and 12, 2026. We identified 4 records (3 databases; 225 registers). Twenty duplicates were removed, leaving 10 records for title/abstract screening. Four reports were assessed at full text, and 4 studies were included in the review.

3. Results

Study Selection

All records that met the predefined eligibility criteria and complied with the temporal restriction to publications from 2025 were considered for inclusion in the review, regardless of access status. The selection process involved an initial screening of titles and abstracts to assess relevance, followed by full-text evaluation of potentially eligible studies. Screening was conducted with particular attention to studies that directly addressed the guiding research question: "What are the effectiveness and challenges of video-assisted surgery in graduate medical education?" Records failing to meet the eligibility criteria at any stage of the selection process were excluded. The overall study selection process is summarized in the corresponding flow diagram (figure 1) (18).

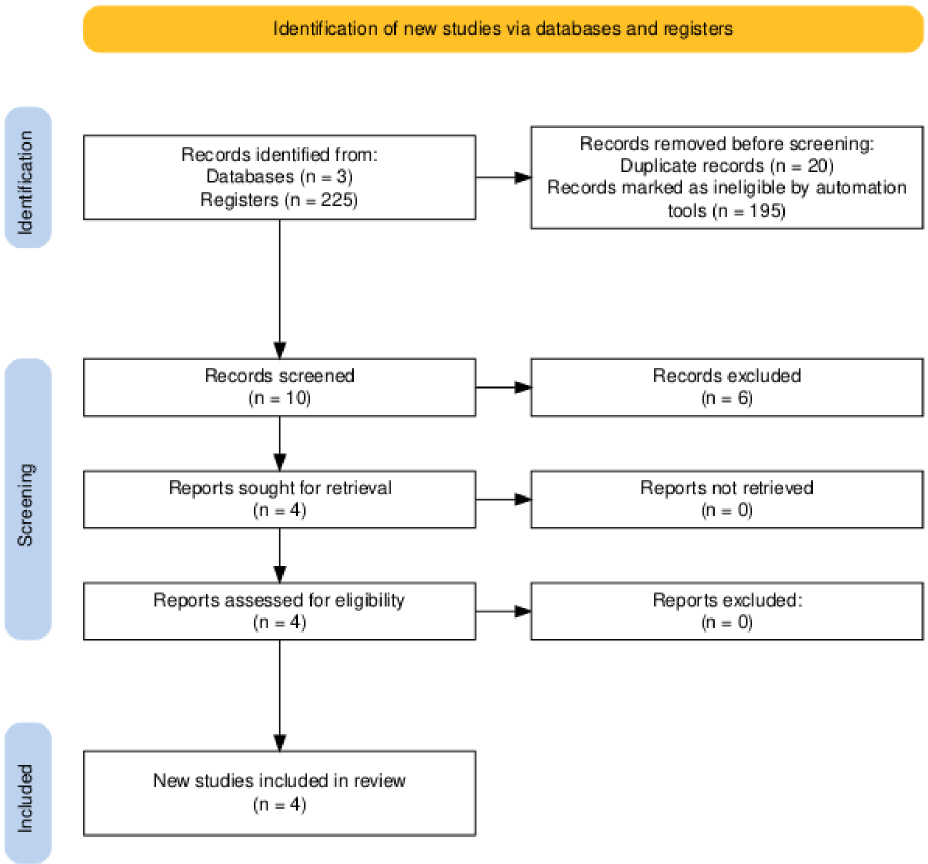

Figure 1. PRISMA 2020 flow diagram.

Included Studies (2025)

Four studies published in 2025 met the predefined eligibility criteria and were included in the systematic synthesis (19–22). These studies comprised heterogeneous designs, including descriptive observational program evaluations, a multi-institutional observational study, qualitative repository development, and one randomized controlled trial. Englert et al. (19) described the development and implementation of a structured robotic surgery training program integrated into routine clinical practice, reporting progressive reductions in workflow times and improved trainee acceptance. Sagae et al. (20) evaluated an online live-streaming robotic surgery system with bidirectional discussion, demonstrating high participant satisfaction and improved perceived comprehension, although primarily based on self-reported measures. Ramos et al. (21) developed a large trauma surgical video repository for educational and quality improvement purposes, reporting perceived educational benefit but limited objective outcome measures. Wang et al. (22) conducted a randomized controlled trial comparing video-assisted debriefing with traditional verbal feedback, demonstrating significantly higher technical skill scores in the video-assisted group ($p < 0.001$). Across the four studies, reported outcomes included procedural understanding, technical skill acquisition, workflow efficiency, and learner engagement. However, methodological heterogeneity, small sample sizes, and limited use of standardized objective metrics were common across studies.

