Evaluating performance: a scoping review on video-based assessments of non-technical skills in the operating room

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Abstract

Background: **Patient safety remains a critical concern in the high-stakes environment of the operating room (OR). Human factors and non-technical skills (NTS) play pivotal roles in surgical performance and in preventing errors. Various assessment tools and methodologies have been developed to evaluate NTS among OR personnel, reflecting the growing recognition of their importance.**

Objectives: **To map and analyze NTS among OR personnel during real-life surgeries using medical video recording systems and to evaluate NTS assessment tools described in existing literature.**

Methods: **Four databases, PubMed, Web of Science, Medline and Embase, were searched for relevant studies. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol was followed. Eligibility criteria included studies focusing on video recordings providing an overview of the entire OR with a focus on NTS.**

Results: **Twenty-four articles were included in this scoping review. A total of eight NTS were assessed, most frequently communication (79%), leadership (54%), teamwork (50%) and situational awareness (50%). Observational methods varied, ranging from one or more cameras to more sophisticated medical data recorders, such as the OR Black Box (ORBB). Additionally, a wide variety of assessment methods were used, mostly validated tools (NOTSS, SPLINTS, ANTS), but also broader systems-based frameworks (SEIPS) or self-developed tools.**

Conclusions: **This scoping review highlights the diverse methodologies used to measure NTS in the OR using medical video recordings, indicating a need for further research to address challenges and standardize practices. Despite the proven potential benefits of video recording in the OR, legal, ethical and logistical challenges may serve as possible barriers to actual implementation.**

Keywords: **Video Recording, Operating Rooms, Interpersonal Skills, Communication, Leadership.**

Introduction

In a high-stakes environment like the operating room (OR), patient safety and high-quality care are fundamental. Despite the introduction of improvement initiatives, the incidence of preventable errors remains high[1-5]. According to research, 30-65% of all in-hospital adverse events occur in the OR[5-9] and up to 30-50% of these events are considered preventable[2,8-14].

The landmark publication 'To Err is Human' advocated to develop a safety culture to enhance patient safety, rather than blaming individuals, using a systems approach. This has been widely accepted as it recognizes the inevitability of human error[11,15,16]. This 'systems approach' intertwines with the concept of 'human factors'[11,16-20]. Human factor studies accept the fact that human error can never be fully eliminated and that performance of individuals and teams may deteriorate in high-pressure situations[20-23]. Human factors include – but are not limited to – a set of non-technical skills (NTS) such as communication, situational awareness, decision making, teamwork and leadership. These cognitive and social skills are proven to impact technical skills and patient safety[22,24-33]. Up to 70% of adverse events in hospitalized patients are caused by human error and almost half of surgical errors are – to at least some degree – due to failing NTS[12,13,34-37]. It is considered that, while human behavior can be a potential source of error, humans also possess unique abilities to adapt, learn and improve. Strong communication, situational awareness and other NTS can enhance safety and contribute to resilience[15,27,38,39].

Extensive efforts to quantify NTS have been undertaken. Measurement tools are vital for identifying deficiencies, guiding training programs and providing a structured framework for feedback and evaluation of NTS-related interventions. Available tools consist of domain-specific taxonomies of observable behaviors and can be evaluated by an independent observer. Examples are: ANTS (Anesthetists' Nontechnical Skills) for anesthetists[24,40], NOTSS (Nontechnical Skills for Surgeons)[41] for surgeons, SPLINTS (Scrub Practitioner's List of Intraoperative Nontechnical Skills)[42] for scrub nurses, and NOTECHS (Oxford Nontechnical Skills)[43] for surgical teams in general. Additionally, other models are more focused on human factors in general, like SEIPS (Systems Engineering Initiative for Patient Safety)[44].

Traditionally, observational field studies to assess NTS, have been performed by live observers. In recent years, however, video recordings have been increasingly used. Drawing inspiration from the aviation industry, where black box recordings have been used for safety investigations, healthcare is adopting a similar approach[45,46].

Acknowledging the crucial influence of human factors and NTS on surgical safety and patient outcomes, underpins the necessity for precise assessment and improvement strategies. This scoping review aims to map and analyze the range of NTS assessed among OR-personnel during real-life surgeries using medical video recording systems, and to evaluate the methodologies and tools used for this assessment in existing literature.

Methods

A scoping review was completed following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for Scoping Reviews (PRISMA-Scr; Figure 1)[47].

Research question

The assessment of NTS of OR-personnel during surgery using video recordings has been reviewed. The studied population consists of OR-staff present during surgery. The exposure is the placement of video recorders in the OR, recording an overview of the entire OR during real-life surgery. The outcomes include the range of NTS assessed during these recordings and the measurement tools used to assess them.

