

Virtual Supervision in Graduate Medical Education: A Systematic Review

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ABSTRACT

Background Despite the increased use of telemedicine, the evidence base on virtual supervision in graduate medical education (GME) is not well described.

Objective To systematically review the impact of virtual supervision on trainee education, patient care, and patient satisfaction in Accreditation Council for Graduate Medical Education (ACGME)-accredited specialties.

Methods Two databases (PubMed, EMBASE) were searched from database inception to December 2022. Inclusion criteria were peer-reviewed, full-text, English-language articles reporting the use of virtual supervision in GME in ACGME-accredited specialties. Exclusion criteria were studies involving direct supervision, supervisors who were not credentialed physicians, or non-GME trainees. Two investigators independently extracted data and appraised the methodological quality of each study using the Mixed Methods Appraisal Tool (MMAT). The reporting of this systematic review was guided by the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement.

Results Of 5278 records identified, 26 studies met the eligibility criteria. Virtual supervision was predominantly utilized in operating rooms and inpatient settings, facilitating clinical examinations or surgical procedures through videoconferencing software in specialties such as dermatology, neurosurgery, and orthopedics. However, some studies reported technical challenges that hindered effective teaching and communication. Based on self-reported surveys, supervisor and trainee satisfaction with virtual supervision was mixed, while patient satisfaction with the care was generally high. The MMAT ratings suggested limitations in sampling strategy, outcome measurement, and confounding factors.

Conclusions Virtual supervision was applicable to various specialties and settings, facilitating communication between supervisors and trainees, although there were some technological challenges.

Introduction

Supervision is a key component of graduate medical education (GME) for the delivery of safe and effective patient care as well as the acquisition of knowledge and skills by trainees.¹ The significant increase in telemedicine, largely driven by the COVID-19 pandemic, has fostered a growing interest in virtual supervision in GME.^{2,3}

The Accreditation Council for Graduate Medical Education (ACGME) defines 2 forms of supervision: direct and indirect.⁴ In direct supervision, the supervising physician is colocated with the trainee and the patient. In indirect supervision, the supervising physician is immediately available by means of telephonic or electronic modalities but not physically present.⁵

Virtual supervision is defined as a form of hybrid supervision in which non-colocated supervisors and

trainees interact via synchronous audio and/or video modalities while the patient is being seen.^{6,7} Forms of virtual supervision include video teleconferencing, phone calls, text-based approaches, and mobile apps that facilitate virtual supervision in real time.⁷ Virtual supervision offers the opportunity to provide clinical supervision, feedback, and trainee learning and engagement, while also addressing some of the challenges associated with direct supervision, such as scheduling conflicts and geographic barriers.⁸

In July 2022, the ACGME published guidelines regarding the use of telecommunication technology for supervision in GME.⁹ These guidelines include one common program requirement that postgraduate year (PGY) 1 residents should start with direct supervision but may progress to supervision via telecommunication technology, depending on specialty-specific conditions set by review committees. However, the current review committee guidelines vary significantly by specialty, and some review committees have not yet determined specialty-specific guidelines. For example, anesthesiology, neurology, medical genetics, obstetrics and gynecology (OB/GYN), and urology permit the

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use of virtual supervision with history-taking, patient examination, assessment, and counseling, but not with invasive procedures such as the conduct of anesthesia and labor and delivery. Urology, ophthalmology, and OB/GYN permit the use of virtual supervision in ambulatory and acute care settings but not in the operating room. Other specialties such as family medicine, pathology, pediatrics, and plastic surgery permit virtual supervision but do not have any specific guidelines. The generally cautious approach to resident surgical education in many specialties is echoed in the United States Department of Veterans Affairs (VA) guidelines, which require the supervisor to be colocated for all operating room procedures.¹⁰

The current literature on virtual supervision in GME is not well described. To this end, we investigated the following research question: In ACGME-accredited specialties, what is the impact of virtual supervision on trainee education, patient care, and patient satisfaction? We hope this information can help national GME stakeholders such as the ACGME and VA refine their guidelines for virtual supervision and help program-level GME leaders formulate appropriate virtual supervision strategies for their faculty and trainees.

Methods

The reporting of this systematic review was guided by the standards of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Statement.¹¹ In consultation with a reference librarian, we searched 2 databases on December 19, 2022 for eligible studies: PubMed (January 1950 to December 19, 2022), and EMBASE (January 1950 to December 19, 2022). MEDLINE, included within PubMed, was also searched via OVID to ensure comprehensive coverage (January 1946 to December 19, 2022). Our search included database-specific thesaurus terms and keywords related to virtual supervision in GME (online supplementary data).