Data synthesis

Given the marked heterogeneity across the included studies—encompassing experimental and quasi-experimental video-assisted training interventions, simulator-based evaluations, retrospective and cross-sectional observational analyses, multi-institutional program evaluations, and structured narrative syntheses—we did not prespecify or conduct a quantitative meta-analysis. Instead, a narrative thematic synthesis was undertaken to integrate evidence across diverse methodological approaches and educational contexts. This synthesis was organized around two overarching analytical dimensions—effectiveness and challenges—reflecting the dual focus of the review.

First, to address effectiveness, data were systematically extracted and synthesized according to intervention characteristics and outcomes, including intervention type, tools and equipment used, video-related features (such as quality, framing, and any AI-supported components), evaluation metrics (knowledge acquisition, technical skills, and proficiency), primary outcomes, and significant results with reported statistical indicators (e.g., p-values or confidence intervals). Quantitative findings were summarized descriptively without statistical pooling, highlighting patterns of improved technical performance, enhanced procedural understanding, or measurable gains in proficiency associated with video-assisted educational strategies.

Second, to elucidate the challenges, we synthesized evidence on study limitations, observer bias, reports of fatigue or discomfort, learning initiative characteristics, and ethical approval considerations. Qualitative and descriptive data from empirical studies and program evaluations were integrated to identify recurrent constraints affecting implementation and interpretation, including methodological limitations, variability in assessment rigor, potential bias introduced by evaluators or self-report measures, learner burden associated with prolonged video-based or simulator exposure, and heterogeneity in institutional ethical oversight.

Across both dimensions, findings were examined comparatively to identify cross-cutting trends and tensions between reported educational benefits and implementation challenges. This integrative approach enabled a comprehensive understanding of how video-assisted strategies function within GME, while also delineating structural, methodological, and contextual factors that shape their effectiveness. Sensitivity analyses and assessments of publication bias were not applicable, given the absence of a pooled quantitative synthesis and the diversity of study designs included.

Outcomes

The outcomes of this review are intended to provide an overview of how video-assisted surgical approaches are being incorporated into GME and to identify the educational dimensions in which their impact has been explored. Across the included literature, outcomes were reported in relation to access to video-based resources, curricular use, institutional support, learning experiences, and evaluation practices. These outcome measures reflect how video-assisted strategies are positioned within training environments and how trainees engage with them, rather than assuming uniform implementation or effectiveness across programs.

More broadly, the reported outcomes focus on educational processes and performance indicators used to assess the contribution of video-assisted approaches to GME. Studies examined a range of outcome measures, including knowledge acquisition, technical skill development, proficiency, learner perceptions, and program-level indicators, as well as methodological and contextual factors that may influence interpretation. Together, these outcomes establish a framework for understanding both the potential educational contributions of VAS strategies and the challenges inherent in their implementation and evaluation, setting the stage for a critical appraisal of how such approaches may shape training quality and patient safety within GME.

Data Extraction

Data were extracted using a standardized and piloted data extraction form, developed a priori to capture key methodological, educational, and contextual characteristics relevant to the research objectives. For each included study, the following items were systematically collected: Author(s), Year of publication, Country of origin, Aim/purpose, Study design, Intervention type, Tools and equipment used, Video-related characteristics (including quality, framing, and any AI-supported features), Evaluation metrics (knowledge, technical skills, and proficiency), Primary outcomes, and Significant results with reported statistical indicators (e.g., p-values or confidence intervals). In addition, data pertaining to Study limitations, Observer bias, Fatigue or discomfort reports, Learning initiative characteristics, and Ethics approval were extracted to contextualize both effectiveness and implementation challenges. Data extraction was conducted independently and cross-checked for consistency, with discrepancies resolved through discussion and consensus. Items not reported in the original publications were explicitly recorded as NR. When the country of origin was not explicitly stated, it was inferred from author affiliations. The complete set of extracted variables and corresponding study-level data are presented in the supplementary materials (Supplementary Table S3). Only the four studies meeting the predefined eligibility criteria (published in 2025) were included in the systematic synthesis. References outside this temporal frame were used exclusively for contextual interpretation in the Introduction and Discussion sections and were not part of the systematic selection or data extraction process.