Literature search

A provisional search using the search term 'black box in the operating room' was conducted in PubMed, resulting in 47 articles. The Yale MeSH Analyzer was then used to extract common Medical Subject Headings (MeSH) and keywords from the articles that were considered most relevant on initial screening. The literature search was conducted in PubMed, Medline, Web of Science and Embase. The search question was divided into three parts: exposure, population and outcome. For exposure, examples are: 'video recording, videotape, black box, medical data recording'. For population, examples are: 'operating room, operation theatre, hybrid room, surgery, intraoperative'. For outcome: 'non-technical, communication, decision making, leadership, situation awareness.'. Boolean operators were used to combine these searches, as well as MeSH-terms, subject headings and field tags. A detailed version of the applied search strategy can be found in Appendix 1. A first search was conducted on 01/07/2023 and repeated on 10/03/2024 to be able to include the most recent articles.

Eligibility criteria

After defining the research question, the inclusion and exclusion criteria were established to select articles needed to answer the question. The criteria can be found in Table I.

Scoping review

A scoping review was considered appropriate for this article, given that (a) the goal of this work is to explore a broad topic, namely, identifying the role of video recordings in assessing non-technical skills during real-life surgery, (b) the nature of this topic and the available studies include an enormous heterogenicity in study design and outcomes, which makes a systematic literature review less preferable, and (c) one of the topics for discussion was to envisage where gaps and innovative approaches regarding this topic may lie[48].

Statistics

Interrater reliability (Cohen's Kappa) was calculated using IBM SPSS Statistics for Windows, version 29 (IBM Corp., Armonk, NY) as described by McHugh[49].

Table I. — Summary of inclusion and exclusion criteria for study selection.

INCLUSION
• Video recordings (with/without audio) with an overview of the entire OR • Stored or live recordings • During real-life anesthesia and/or surgery • Focus on non-technical skills and/or human factors • English language • Publication year 2000 or later • Humans
EXCLUSION
• No full text available • Only audio recordings • Only recordings of the surgical field • Study population < 10 cases • Simulations • Recordings in post anesthesia care units • Case reports, conference papers, correspondences and editorials Interviews, master's and PhD dissertations

Results

Article selection

For this systematic search, four databases were explored. This comprehensive search yielded a total of 4835 articles. All results were uploaded into Rayyan[50] and after removing duplicates, a total of 3539 articles remained, each of which underwent screening based on their titles and abstracts by two researchers separately (CV and BB). In 97.5% of the articles, there was an immediate inter-rater agreement. For 87 articles consensus was reached only after discussion. Subsequently, 117 articles were identified as potentially relevant and were retrieved for detailed evaluation. All 117 articles were reviewed by CV and 23 randomly selected articles underwent review by BB as well. This resulted in an interrater agreement of 87% and Cohen's Kappa of 0.742 (95% CI, 0,60 – 0,99), $p < 0.01$, which suggests a moderate to strong level of agreement. Upon full-text review, 24 articles were deemed eligible for inclusion. This process is summarized in the PRISMA flow diagram (Figure 1).

Study characteristics

All 24 articles had a prospective, observational study design and all but one were performed in a single center. A quantitative and qualitative research methodology was adopted in 42% (n=10) and 21% (n=5) of the cases, respectively. A mixed methods approach occurred in 37% (n=9) of all articles. In half of the studies, the OR Black Box® (Surgical Safety Technologies, Toronto, Canada) was used. A single camera with an OR overview was used in five articles, while multiple overview cameras were used in six articles. One did not specify the type of recording equipment used[51]. All researchers recorded audio as well. Study samples varied from 10 (inclusion criteria) to 144 with a total of 727 cases. Only four articles were older than ten years. All articles originated from either American or European sources, 14 and 10 respectively. Among all studies, 14 exclusively investigated laparoscopic surgery, four encompassed both laparoscopic and open surgery and three focused on endovascular surgery. These findings are presented in Table II and Appendix 2.

Video-based observations

Recent advancements in recording methodologies are evident in the articles reviewed. Earlier studies often used one or occasionally several separate cameras, but sophisticated systems have become more prevalent in recent years. The OR Black Box (ORBB) was launched in 2013 in Canada[52]. The earliest article using the ORBB included in this review was published six years ago, with all articles since 2021 employing this technology (Figure 2). The ORBB captures and synchronizes several sources of audio-visual and procedural data for analysis by experts and artificial intelligence algorithms. This technology is used to analyze errors and events during laparoscopic, endovascular and open surgery across various specialties[46,53,54].