The inclusion criteria were full-text articles published in an English-language, peer-reviewed journal that reported the use of supervision through virtual modalities in GME, namely internship, residency, and fellowship programs in ACGME-accredited specialties and subspecialties. We included all study types, including randomized control trials, cohort studies, case reports, case series, cross-sectional studies, and quasi-experimental studies. The exclusion criteria were studies with in-person direct supervision as defined by ACGME, supervisors who were not credentialed physicians, and non-GME trainees such as medical students. We also excluded studies that focused on online learning, virtual simulation,

telesurgery, and telehealth platforms for communication with patients, as well as studies that did not report empirical outcomes. In addition, we excluded abstracts, conference proceedings, non-peer-reviewed manuscripts, and non-English language studies without translations.

The authors deduplicated eligible studies in EndNote (Clarivate Analytics) and imported the studies into the systematic review software Covidence for screening, full-text review, and data extraction. The screening and selection process is displayed in a PRISMA flowchart (FIGURE). Two investigators (J.H., C.J.S.) independently conducted title/abstract screening, full-text review, and data extraction in Covidence following screening training and screening test sessions. Disagreements were resolved by the senior investigator (P.B.G.).

The authors developed a data template in Covidence to extract relevant information, including year of publication, location, study design, study timing, specialty, study setting, type of care performed, number of patients and trainees involved, and the postgraduate years of the trainees. We also collected information on the type of technology used for virtual supervision, as well as the objective and outcomes of the study. Two investigators (J.H., C.J.S.) independently appraised the methodological quality of the studies using the Mixed Methods Appraisal Tool (MMAT), and disagreements were resolved by the senior investigator (P.B.G.). The MMAT appraises studies based on 5 questions assessing the sampling strategy, outcome measurement, confounders, and statistical analysis of the study.¹² Studies were scored on a scale of 1 to 5 based on the MMAT.

Results

General Study Characteristics

The initial database search yielded 5278 articles. Following duplicate removal, title and abstract screening, and full-text review, 26 articles were included in our review (FIGURE). The Cohen's Kappa statistic for interrater reliability was 0.112 for title and abstract screening and 0.571 for full-text review.

Study design included quasi-experimental studies (35%, 9 of 26),¹³⁻²¹ cohort studies (27%, 7 of 26),²²⁻²⁸ cross-sectional studies (19%, 5 of 26),²⁹⁻³³ case reports or case series (15%, 4 of 26),³⁴⁻³⁷ and a randomized control trial (4%, 1 of 26)³⁸ (TABLE 1). The publication year of the articles ranged from 1999 to 2022. Most studies were conducted in the United States. Other studies were conducted in the United Kingdom,^{21,27} Norway,²⁰ Italy,¹⁶ Nepal,²³ the Czech Republic,¹⁵ and Singapore.²² Twenty studies were prospective (77%),^{13-24,26,28-33,38} while 6 studies