4. Discussion

The following discussion first synthesizes findings derived exclusively from the four studies included under the predefined 2025 eligibility criteria (19–22). Subsequent references to earlier literature are used solely for contextual comparison and were not part of the systematic selection process. This discussion critically examines the implementation of video-assisted surgical education in graduate medical training through an integrated lens that captures both educational effectiveness and persistent challenges identified across the included studies. Specifically, the synthesis is structured around interconnected domains encompassing the design of video-based interventions, the technological characteristics of audiovisual tools, the alignment of evaluation metrics with learning objectives, and the resulting educational outcomes, alongside methodological, ergonomic, and institutional constraints that shape their impact. Attention is given to how variations in video quality, instructional framing, and curricular integration influence knowledge acquisition, technical skill development, and procedural proficiency, while also addressing limitations related to study design, observer bias, learner fatigue, ethical oversight, and the sustainability of learning initiatives. By situating effectiveness and challenges within a unified analytical framework, this discussion highlights both the pedagogical promise of video-assisted approaches in GME and the critical gaps that must be addressed to support standardized implementation, rigorous evaluation, and meaningful transfer to clinical practice (19-22).

Effectiveness of Video-Assisted Surgery in Graduate Medical Education

The findings synthesized from the included studies demonstrate that video-assisted surgical interventions contribute positively to educational effectiveness across multiple dimensions, particularly when integrated within structured training initiatives. Interventions ranged from modular, stepwise curricula incorporating recorded procedures and simulation to live, interactive remote robotic surgery education, reflecting diverse pedagogical approaches supported by audiovisual technologies (19-22).

Regarding tools and equipment, studies consistently employed high-definition video systems, robotic platforms, and simulation environments, which enabled precise visualization of anatomical landmarks and procedural steps. Enhanced video quality, stable framing, and targeted instructional focus were associated with improved learner engagement and procedural comprehension, particularly in video-assisted and group-based learning formats (22). Although none of the included studies reported advanced AI-driven analytics as a central component, structured video feedback and guided observation emerged as key facilitators of skill acquisition.

Evaluation metrics across studies encompassed knowledge acquisition, technical skills, and procedural proficiency, assessed through objective performance measures, comparative group analyses, and learner-reported outcomes. Video-assisted cohorts consistently demonstrated greater learning efficiency and skill development compared with traditional or non-video-supported approaches, with several studies reporting statistically significant improvements in procedural understanding and performance outcomes. However, the reporting of statistical parameters varied across studies, with limited standardization in the presentation of significance testing. Collectively, these findings support the educational value of video-based modalities when aligned with clearly defined learning objectives and coherent assessment frameworks (21-22). These findings reinforce the educational value of video-based modalities when aligned with explicit learning objectives and standardized assessment strategies.

Primary outcomes further highlighted gains in learner confidence, task efficiency, and structured progression through competency-based pathways. Live and interactive video formats supported real-time feedback and collaborative learning, fostering deeper cognitive processing and contextualized skill transfer, particularly in complex surgical and trauma-related scenarios (20-21). Findings from the four included 2025 studies suggest that video-assisted surgical education may support learning outcomes in GME when embedded within structured curricular frameworks.

Overall, findings derived from the included 2025 studies indicate potential educational benefits of video-assisted surgical education in graduate medical training depends primarily on coherent curricular integration, structured feedback, and deliberate instructional design rather than on technological sophistication alone. To contextualize these results, evidence from the broader medical education literature suggests that video-supported interventions can enhance technical performance, learning efficiency, and learner confidence when embedded within competency-based frameworks, particularly in complex surgical and trauma-related settings (23-26). Nevertheless, substantial heterogeneity in evaluation metrics and reporting practices—both within the included studies and across external literature—limits cross-study comparability and constrains inferences regarding long-term educational impact, highlighting the need for standardized assessment frameworks in future research (27, 28).

Challenges of Video-Assisted Surgery in Graduate Medical Education

Despite demonstrated effectiveness, several challenges and limitations were consistently identified across studies. Methodological constraints, including heterogeneous study designs, limited sample sizes, and variability in outcome measures, restricted the generalizability of findings and hindered cross-study comparisons (19, 22). The absence of harmonized evaluation standards remains a critical barrier to establishing robust evidence for long-term educational impact.