Available validated measurement tools

Before exploring the included articles, some commonly used measurements tools should be clarified. Their abbreviations are once more explained in Table III for clarification. ANTS, NOTSS and SPLINTS respectively categorize anesthetists', surgeons' and scrub nurses' NTS into four categories, scoring them from 1 to 4, though behaviors are sometimes just counted[24,40-42]. Categories differ slightly across specialties.

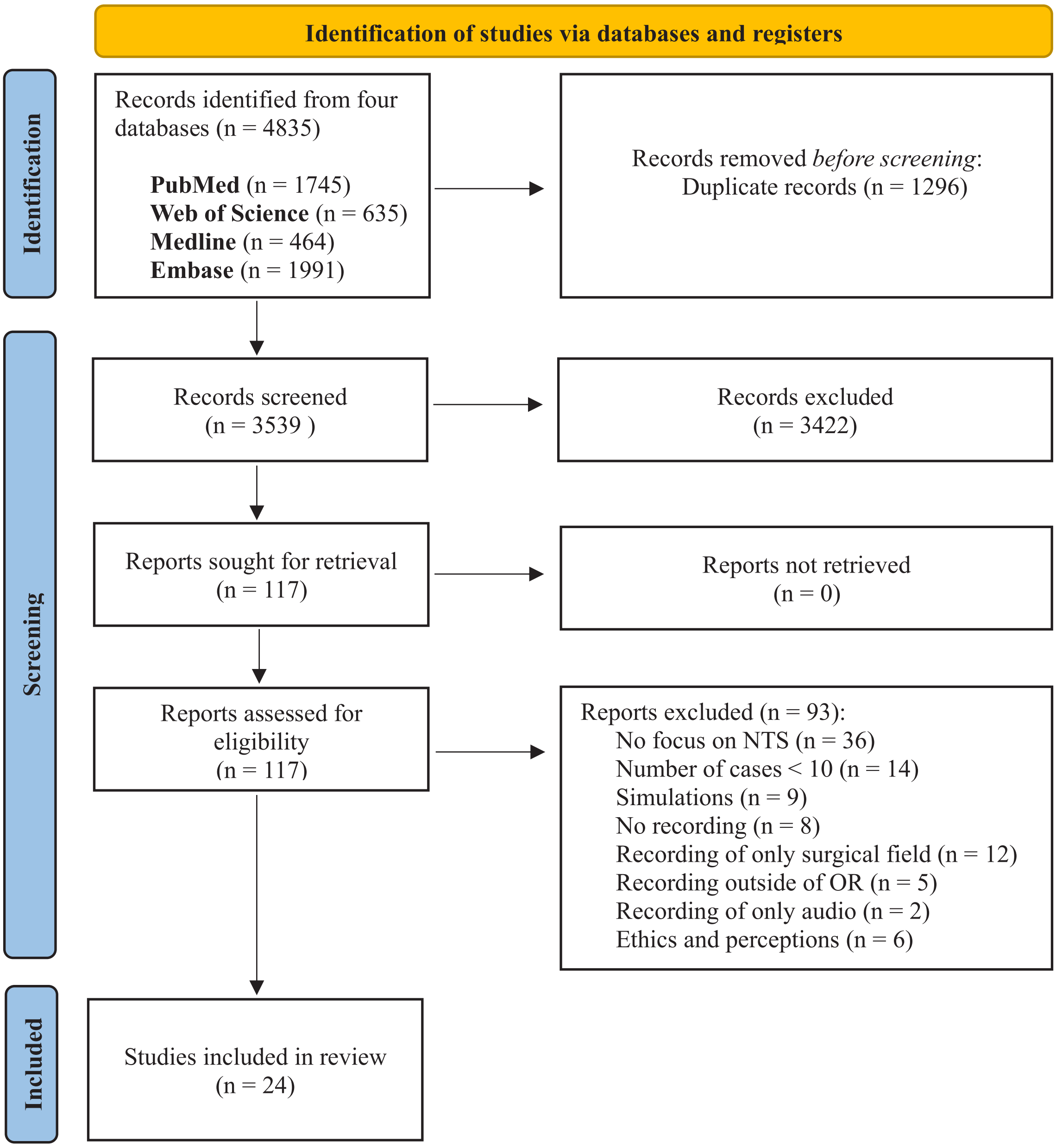

Fig. 1 — PRISMA flowchart.

NOTECHS explores teamwork within the OR and contains four categories. Additionally, this tool studies three different sub-teams: anesthetists, surgeons and nurses. Consequently, scores range from 12 to 48[43]. These tools are elaborated upon in greater detail in Appendix 3.