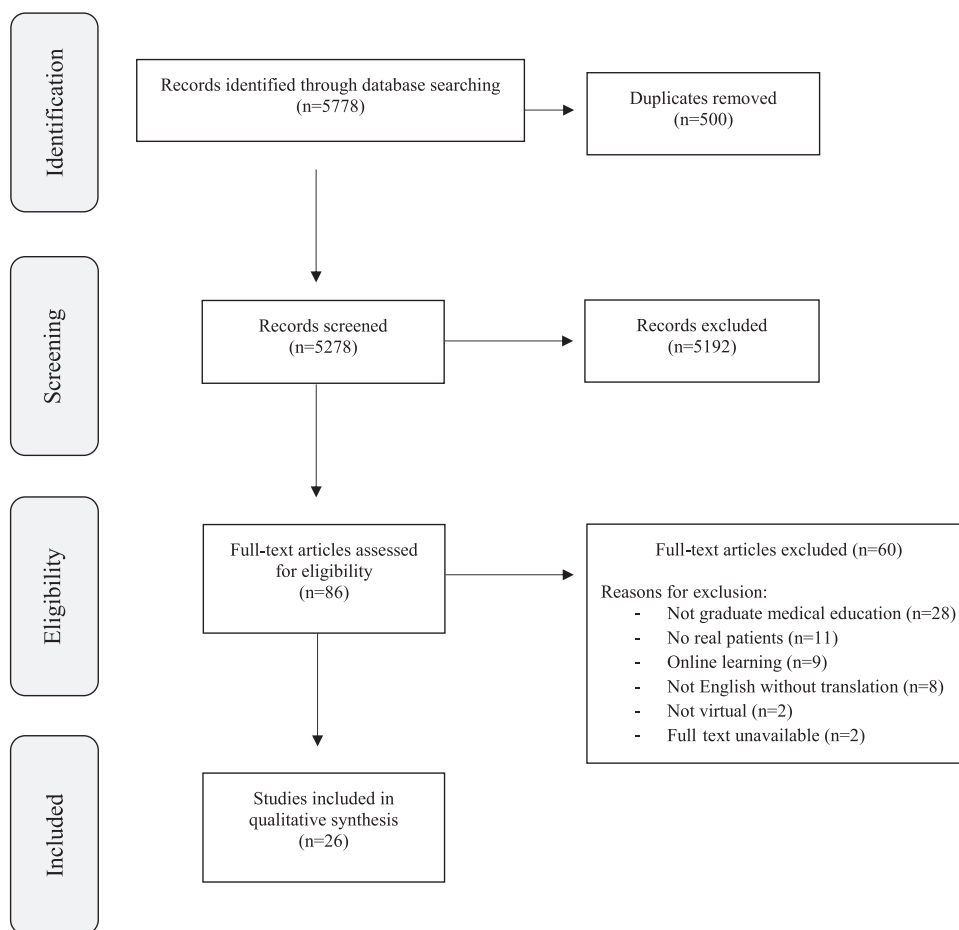


FIGURE
PRISMA Flow Diagram

were retrospective in design (23%).^{25,27,34-37} The objective of the studies ranged from comparing safety and quality of care between virtual supervision and direct supervision (31%, 8 of 26),^{15,17,18,20,25-27,38} and determining the feasibility of using virtual supervision for remote consultations (23%, 6 of 26)^{13,16,21,23,24,34} to such aims as describing the effectiveness of virtual supervision in trainee education (19%, 5 of 26),^{14,19,22,35,37} characterizing resident acceptance of virtual supervision (15%, 4 of 26),^{30-32,36} and understanding patient access and satisfaction levels with virtual supervision (12%, 3 of 26).^{28,29,33}

Characteristics of Virtual Supervision

A total of 1561 patients and 160 trainees were included. Specialty of focus included dermatology,^{14,16,18,26,28,33} neurosurgery,^{15,34,35} orthopedics,^{17,22,37} radiology,^{19,30} psychiatry,¹⁹ ophthalmology,^{23,27} otolaryngology,^{24,38} urology,^{29,32} emergency medicine,¹³ pathology,²⁰ neurology,³¹ anesthesiology,²¹ and general surgery.³⁶ The supervisors and trainees were in the same specialty except for one study in which

toxicology physicians supervised emergency medicine residents.¹³

Study location varied among the operating room (10 of 26, 38%),^{17,23,27,29,32,34-38} inpatient settings (7 of 26, 27%),^{14,15,19,22,24,26,28} outpatient clinics (4 of 26, 15%),^{16,18,21,25} the emergency department (4 of 26, 15%),^{13,30,31,33} and the autopsy room (1 of 26, 4%).²⁰ Virtual supervision was used for clinical examinations (14 of 26, 54%),^{13-16,18,19,21,22,24-26,28,31,33} surgical procedures (11 of 26, 42%),^{17,22,23,27,29,32,34-38} a diagnostic examination (1 of 26, 4%),³⁰ and autopsies (1 of 26, 4%).²⁰ For studies involving in-office procedures or surgeries in the operating room, virtual supervision was used to supervise arthroscopy,³⁷ repair of retinal detachments,²⁷ dermatology inpatient consultations,¹⁶ neuro-endovascular surgeries,³⁴ and endoscopic sinus surgeries.³⁸

Thirteen studies reported the PGY of the trainees, which included PGY-1 (6 of 13, 46%),^{19,20,24,26,28,30} PGY-2 (7 of 13, 54%),^{13,26,28-32} PGY-3 (6 of 13, 46%),^{16,17,25,26,28,31} PGY-4 (3 of 13, 23%),^{25,28,31} PGY-5 (2 of 13, 15%),^{17,31} PGY-6 (1 of 13, 8%),³¹