Observer bias was variably reported, with some studies lacking explicit strategies to mitigate subjective assessment influences. In contexts where faculty observation or self-reported learner outcomes predominated, the potential for bias may have influenced performance evaluations and perceived effectiveness (19, 21). This underscores the need for blinded assessments and objective performance metrics in future research.

Fatigue and discomfort were minimally reported but not entirely absent. Mild neck fatigue associated with prolonged video viewing was noted in isolated cases, suggesting that ergonomic considerations and session duration should be accounted for when designing video-based learning activities (22). While these reports were limited, they highlight the importance of monitoring learner well-being alongside educational outcomes.

Learning initiatives varied substantially, ranging from highly structured, longitudinal programs to single-module or context-specific implementations. This heterogeneity influenced both depth of learning and sustainability of outcomes, with more comprehensive, stepwise initiatives demonstrating greater educational coherence (19). Institutional support, including protected time, trained faculty, and formal integration into curricula, was inconsistently documented, representing a systemic challenge to scalability.

Ethical oversight was generally addressed, with most studies reporting formal approval by institutional ethics committees or justification for exemption when human or animal subjects were not directly involved. However, inconsistencies in reporting ethical considerations reflect broader variability in research governance practices within educational interventions (20-22).

Beyond the formal reporting of ethics committee approval, additional ethical dimensions warrant critical consideration. The educational use of intraoperative video involves issues related to informed consent for recording and secondary educational use, protection of patient identity, secure storage and transfer of audiovisual data, and governance of access to digital materials. Live-streamed or remotely accessed procedures may also raise concerns regarding data security and the potential impact of technological mediation on surgical focus and patient safety. While the included studies primarily addressed research ethics compliance, future investigations should more explicitly examine ethical frameworks tailored to video-based surgical education, particularly regarding data protection regulations and institutional accountability.

The challenges identified across the included studies—methodological heterogeneity, potential observer bias, limited reporting of fatigue, variability in program structure, and inconsistencies in ethical documentation—reflect well-recognized constraints in contemporary medical education research. Evidence from the wider literature situates these limitations within broader patterns of non-standardized evaluation, reliance on unblinded or self-reported outcomes, and fragmented curricular implementation, all of which restrict generalizability and may overstate educational effects (29-32). Taken together, these considerations highlight the importance of harmonized assessment frameworks, objective evaluation strategies, and clearer governance practices to support the sustainable and rigorous application of video-assisted surgical education.

Although the included studies were conducted in diverse international contexts, their findings may hold relevance for residency programs in Spain and Latin America. Variability in access to robotic platforms, simulation infrastructure, and high-definition recording systems may influence feasibility across institutions in these regions. However, structured integration of video-assisted approaches within competency-based specialist training frameworks—such as those used in European and Latin American residency systems—may facilitate adaptation while accounting for resource constraints. Future research should explore context-specific implementation models and equity considerations in Spanish-speaking training environments.

Limitations and Strengths

Among the principal limitations of this review is the relatively small number of eligible studies (four in total) and their pronounced heterogeneity in terms of study design, educational aims, clinical contexts, and outcome measures. This diversity precluded the conduct of a quantitative synthesis or meta-analysis and necessitated a narrative thematic approach. Several included studies relied on observational designs, single-institution reports, or short-term simulator-based interventions with modest sample sizes, limiting causal inference and restricting the assessment of long-term educational and clinical impact. In addition, outcome reporting was inconsistent across studies, with variable use of validated assessment tools and limited standardization of performance metrics, which constrained cross-study comparability. Potential publication bias cannot be excluded, as the review was restricted to English-language, peer-reviewed literature indexed in PubMed, Scopus, and Web of Science and focused exclusively on studies published in 2025, reflecting the emergent and rapidly evolving nature of research on video-assisted surgical education.

Despite these limitations, this review demonstrates several notable strengths. It adhered rigorously to PRISMA-S guidelines and employed a transparent, multi-database search strategy with a clearly defined eligibility framework. Study selection and screening were conducted using a structured, multi-reviewer process in Rayyan, with independent assessment and consensus-based resolution of discrepancies, enhancing methodological rigor and reducing selection bias. Data extraction followed a standardized and piloted template that captured both effectiveness-related outcomes and implementation challenges, including methodological limitations, observer bias, ergonomic considerations, and ethical oversight. Furthermore, organizing the synthesis around the dual dimensions of effectiveness and challenges enabled an integrated appraisal of educational benefits alongside structural and methodological constraints, providing a comprehensive and balanced overview of the current evidence base.