Assessed non-technical skills and their measurement

The included articles explored a diverse range of NTS within the operating theater. Across 24 studies, a total of eight distinct NTS were identified, with several articles addressing multiple NTS. The most explored NTS were Communication (79%, n=19), Leadership (54%, n=13), Teamwork (50%, n=12), Situational awareness (50%, n=12) and Decision making (42%, n=10). These findings are represented below (Figure 3).

An overview of the NTS explored and the assessment tools used is described below and presented in Table II.

1) Communication

Communication was identified as the predominant NTS of interest. Notably, seven articles almost exclusively focused on communication[39,55-60]. Additionally, twelve articles investigated communication among other NTS, often integrated into specific tools or frameworks[27,28,52,61-69].

Different approaches to study communication were identified. Bleakley et al. and Santos et al. developed a self-developed typology to classify and count communication types (requests, reports, questions)[39,55]. Santos et al. investigated dyads to identify communication recipients[39]. The first study noted that requests outnumbered reports, indicating

Table II. — Included articles with: article identification, sample size, study goal, type of study, type of recording, assessed non-technical skills, metrics and applied tools/frameworks.

Author Year + country	N° cases	Goal	Study type	Recording type	Assessed non-technical skill (+ Team member)	Metrics	Tool/Framework
Bleakley et al.[55] 2012 UK	13	To look at interaction (communication exchange patterns in the form of reports and requests) across all surgical team members to develop situation awareness.	Prospective Observational [Qualitative]	Video + Audio > 3 wall-mounted cameras	Communication (S+A+N)	Frequency of Communication exchanges	Self-developed communication typology (10 types of exchanges)
Van Dalen et al.[61] 2022 The Netherlands	35	To analyze safety threats (ST) and resilience support events (RS) during surgery + to identify the most frequently discussed safety and quality improvement issues during the postoperative multidisciplinary debriefing sessions.	Prospective Observational Cross-sectional [Mixed methods]	Video + Audio > Black box	Situational awareness (T) Communication (T) Teamwork (T) Decision making (T) Leadership (T)	Frequency of Behaviors per scale element (positive or negative) Postoperative debriefing	SEIPS
Boet et al.[80] 2021 Canada	50	To characterize teamwork: using 2 conventional tools (NOTECHS, TEAM) and one alternative approach (SEIPS) and exploring advantages and disadvantage of each.	Prospective Observational [Mixed methods]	Video + Audio > Black box	Teamwork (T)	Scores of NTS-elements - NOTECHS - TEAM Frequency of Behaviors per scale element (positive or negative)	NOTECHS TEAM SEIPS
Sexton et al.[62] 2018 USA	12	To investigate how anticipation of surgical steps and familiarity between team members impact operative time and number of inconveniences (as a proxy for OR efficiency) and cognitive workload.	Prospective Observational [Quantitative]	Video + Audio > 3 cameras for whole OR + video feed from surgical console	Anticipation (T) Teamwork (T) Communication (T)	Frequency + duration of Requests (verbal/non-verbal) Anticipation ratio Frequency of Inconveniences Duration of Surgery	Self-developed framework

Table II. (continued) — Included articles with: article identification, sample size, study goal, type of study, type of recording, assessed non-technical skills, metrics and applied tools/frameworks.

Doyen et al.[52] 2023 Belgium	22	To analyze technical, non-technical and radiation safety performance of teams during 2 types of endovascular procedures + evaluate environmental influences which may affect performances using a new comprehensive data capturing system.	Prospective Observational Cohort [Mixed methods]	Video + Audio > Black box	Leadership (S) Decision making (S) Situational awareness (S+N) Communication & teamwork (S+N) Task management (N)	Scores of NTS-elements - NOTSS - SPLINTS Frequency of Behaviors per scale element (positive or negative)	NOTSS SPLINTS
Guerlain et al.[75] 2004 USA	10	To develop and utilize a digital recording and analysis system to monitor intraoperative performance (i.e. technical performance and errors, situational awareness and comfort/satisfaction with procedures).	Prospective Observational [Mixed methods]	Video + Audio > RATE software, including 4 cameras: room + overhead + physiologic screen + laparoscopic view	Situational awareness (S+A+N)	Scores (%) on Questionnaires (verified by recordings and charts)	Self-developed situational awareness tool (post-procedure questionnaire, 15 questions)
Santos et al.[39] 2011 Portugal	10	To analyze and characterize cross-professional communication flow (frequency, direction, type, content and pattern) + factors influencing communication in pediatric cardiac surgery.	Prospective Observational [Mixed methods]	Video + Audio > 1 camera at the feet of the patient	Communication (S+A+N)	Frequency + direction of Communication exchanges (from/to) Description of Communication exchanges: (Content and Pattern)	Self-developed communication typology (6 types of exchanges)
Rydenfält et al.[71] 2014 Sweden	10	To explore leadership behaviors and its distribution among different professions in the OR + to test whether a distributed leadership approach leads to any difference compared to the traditional leadership-centered approach.	Prospective Observational [Qualitative]	Video + Audio > 1 camera in a corner	Leadership (S+A+N)	Frequency of Leadership behaviors	Self-developed leadership typology (9 behaviors)
Parker et al.[51] 2013 UK	29	To identify surgeons' intraoperative leadership behaviors, with reference to the effect of intraoperative events on leadership, for both attending surgeons and residents.	Prospective Observational [Quantitative]	Video + Audio > N/A	Leadership (S)	Frequency + direction of Leadership behaviors (from/to)	Surgical Leadership Inventory (SLI) (8 behaviors)