TABLE 1
Characteristics of Included Studies

Study, Year	Location	Study Design	Study Timing	Specialty	Setting	Type of Care	Patient (N)	Trainee (N)	Trainee Postgraduate Year
Anderson, 2013 ²⁹	United States	Cross-sectional study	Prospective	Urology	Operating room	Surgical procedure	100	NR	2
Burgess, 2002 ³⁸	United States	Randomized control trial	Prospective	Otolaryngology	Operating room	Surgical procedure	87	NR	NR
Chai, 2015 ¹³	United States	Quasi-experimental	Prospective	Emergency medicine	Emergency department	Clinical examination	18	NR	2
Chung, 2007 ¹⁴	United States	Quasi-experimental	Prospective	Dermatology	Inpatient consult	Clinical examination	10	1	NR
Daruwalla, 2014 ²²	Singapore	Cohort study	Prospective	Orthopedics	Inpatient consult	Clinical examination and surgical procedure	NR	NR	NR
Filip, 2012 ¹⁵	Czech Republic	Quasi-experimental	Prospective	Neurosurgery	Inpatient consult	Clinical examination	17	NR	NR
Hassan, 2022 ³⁴	United States	Case report/series	Retrospective	Neuro-endovascular surgery	Operating room	Surgical procedure	8	1	NR
Hickman, 2022 ²³	Nepal and South Africa	Cohort study	Prospective	Ophthalmology	Operating room	Surgical procedure	20	12	NR
Joffe, 2006 ³⁰	United States	Cross-sectional study	Prospective	Radiology	Emergency department	Diagnostic test	NR	20	1, 2
Kramer, 2014 ³¹	United States	Cross-sectional study	Prospective	Neurology	Emergency department	Clinical examination	NR	36	2, 3, 4, 5, 6
Lozada, 2018 ²⁴	United States	Cohort study	Prospective	Otolaryngology	Inpatient consult	Clinical examination	79	3	1
Moussa, 2022 ²⁷	United Kingdom	Cohort study	Retrospective	Vitreoretinal surgery	Operating room	Surgical procedure	435	NR	10, 11
Nakhla, 2017 ³⁵	United States	Case report/series	Retrospective	Neurosurgery	Operating room	Surgical procedure	NR	NR	NR
Nami, 2015 ¹⁶	Italy and Austria	Quasi-experimental	Prospective	Dermatology	Outpatient clinic	Clinical examination	391	1	3
Nelson, 2015 ²⁶	United States	Cohort study	Prospective	Dermatology	Inpatient consult	Clinical examination	84	9	1, 2, 3
Ponce, 2014 ¹⁷	United States	Quasi-experimental	Prospective	Orthopedics	Operating room	Surgical procedure	15	20	3, 5
Rafiq, 2004 ³⁶	United States	Case report/series	Retrospective	Surgery	Operating room	Surgical procedure	15	4	NR
Safir, 2015 ³²	United States	Cross-sectional study	Prospective	Urology	Operating room	Surgical procedure	NR	21	2
Scheinfeld, 2003 ³³	United States	Cross-sectional study	Prospective	Dermatology	Emergency department	Clinical examination	51	10	NR
Scheinfeld, 2005 ¹⁸	United States	Quasi-experimental	Prospective	Dermatology	Outpatient clinic	Clinical examination	NR	NR	NR
Sharma, 2016 ²⁸	United States	Cohort study	Prospective	Dermatology	Inpatient consult	Clinical examination	26	8	1, 2, 3, 4
Shore, 2011 ²⁵	United States	Cohort study	Retrospective	Psychiatry	Outpatient clinic	Clinical examination	NR	11	3,4
Steckel, 2003 ¹⁹	United States	Quasi-experimental	Prospective	Radiology	Inpatient consult	Clinical examination	50	2	1
Stetson, 2022 ³⁷	United States	Case report/series	Retrospective	Orthopedic surgery	Operating room	Surgical procedure	NR	NR	NR
Vodovnik, 2018 ²⁰	Norway	Quasi-experimental	Prospective	Pathology	Autopsy room	Autopsy	9	1	1
Wan, 1999 ²¹	United Kingdom	Quasi-experimental	Prospective	Anesthesiology, orthopedics, general surgery	Outpatient clinic	Clinical examination	146	NR	NR

Abbreviation: NR, not reported.

and PGY-10 or 11 (1 of 13, 8%),²⁷ with some studies targeting multiple PGY levels (TABLE 1). For surgical procedures, studies used virtual supervision only for PGY-2 with at least 4 months of training in endourology suites, PGY-3, PGY-5, or fellows.^{17,23,29,32,34} In another study, trainees had to have performed at least 4 endoscopic sinus surgeries in order to participate in virtual supervision.^{27,38}

Synchronous communication between the supervisor and trainee was facilitated through various modalities such as videoconferencing software (15 of 26, 58%),^{17,19,20,23-25,29-34,36-38} telephone (5 of 26, 19%),^{14,15,18,21,22} and mobile apps (5 of 26, 19%)^{13,16,26,28,35} (TABLE 2).