Future Directions

Future research should move beyond predominantly descriptive and single-center studies by adopting multicenter, longitudinal, and, where feasible, randomized or quasi-experimental designs that directly compare structured, competency-based video-assisted curricula with unstructured or opportunistic exposure models. There is a clear need for the systematic use of validated and standardized outcome measures—such as objective technical skill assessments, procedural autonomy scales, and longitudinal proficiency trajectories—to enhance comparability and strengthen causal inference. Significantly, future studies should extend evaluation beyond short-term performance gains to include retention of skills, transfer to independent clinical practice, and downstream patient-related outcomes.

In addition, research agendas should incorporate implementation science and mixed-methods approaches to examine feasibility, scalability, cost-effectiveness, and sustainability across diverse institutional and resource settings. Greater attention is warranted to ethical governance, data protection, and equity of access, particularly as video-assisted and AI-supported tools expand across training programs. Finally, collaborative co-design involving educators, trainees, program directors, and accrediting bodies—alongside targeted faculty development in video-based coaching, simulation pedagogy, and emerging analytic technologies—will be essential to integrate VAS safely, ethically, and sustainably into GME curricula.

5. Conclusions

- Evidence from four 2025 studies indicates that video-assisted surgical training (VAS) can improve procedural knowledge, the acquisition of technical skills, and progress toward surgical competence when integrated into structured and purposeful training programs.
- VAS is most effective when combined with simulation, guided feedback, and reflective review, serving as a complement to the traditional mentor-based learning model rather than a replacement.
- Its effectiveness depends less on technological sophistication and more on its sound curricular integration, clear objectives, and longitudinal evaluation; isolated or optional video activities tend to generate short-term benefits with limited transfer to clinical practice.
- Although VAS is a promising modality, methodological heterogeneity, small sample sizes, poorly standardized outcome measures, and institutional barriers necessitate cautious interpretation of the results and require standardized assessment frameworks, longitudinal integration, and attention to resident well-being and ergonomics.

Funding: There was no funding.
Declaration of conflict of interest: The authors declare that they have no conflict of interest.
Author contributions: Conceptualization: R.J.L.L., J.H.V.V., G.P.Z.Z., A.H.L.L.; Data curation: E.F.O.B., M.V.A.V.; Formal analysis: A.H.L.L., J.A.C.O.; Investigation: G.P.Z.Z., A.H.L.L., J.H.V.V., E.F.O.B.; Methodology: G.P.Z.Z., A.H.L.L.; Project administration: E.F.O.B.; Resources: A.M.S., P.C.A.M., J.H.V.V.; E.F.O.B.; Software: A.H.L.L.; Supervision: G.P.Z.Z., A.H.L.L., J.A.C.O.; Validation: J.H.V.V.; E.F.O.B., J.A.C.O., A.M.S., P.C.A.M.; Visualization: J.A.C.O., A.M.S., P.C.A.M.; Writing – original draft: R.J.L.L., G.P.Z.Z., A.H.L.L.; Writing – review & editing: R.J.L.L., G.P.Z.Z., A.H.L.L., M.V.A.V.

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Supplementary Table S1. PRISMA-S Checklist.

Section/topic	#	Checklist item	Location(s) Reported
INFORMATION SOURCES AND METHODS			
Database name	1	Name each individual database searched, stating the platform for each.	1-2, 4-5, 10, 17
Multi-database searching	2	If databases were searched simultaneously on a single platform, state the name of the platform, listing all of the databases searched.	NR
Study registries	3	List any study registries searched.	4-5
Online resources and browsing	4	Describe any online or print source purposefully searched or browsed (e.g., tables of contents, print conference proceedings, web sites), and how this was done.	NR
Citation searching	5	Indicate whether cited references or citing references were examined, and describe any methods used for locating cited/citing references (e.g., browsing reference lists, using a citation index, setting up email alerts for references citing included studies).	5, 10
Contacts	6	Indicate whether additional studies or data were sought by contacting authors, experts, manufacturers, or others.	NR
Other methods	7	Describe any additional information sources or search methods used.	NR
SEARCH STRATEGIES			
Full search strategies	8	Include the search strategies for each database and information source, copied and pasted exactly as run.	4-5, 10, 17
Limits and restrictions	9	Specify that no limits were used, or describe any limits or restrictions applied to a search (e.g., date or time period, language, study design) and provide justification for their use.	1-2, 4-5, 10
Search filters	10	Indicate whether published search filters were used (as originally designed or modified), and if so, cite the filter(s) used.	1-2, 4-5, 10
Prior work	11	Indicate when search strategies from other literature reviews were adapted or reused for a substantive part or all of the search, citing the previous review(s).	NR