Table II. (continued) — Included articles with: article identification, sample size, study goal, type of study, type of recording, assessed non-technical skills, metrics and applied tools/frameworks.

Frasier et al.[56] 2019 USA	10	To evaluate the relationship between team familiarity, communication rates and communication ineffectiveness in the OR.	Prospective Observational [Quantitative]	Video + Audio > 1 GoPro camera mounted on a mobile pole + audio-video recording glasses for operative field	Communication (S+A+N)	Frequency + direction of Communication exchanges (from/to) Familiarity scores of Dyads	Self-developed framework
Etherington et al.[63] 2022 Canada	25	To explore both positive and negative use of non-technical skills by anesthesiologists.	Prospective Observational [Mixed methods]	Video + Audio > Black box	Situational awareness (A) Communication & teamwork (A) Decision making (A) Leadership (A) Task management (A)	Frequency of - Behaviors per scale element (positive or negative) - Safety threats	Self-developed Teamwork Behaviors Framework (based on ANTS and BARS) (SEIPS)
Kunkes et al.[64] 2020 USA	10	To examine how the surgical team's hierarchical relationships affect the frequency and timing of risk communication and their influence on situational awareness in the OR.	Prospective Observational [Quantitative]	Video + Audio > 3 ceiling-mounted cameras	Communication (S+N) Situational awareness (S+N)	Frequency of Utterances (general + risk) Direction + Timing of Utterances (high/low status) (pro- or reactive) Scores of NTS-elements - NOTECHS (only situational awareness element)	NOTECHS (situ-ational awareness)
Sharma et al.[65] 2020 Canada	144	To identify risk factors (for example NTS) associated with intraoperative device-related interruptions.	Prospective Observational Cohort [Quantitative]	Video + Audio > Black box	Leadership (S) Decision making (S) Situational awareness (S+N) Communication & teamwork (S+N) Task management (N)	Frequency of Behaviors per scale element (positive or negative)	NOTSS SPLINTS
Rai et al.[66] 2021 USA	80	To determine the frequency and characteristics of intraoperative adverse events (IAE's) and environmental distractions + the role of non-technical skills potentially mitigating the effects of IAE's and distractions.	Prospective Observational Cohort [Quantitative]	Video + Audio > Black box	Situational awareness (S+A+N) Communication & teamwork (S+A+N) Decision making (S+A) Task management (A+N) Leadership (S)	Frequency of Behaviors per scale element (positive or negative)	NOTSS SPLINTS ANTS

Table II. (continued) — Included articles with: article identification, sample size, study goal, type of study, type of recording, assessed non-technical skills, metrics and applied tools/frameworks.