Trainee Education With Virtual Supervision

Virtual supervision offered innovative tools and techniques to enhance trainees' understanding of complex procedures, but its implementation was not without technical challenges. For example, virtual supervision encouraged supervisors to be more specific with their feedback rather than using hand signals or gestures, which helped trainees better understand how to locate anatomical landmarks during flexible cystoscopies.²⁹ Other studies used videoconferencing software with augmented reality features with which supervisors could annotate the live surgical field,^{34,38} virtually "touch" the tissues,¹⁷ or use a screen pointer³⁶ that enhanced the trainees' ability to visualize and understand complex medical procedures. At the same time, technical difficulties, such as the lack of reliable internet connectivity,^{14,23,28} low image quality,^{14,23} low battery life of videoconferencing devices,³⁵ and inability to adjust the frame,^{23,35} posed obstacles to effective teaching.

In 4 studies, virtual supervision provided flexibility in scheduling and location, allowing for increased patient volume in training and trainee autonomy. For example, a toxicology residency program used virtual supervision to work with distant institutions, decreasing the program's reliance on poison control centers and increasing the number of bedside consultations for trainees.¹³ Virtual supervision was also useful for night call, during which supervising radiologists at their home work stations communicated with trainees.¹⁹ Another study explored the use of international teleradiology attending radiologist coverage (ITARC) for a residency program, where radiologists living abroad worked normal daytime hours to cover the night shifts of the home institution.³⁰ On UK bank holidays and weekends, an eye center utilized virtual supervision to supervise trainees performing retinal detachment repair, noting that virtual

supervision facilitated trainees' progression toward increased independence and confidence.²⁷

Virtual supervision also helped increase trainees' exposure to patients in rural or underserved areas while eliminating the burden of travel. One psychiatry residency program used virtual supervision to add an elective during which trainees worked with veterans in rural Colorado.²⁵ The study found that virtual supervision improved patient access to care and may increase the recruitment of qualified psychiatrists to work with rural populations. Finally, 3 studies emphasized that virtual supervision provided additional educational opportunities by allowing trainees to rewatch video recordings taken during virtual supervision to review clinical examination skills and surgical techniques after the patient encounter.^{23,24,29}

Four studies, which assessed educational outcomes based on self-reported questionnaires, found mixed opinions on the satisfaction of virtual supervision by supervisors and trainees.^{30-32,37} Two studies noted a self-reported increase in competency levels of trainees post-virtual supervision and a decrease in stress and anxiety levels related to on-call shifts.^{30,32} Another study indicated that neurology supervisors and their trainees preferred direct supervision to virtual supervision, expressing concerns that telephonic modalities were not sufficient for supervising the trainee's acquisition of patient history and clinical skills.³¹ An additional study on the use of virtual supervision for teaching arthroscopy skills concluded that virtual supervision cannot replace direct supervision for basic surgical and decision-making skills.³⁷

Effect on Patient Care With Virtual Supervision

Studies investigating the quality and effectiveness of patient care communication through virtual supervision reported mixed results (TABLE 2).^{13,15-18,21,22,24,34,38} In some cases, virtual supervision allowed for quick and efficient communication between supervisors and trainees when clinical decisions needed to be made due to the minimal time needed to transmit images and videos.^{16,24} Furthermore, real-time communication between supervisor and trainee improved the precision of the medical history obtained by the trainee, prompting the administration of an additional medication.¹³ Another study suggested that virtual supervision expedited patient care by allowing immediate evaluation and escalation of care, which is crucial for time-sensitive situations such as airway evaluations.²⁴ In other cases, virtual supervision limited the supervisor's ability to observe physical cues and aspects of patient care that are not captured through a screen. For example, one study noted the inability of supervisors to use olfactory and tactile senses during remote autopsies.²⁰