NR= Not reported

Updates	12	Report the methods used to update the search(es) (e.g., rerunning searches, email alerts).	3-4
Dates of searches	13	For each search strategy, provide the date when the last search occurred.	4-5
PEER REVIEW			
Peer review	14	Describe any search peer review process.	4-5
MANAGING RECORDS			
Total Records	15	Document the total number of records identified from each database and other information sources.	4-5, 17
Deduplication	16	Describe the processes and any software used to deduplicate records from multiple database searches and other information sources.	4-5

NR= Not reported

Supplementary Table S2. Bibliographic search strategy.

Engine	Strategy	Results
PUBMED	#1= (“Video-Assisted Surgery”)	205
	#2= (“Education, Medical, Graduate”)	
	#3 = #1 AND #2	
SCOPUS	#1= TITLE-ABS-KEY (“Video-Assisted Surgery”)	9
	#2= TITLE-ABS-KEY (“Education, Medical, Graduate”)	
	#3 = #1 AND #2	
WEB OF SCIENCE	#1= (“Video-Assisted Surgery”)	11
	#2= (“Education, Medical, Graduate”)	
	#3 = #1 AND #2	

Supplementary Table S3-1. Characteristics of included studies (part 1).

Author(s)	Year of publication	Country of origin	Aim/purpose	Study Design
Englert et al.	2025	Germany	To develop and implement a structured, modular, and industry-independent training program to introduce advanced surgical residents and young specialists to robotic surgery during routine clinical practice.	Descriptive observational study with program development and implementation evaluation.
Sagae et al.	2025	Japan	To evaluate the feasibility and educational effectiveness of a modified online live-streaming system for robotic surgery incorporating a commentator to enable bidirectional discussion while maintaining surgical safety in the Japanese clinical context.	Multi-institutional observational study.
Ramos et al.	2025	Chile	To develop and describe a high-quality trauma surgical video repository to enhance trauma surgical training.	Descriptive/Qualitative.
Wang et al.	2025	China	To investigate the effectiveness of point-of-view video-assisted debriefing (VAD) in spinal surgery training.	Randomized controlled trial.

NR = Not Reported

Supplementary Table S3-2. Characteristics of included studies (part 2).

Author(s)	Intervention Type	Tools/Equipment Used	Video Details (Quality, Framing, AI Focus)	Evaluation Metrics (Knowledge, Skills, Proficiency)	Primary Outcomes	Significant Results and Statistical Significance (p-value, CI)
Englert et al.	Structured robotic surgery training program integrated into clinical workflow.	Intuitive Surgical da Vinci robotic systems (da Vinci SI, da Vinci X); surgical simulators; institutional and open-access instructional videos.	Standardized institutional surgical videos used for self-directed learning; videos focused on procedural steps and workflow standardization; no AI-based video analysis reported.	Time-based performance metrics (e.g., docking time, workflow steps); progression through predefined training stages; participant questionnaire evaluating learning progress and integration into clinical routine.	Feasibility of integrating structured robotic training into routine surgery; improved workflow efficiency; increased acceptance of robotic surgery among trainees.	Progressive reduction in docking and workflow times over successive procedures; descriptive comparison between trainees and experienced surgeons; no p-values or confidence intervals reported.
Sagae et al.	Online live streaming of robot-assisted	Intuitive Telepresence (ITP) system; da Vinci	Real-time live-streamed robotic endoscopic surgery video via	Surgical comprehension, usability, bidirectional discussion effectiveness,	Participant satisfaction with bidirectional discussion and	High satisfaction with bidirectional discussion (94.7% ≥4);