Fecso et al.[28] 2018 Canada	56	To explore the relationship between technical and non-technical performance of surgical and nursing teams during surgery.	Prospective Observational Cohort [Mixed methods]	Video + Audio > Black box	Leadership (S) Decision making (S) Situational awareness (S+N) Communication & teamwork (S+N) Task management (N)	Frequency of Behaviors per scale element (positive or negative)	NOTSS SPLINTS
Ivarsson et al.[57] 2019 Sweden	12	To investigate how requests (during apnea sequences) help organize the coordination of interprofessional communication + to describe instances of potential miscommunication to scrutinize how repairs are used to address and prevent mistakes.	Prospective Observational [Qualitative]	Video + Audio > 1 ceiling-mounted camera	Communication (S+A+N) Coordination (S+A+N)	Frequency of Requests and repairs (verbal) Examples of Communication models during requests (transcription)	Conversation analysis
Soenens et al.[72] 2023 Belgium	22	To assess the relationship between surgeons' leadership style and team behavior + to study possible fluctuations in leadership styles and team behavior during operative phases.	Prospective Observational [Quantitative]	Video + Audio > Black box	Leadership (S) Teamwork (T)	Scores of BARS-elements - Leadership style - Team behaviors	Self-developed Behavior Anchored Rating Scales (BARS) (6 elements)
Kolodzey et al.[67] 2020 Canada	19	To identify and categorize system factors that have the potential to either threaten patient safety or support system resilience.	Prospective Observational [Mixed methods]	Video + Audio > Black box	Situational awareness (T) Communication (T) Teamwork (T) Decision making (T) Leadership (T)	Frequency of Behaviors per scale element (positive or negative)	SEIPS
Adams-McGavin et al.[27] 2021 The Netherlands	24	To determine the characteristics and frequency of intraoperative safety threats and resilience supports using a human factors measurement tool.	Prospective Observational Cross-sectional [Quantitative]	Video + Audio > Black box	Situational awareness (T) Communication (T)	Frequency of Behaviors per scale element (positive or negative)	SEIPS
Emmerton-Coughlin et al.[58] 2017 Canada	40	To investigate verbal and physical control strategies in laparoscopic surgical training, with particular emphasis on the role of deictic language, in order to enhance learning and improve patient safety.	Prospective Observational [Qualitative]	Video + Audio > 1 camera with an OR overview + laparoscopic view	Communication (S)	Examples of Verbal and physical strategies + bidirectional communication (transcription)	Multimodal interaction analysis

Table II. (continued) — Included articles with: article identification, sample size, study goal, type of study, type of recording, assessed non-technical skills, metrics and applied tools/frameworks.

Bezemer et al.[59] 2015 UK	20	To examine how the dynamic and often temporary composition of surgical teams impacts both communication patterns and learning opportunities among nurses and surgeons.	Prospective Observational [Qualitative]	Video + Audio > 2 tripod-mounted cameras	Communication (S, N)	Examples of Communication models during requests (transcription)	Multimodal interaction analysis
Incze et al.[68] 2024 Canada	23	To identify how surgical team members uniquely contribute to teamwork and adapt their teamwork skills during instances of uncertainty.	Prospective Observational [Mixed methods]	Video + Audio > Black box	Coordination (S+A+N) Communication (S+A+N) Decision making (S+A+N) Leadership (S+A+N) Teamwork (S+A+N) Situational awareness (S+A+N)	Frequency of Behaviors per scale element	Self-developed Teamwork Skills Framework (based on existing tools, like NOTSS, NOTECHS, OTAS, etc.) (6 themes, 16 sub-themes)
Nensi et al.[69] 2021 Canada	25	To identify and characterize intra-operative distractions, errors and threats, as well as the non-technical skills of the team during common procedures.	Prospective Observational Cross-sectional [Quantitative]	Video + Audio > Black box	Situational awareness (S+A+N) Decision making (S+A) Task management (A+N) Leadership (S) Communication & teamwork (S+A+N)	Frequency of Behaviors per scale element (positive or negative)	NOTSS SPLINTS ANTS
Raheem et al.[60] 2018 USA	26	To investigate and analyse the different ways surgeons communicate with bedside assistants during robot-assisted surgery.	Prospective Observational [Quantitative]	Video + Audio > 3 cameras with aerial view	Communication (S)	Frequency of - Requests (verbal) - Acknowledgments (verbal) - Inconveniences Duration of Time between request and execution of the task	Self-developed framework

SEIPS: Systems engineering initiative for patient safety; NOTECHS: Oxford Non-technical skills; TEAM: Team emergency assessment measure; NOTSS: Non-technical skills for surgeons; SPLINTS: Scrub practitioners' list of intraoperative non-technical skills; SLI: Surgical Leadership Inventory; ANTS: Anesthetists' non-technical skills; BARS: Behaviorally anchored rating scale; OTAS: Observational Teamwork Assessment for Surgery; (S): Surgeon; (A): Anesthetist; (N): Nurse; (T): Whole team without specification; NTS: Implicitly evaluated NTS, without explicit mentioning in the article.