TABLE 2

Technology Used, Objectives, Outcomes, and MMAT Ratings in Included Studies

Study, Year	Technology for Virtual Supervision	Objective	Outcome	MMAT Rating
Anderson, 2013 ²⁹	IES	To report on the use of an IES for RMS of urology residents and evaluate patients' opinions, acceptance, and level of satisfaction with IES and RMS.	Using IES, urologists successfully supervised residents perform flexible cystoscopies. There was a high level of patient acceptance and satisfaction with the use of IES.	4/5 ^a
Burgess, 2002 ³⁸	A roll-about unit with 2 room cameras, 2 monitors, a patient camera, and videocassette recorder	To compare the safety and feasibility of teleproctored endoscopic sinus surgeries with the current standard of care.	Otolaryngologists supervised residents perform endoscopic sinus surgery with a slight increase in surgery time.	3/5 ^{a,b}
Chai, 2015 ¹³	Google Glass	To evaluate the usability of Google Glass for real-time remote toxicology consults.	Toxicologists successfully communicated with emergency medicine residents wearing the Google Glass during bedside evaluation of poisoned patients.	5/5
Chung, 2007 ¹⁴	Dual-band Sprint smart camera scp-5300 pcs phone	To determine whether digital image examinations via cell phones are feasible for inpatient dermatology consults.	There was a high diagnostic concordance rate between the resident and supervising dermatologist when using virtual supervision, although there were technical difficulties such as poor photographic quality and unreliable internet connectivity.	3/5 ^{a,b}
Daruwalla, 2014 ²²	Mobile phone (MyDoc app)	To assess the user satisfaction of MyDoc, a mobile telehealth application that provides a HIPAA compliant form of communication between physicians.	Orthopedic surgeons and residents were highly satisfied with using MyDoc to discuss cases in real time.	4/5 ^a
Filip, 2012 ¹⁵	Mobile phone	To compare the efficacy of mobile phone consultations with standard hospital workstation consultations in spinal injury patients.	There was no difference in evaluation of the location and type of spinal injury or quality of images between mobile phone and workstation consultations.	4/5 ^a
Hassan, 2022 ³⁴	Cloud-based teleproctoring platform (Proximie)	To test if a novel augmented reality teleproctoring platform can be used to guide neuro-endovascular surgeries.	A neurosurgeon successfully used Proximie to guide a fellow through 10 complex procedures without any complications.	5/5
Hickman, 2022 ²³	Skype, iPhone	To evaluate the use of a smart phone for virtual supervision of ophthalmic surgeries between Nepal and South Africa.	It was possible to establish real-time consultation of ocular surgeries between Nepal and South Africa with generally high video quality.	4/5 ^b
Joffe, 2006 ³⁰	IDX radiology information system and Talk Technology voice recognition software	To determine the effects of international teleradiology attending radiologist coverage of radiology residents on night call.	Radiology residents felt that their educational experience was improved via international teleradiology attending radiologist coverage and reported reduced night call-related stress and anxiety.	5/5

TABLE 2

Technology Used, Objectives, Outcomes, and MMAT Ratings in Included Studies (continued)

Study, Year	Technology for Virtual Supervision	Objective	Outcome	MMAT Rating
Kramer, 2014 ³¹	Robotic telepresence through the RP-7 Robot audiovisual platform	To evaluate trainee and faculty members' opinions on robotic telepresence for the management of neurologic emergencies compared to in-person and telephonic communication.	Supervisors and trainees favored in-person communication the most, followed by robotic telepresence, and had the least preference for telephonic communication.	3/5 ^{a,c}
Lozada, 2018 ²⁴	Video recording attachment linked to an iPhone 5	To investigate the impact of smartphone-recorded laryngeal examinations on clinical decision-making of otolaryngology consults.	Otolaryngologists were able to supervise residents perform flexible laryngoscopy through virtual supervision, although there were a few cases in which discordant examination interpretations occurred due to inadequate visualization.	5/5
Moussa, 2022 ²⁷	NR	To determine whether first-year and second-year vitreoretinal fellows can safely conduct macula-on retinal detachments with remote supervision.	The rate of success of rhegmatogenous retinal detachment by vitreoretinal fellows was similar whether supervised in-person or virtually.	5/5
Nakhla, 2017 ³⁵	Google Glass	To assess the applicability of Google Glass as an educational tool for neurosurgical residents.	Supervising neurosurgeons reported that Google Glass was user-friendly and produced adequate video quality. However, the device had a limited battery life and lacked the ability to adjust the field of view.	4/5 ^a
Nami, 2015 ¹⁶	Mobile phone with MugDerma app	To evaluate the efficacy and reliability of a web-based application to remotely supervise of dermatological examinations.	There was a high concordance between face-to-face and store-and-forward diagnosis with a minimal increase in time for dermatologic consultations.	4/5 ^a
Nelson, 2015 ²⁶	AccessDerm mobile platform	To assess the concordance between resident and supervising dermatologists responding to teledermatology consults by primary care providers.	Diagnoses between supervising dermatologists and residents were fully concordant for 53% of dermatological conditions, while management was fully concordant 65% of the time.	4/5 ^a
Ponce, 2014 ¹⁷	VIP platform	To assess the feasibility of using VIP technology in telementoring surgeries.	Supervisor and trainees favorably rated the utility of the VIP. The surgical team felt that VIP did not compromise patient safety and the efficiency of the procedures.	5/5
Rafiq, 2004 ³⁶	An interactive telementoring system (Socrates System)	To assess the use of videoconferencing to help trainees locate anatomical landmarks during thyroidectomies.	Surgical trainees were able to locate anatomic landmarks during thyroidectomies for more than 90% of the time using videoconferencing.	5/5
Safir, 2015 ³²	IES	To determine the impact of RMS on residents' achievements of endoscopic training milestones.	Residents expressed a high level of acceptability and satisfaction with RMS and reported a self-perceived increase in their competency levels.	5/5