	surgeries with commentator-facilitated bidirectional discussion.	Surgical System; online questionnaires; GraphPad Prism 10.0.	Intuitive Telepresence; surgeon endoscopic view and limited operating room view; no AI components reported; initial sessions affected by video instability that improved with wired internet connections.	understanding of robotic instrument handling, anatomy, assistant procedures, and operating room environment assessed using 5-point Likert scales.	understanding of robotic surgical techniques and anatomy.	high understanding of robotic instrument handling and anatomy (94.7% ≥4); assistant operations and operating room environment rated unsatisfactory by 57.9%; significant differences among domains ($p < 0.0001$); CI not reported.
Ramos et al.	Video recording of open trauma surgeries.	Hand-held GoPro, head-mounted PivotHead, Google Glass.	High-fidelity, multi-angle, well-framed videos focusing on trauma surgical procedures; videos include multiple perspectives (surgeon, external). Purpose includes educational review and quality improvement.	Subjective assessments via trainee surveys; qualitative feedback on educational benefit; no objective skill metrics provided.	Large video repository (>1000 hours, 250+ surgeries), utilized for education, review, and quality improvement.	Not explicitly reported; subjective trainee feedback indicates perceived benefit.
Wang et al.	Video-assisted coaching vs. traditional verbal debriefing.	Lenovo LX918 head-mounted camera, GoPro Hero4, Google Glass.	4K resolution, 110-degree field of view, AI-powered focusing, stereo noise reduction microphone.	Evaluated technical skills and proficiency in pedicle screw fixation using a modified Objective Structured Assessment Scoring Scheme (OSASS-PSF).	Improved technical skills in the video-assisted group, particularly in recognizing anatomical structures and performing specific surgical steps.	Improved technical skills in video-assisted group: 37 ± 9.7 vs. 25 ± 8.5, $p < 0.001$.

NR = Not Reported

Supplementary Table S3-3. Characteristics of included studies (part 3).

Author(s)	Study Limitations	Observer Bias	Fatigue or Discomfort Reports	Learning Initiative	Ethics Approval
Englert et al.	Small sample size; single-center experience; absence of control group; lack of long-term outcome assessment.	NR	NR	Structured, modular, stepwise robotic surgery training program integrating theoretical instruction, standardized surgical videos, simulation-based practice, bedside assistance, and progressive console training during routine clinical operations.	No studies involving human or animal subjects were conducted; therefore, formal ethics committee approval was not required.
Sagae et al.	Small sample size; observational design; limited visualization of operating room environment; absence of direct surgeon–participant interaction; subjective questionnaire-based outcomes; dependence on internet stability.	Not explicitly reported, but participants were grouped and stratified (e.g., by robotic surgery experience, career length, in-person observation experience) to evaluate differences in satisfaction and feedback.	Not explicitly reported. However, the online format was noted to "save time" and allowed for easier participation compared to in-person visits.	Live, interactive, remote robotic surgery education through commentator-mediated bidirectional discussion.	Approved by the Ethics Committee of Kyoto University (Approval No. R3227); written informed consent obtained from patients and participants.
Ramos et al.	Limitations include lack of objective measurements of skills; single-center, small sample for study.	Not specified, but potential for bias due to subjective evaluation.	Reports of minimal discomfort with equipment; no significant fatigue reported.	Implemented as part of trauma education; aims to improve surgical training amid reduced trauma cases.	Ethical approval obtained from the Ethics Committee of Sotero del Rio Hospital.
Wang et al.	Observer bias, limited sample size, no objective	Possible due to the evaluator knowing	Mild neck fatigue reported by 2 residents in the video-assisted group.	Video-assisted group showed greater learning	Approved by the Ethics Committee of

	measurement of skill improvement.	the group assignments.		initiative and engagement with self-learning post-debriefing.	the China-Japan Friendship Hospital (2022jy038).

NR = Not Reported

Supplementary Table S3-4. Characteristics of included studies (part 4).

Author(s)	Design	Level of Evidence*	Reported Effectiveness Outcomes	Reported Challenges / Limitations
Englert et al.	Descriptive observational program evaluation	Level III–IV	Improved workflow efficiency; structured skill progression; increased trainee acceptance	Small sample; single-center; no control group; no long-term assessment
Sagae et al.	Multi-institutional observational study	Level III	High satisfaction with bidirectional discussion; improved perceived comprehension	Subjective Likert-based measures; limited OR visualization; internet dependency
Ramos et al.	Descriptive qualitative repository development	Level IV	Large trauma video repository; perceived educational benefit	Lack of objective skill metrics; subjective feedback; single-center
Wang et al.	Randomized controlled trial	Level II	Higher technical skill scores in video-assisted group ($p < 0.001$); improved anatomical recognition	Limited sample size; potential observer bias; short-term evaluation

*Levels of evidence categorized according to conventional hierarchy of study designs.