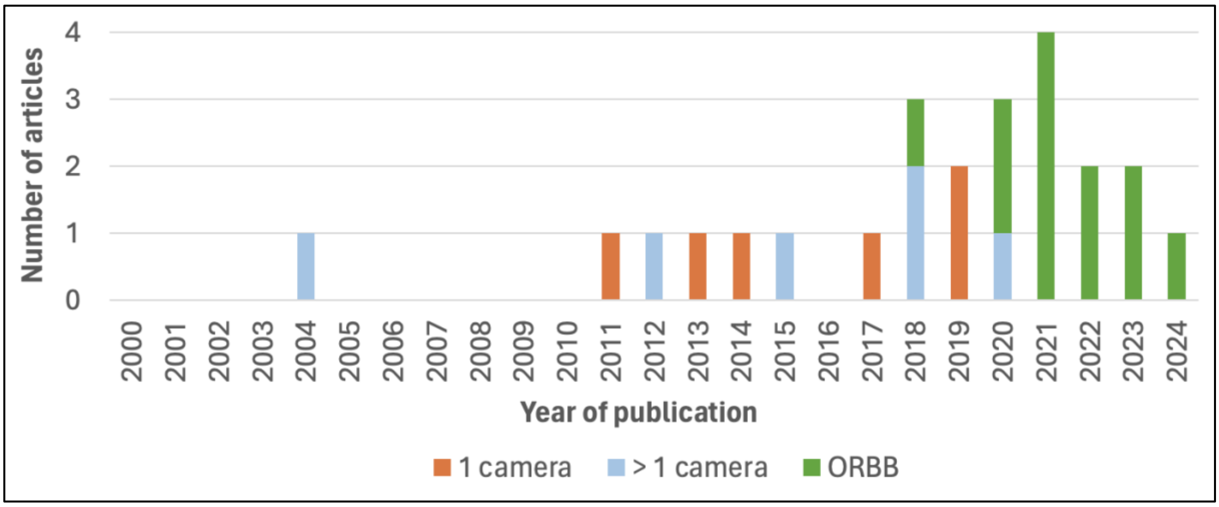

Fig. 2 — Annual distribution of published articles assessing non-technical skills in the operating room according to video recording method: single camera, multiple cameras and the operating room black box (ORBB).

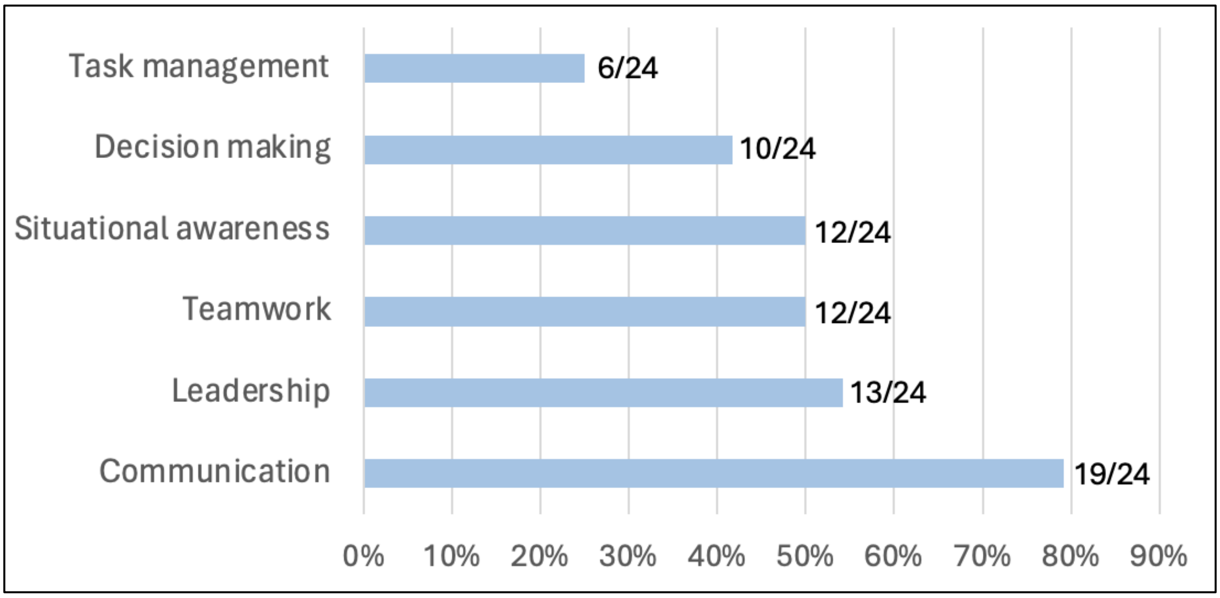

Fig. 3 — Six most commonly reported non-technical skills and the total count and percentage of included articles reporting them.