TABLE 2

Technology Used, Objectives, Outcomes, and MMAT Ratings in Included Studies (continued)

Study, Year	Technology for Virtual Supervision	Objective	Outcome	MMAT Rating
Scheinfeld, 2003 ³³	Nikon Coolpix 990 camera and Dell GX 110 computer	To evaluate patient acceptance and satisfaction with a teledermatology system.	Patients' acceptance of teledermatology was generally high, although some felt self-conscious with the presence of a camera or having pictures taken of their face.	3/5 ^{a,c}
Scheinfeld, 2005 ¹⁸	Telephone	To evaluate the effect of the teledermatology system on physician workflow and satisfaction.	There was a 96% concordance rate in differential diagnoses and disposition plans between supervising dermatologists and residents.	4/5 ^a
Sharma, 2016 ²⁸	Inpatient teledermatology smartphone and internet-based application	To measure the time taken to complete inpatient dermatology consultations when using teledermatology.	Teledermatology reduced the time needed for a primary team to receive a response from an inpatient dermatology consultation.	5/5
Shore, 2011 ²⁵	Desktop and room-based videoconferencing units	To assess the telehealth training program at the Denver Veterans Affairs created to expand care for patients in rural areas.	Training in telepsychiatry helps residents develop skills to deliver psychiatric treatment remotely for patients in rural areas. Resident telepsychiatry services may help increase recruitment and retention of qualified psychiatrists who are willing to work with rural veterans and rural populations.	3/5 ^{c,d}
Steckel, 2003 ¹⁹	Teleconferencing software	To compare virtual and in-person supervision of radiology residents on overnight call.	There was no significant difference between the amount of clinical information added through teleconferencing or direct supervision on images taken overnight.	4/5 ^a
Stetson, 2022 ³⁷	Telesurgery tower and platform (SurgTime)	To describe the technique of telesurgery mentoring for teaching arthroscopic surgery skills.	The telesurgery platform was successfully used to establish real-time interaction between supervisor and trainee, although telesurgery mentoring cannot replace basic surgical skills.	4/5 ^a
Vodovnik, 2018 ²⁰	Double encrypted video link, laptops with in-built cameras, web camera	To determine the feasibility of remote autopsy supervision.	Supervisors and trainees reported a high level of satisfaction with remote autopsies. There was full agreement in gross findings between remote and in-person supervisors.	5/5
Wan, 1999 ²¹	Videoconferencing system and telephone	To evaluate the use of videoconferencing for anesthesiology, orthopedic surgery, and general surgery trainees in a London hospital practice.	There was a high level of acceptance among patients, medical personnel, and trainees involved in teleconsultation.	3/5 ^{a,c}

^a Limitation in accounting for confounding factors.^b Limitation in sampling strategy.^c Lack of appropriate outcome measurement.^d Limitation in study sample.

Abbreviations: MMAT, Mixed Methods Appraisal Tool; IES, integrated endourology suite; RMS, remote monitoring and supervision; NR, not reported; VIP, virtual interactive presence.

Three studies assessed the agreement in diagnosis and treatment plan between supervisors and trainees when using virtual supervision, reporting a kappa coefficient ranging from 0.747 to 0.94.^{16,24,26} In one study, 6% of discordant laryngoscopy examinations required changes in clinical management.²⁴ Another study reported a lower diagnosis concordance rate for complex skin conditions when using images to transmit clinical information.¹⁶ It is noteworthy that the absence of an independent grader²⁴ may have influenced the concordance rate, and technological limitations may have influenced the supervisor's assessment.^{16,24,26}

Only 3 studies examined patient care outcomes when comparing direct supervision and virtual supervision.^{18,27,34} These studies noted no adverse events or significant difference in patient outcomes between direct supervision and virtual supervision when comparing the complication rates of retinal detachment repairs,²⁷ complication rates of complex neuroendovascular procedures,³⁴ and differential diagnoses and disposition plans in dermatology.¹⁸

In some cases, there was an increase in time spent on patient care for virtual supervision compared to direct supervision.^{15-17,38} Reasons included technical difficulties, set-up time, and increased didactic teaching when using virtual supervision.

Patient Satisfaction

Several studies surveyed patient satisfaction with care provided when virtual supervision was utilized^{13,21,23,28,29}; however, none of these studies explicitly compared patient satisfaction between virtual supervision and in-person supervision. Most patients felt comfortable with the images and videos being taken during their clinical examinations and did not feel that their privacy was compromised.^{13,29} Some patients felt that they were getting a more thorough and careful examination due to the supervision of a more experienced physician.²⁹

Study Quality

The MMAT was used to critically appraise the quality of the included studies. Limitations were noted in sampling strategy,^{14,23,25,38} outcome measurement,^{21,25,31,33} and inclusion of confounding factors.^{14-16,18,19,21,22,26,29,31,33,35,37,38} Overall, 10 studies scored a 5 out of 5,^{13,17,20,24,27,28,30,32,34,36} 10 studies scored a 4 out of 5,^{15,16,18,19,22,23,26,29,35,37} and 6 studies scored a 3 out of 5 (TABLE 2).^{14,21,25,31,33,38}

Discussion

We systematically reviewed 26 studies to assess the impact of virtual supervision on trainee education,

patient care, and patient satisfaction in GME. Virtual supervision was used across several medical specialties and PGY levels for clinical examinations and surgical procedures, employing communication channels such as telephone, videoconferencing software, and mobile apps. The existing evidence base suggests that virtual supervision in GME has potential to promote communication, facilitate trainee autonomy, and expand educational opportunities by allowing collaboration between clinicians who are geographically distant. However, technical difficulties posed obstacles to effective patient care and communication, including limitations in conveying certain aspects of patient care (eg, autopsies that require olfactory and tactile senses and differentiating complex skin conditions) that necessitate physical presence.

Addressing Gaps in the Evidence Base

The evidence base for virtual supervision in GME could be strengthened in several areas. First, many studies had methodological limitations such as lack of control groups, small sample sizes, and nonrandomized study designs, which made it difficult to generalize the results to larger populations. Studies often utilized surveys lacking robust validation and reported self-perceived educational outcomes of trainees, which can be unreliable and subjective.^{39,40} Furthermore, most studies had a duration of less than 6 months and did not assess the long-term impact of virtual supervision on resident learning or patient outcomes. Finally, although our search strategy encompassed all GME specialties and subspecialties, we found a lack of primary studies for certain fields, including OB/GYN, pediatrics, physical medicine and rehabilitation, family medicine, and internal medicine. Longitudinal, randomized, and larger-scale studies can help ensure that the available evidence is more comprehensive and reliable.

In addition, we suggest that future research explore the following questions:

1. When is the use of virtual supervision not appropriate due to its potential risks to patient care? As highlighted in the arthroscopy study,¹³ this question is especially important in surgical education, and can inform the development of more detailed ACGME supervision criteria.
2. What are appropriate levels of clinical experience for a trainee for virtual supervision and how may this vary across specialties? Many studies did not report the PGY levels of the trainees, which render preliminary understanding of these questions challenging. Comparing the use of virtual supervision across various PGY levels can provide insight into how virtual supervision can be

effectively incorporated into GME at various stages of training.

3. What is the relationship between varying amounts of virtual supervision and its impact on trainee education and patient outcomes? Achieving an appropriate balance between in-person and virtual supervision can ensure that trainees receive adequate clinical experience while also benefiting from the flexibility and efficiency of virtual supervision.
4. What is the cost-effectiveness of virtual supervision? This is important given the high cost of various teleconferencing devices and software systems.³⁸

Implications for GME

The findings of this systematic review can assist ACGME review committees and the VA in updating their guidelines for virtual supervision in GME. Establishing minimum requirements for face-to-face interactions between supervisors and trainees before utilizing virtual supervision will promote supervisor-trainee relationships and establish clear expectations and goals for virtual supervision. In addition, virtual supervision may be better suited for more experienced trainees, allowing them to work more independently.^{17,34} Hence, we recommend programs specify competencies that trainees must demonstrate via direct supervision before transitioning to virtual supervision. Additionally, comprehensive guidelines covering topics such as emergency procedures, device usage, troubleshooting, and effective communication techniques can also be useful, as supervisors and trainees often experience a learning curve when using virtual supervision.³⁸

Limitations of the Systematic Review

This review has several limitations. First, we excluded articles published in languages other than English and gray literature, such as conference proceedings. Second, we did not hand-search references of included studies. Third, the reproducibility of MMAT ratings is limited by the authors' judgements about the quality of the study design. Fourth, we did not explore databases such as PsychINFO, potentially overlooking relevant studies. Finally, the kappa coefficient for screening was low, indicating a possibility of missing relevant citations. However, we conducted a screening training and screening test session beforehand to mitigate bias and subjectivity.

Conclusions

This systematic review found that virtual supervision is generally technologically feasible and applicable in a wide range of specialties, trainee levels, and settings. Virtual supervision may have benefits such as

increased training opportunities, trainee autonomy and communication, and can be particularly useful in the later stages of training. However, to ensure effective trainee education, future studies should employ large sample sizes, objective outcome measures, and rigorous methodology to expand the evidence base.

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