a surgeon-dominated climate[55]. The second study stated that most of the exchanges occurred between the main surgeon and either the scrub nurse or the first surgical assistant. Additionally, only 5% of the exchanges occurred between the main surgeon and the anesthetist. However, these infrequent interactions often contained the most critical content[39]. Ivarsson et al. used conversation analysis to highlight the importance of conversational repairs to avoid misunderstandings[57]. Similarly, Emmerton-Coughlin et al. and Bezemer et al. employed multimodal interaction analysis to include non-verbal communication[58,59,70]. The former study revealed that, in laparoscopic surgery, verbal deixis is the dominant control strategy and that it is prone to ambiguity. Two strategies used by educators to reduce chances of misunderstanding were combining deictic instructions with physical maneuvers or completely taking over surgery[58]. The latter study investigated how surgeons responded to clarification requests from newly appointed staff, showing both elaborate explanations to maximize learning and minimal responses to focus on the task. They suggest that policies should ensure that local knowledge is explicitly shared to support effective teamwork and patient safety[59]. Frasier et al. counted communication exchanges and dyads[56], noting that a lack of team familiarity did not increase communication, and inter-disciplinary communication occurred less frequently and was more prone to ineffectiveness compared to intra-disciplinary communication[56]. These findings are in line with the results presented by Santos et al.[39]. Raheem et al. counted and categorized the surgeons' verbal requests during robot-assisted surgeries, demonstrating that specific requests led to fewer inconveniences and a reduced the need for repeated requests, which in turn may contribute

Table III. — Common abbreviations and terminologies.

ANTS	**A**nesthetist's' **N**on-**T**echnical **S**kills[24,40]
NOTSS	**No**n-**T**echnical **S**kills for **S**urgeons[41]
SPLINTS	**S**crub **P**ractitioner's **L**ist of **I**ntraoperative Non-**T**echnical **S**kills[42]
NOTECHS	Oxford **NO**n**TECH**nical **S**kills for surgical teams[43]
SEIPS	**S**ystems **E**ngineering **I**nitiative for **P**atient **S**afety[44]
ORBB	**O**perating **R**oom **B**lack **B**ox[52,53]

to decreased cognitive workload and enhanced team performance. In contrast, no request was consistently linked to statistically significant shorter action times across the tasks analyzed[60]. All seven articles emphasize the critical role of communication within surgical teams, highlighting how communication patterns, effectiveness and team dynamics significantly impact patient safety and surgical outcomes.

Twelve additional articles discuss communication within the broader context of NTS, using tools like NOTSS or SPLINTS (n=6), as well as frameworks like SEIPS (n=3) or other self-developed frameworks (n=3). These are detailed later.

2) Leadership

Leadership emerged as the second most discussed NTS in the surveyed literature. Three articles exclusively focused on leadership[51,71,72], while ten others addressed it within a broader NTS exploration[27,28,52,60,61,63,65-68].

Parker et al. used the Surgical Leadership Inventory (SLI) to rate surgeons' leadership behaviors like 'communicating' and 'making decisions'. Their findings highlighted that surgeons' leadership styles were mainly task focused with limited interdisciplinary communication[51]. In contrast, Rydenfält et al. studied leadership behaviors of surgeons, anesthetists and nurses, using a self-developed typology of nine behaviors. They found leadership to be rather distributed among team members. They pointed out that leadership is not one single skill that can be attributed to or claimed by one specific team member[71]. Finally, another recent study by Soenens et al. implemented self-developed Behavior Anchored Rating Scales (BARS) to investigate surgeons' leadership styles and team behaviors[72]. Their results showed that surgeons exhibiting a transformational leadership style tend to enhance performance and patient safety[72].

Nine additional articles explored leadership within a broader NTS context, primarily through NOTSS or NOTECHS (n=5), as well as within broader frameworks like SEIPS (n=2) or other self-developed frameworks (n=2). One article used SEIPS, which includes leadership, but did not explicitly mention this NTS.

3) Situational awareness

Situational awareness, crucial for understanding current and potential events, insignificantly impacts individual and team performance[73,74]. This NTS was addressed in twelve articles, primarily within validated NTS-tool (n=5), self-developed frameworks (n=2) or the SEIPS framework (n=3). Two articles specifically focused on situational awareness[64,75].

The oldest study included, conducted by Guerlain et al. in 2004, implemented a self-developed tool to assess the teams members' situational awareness skills. A 24-item questionnaire, containing 15 questions regarding situational awareness, was conducted postoperatively. The attending surgeon exhibited the highest comprehensive knowledge on the cases, scoring almost 80%, whereas surgical residents, anesthesia residents and attending anesthetists scored lower, below 60%, 40% and 30% respectively[75]. This study uniquely used video recordings to verify answers rather than for direct NTS observation. Kunkes et al. focused exclusively on situational awareness with the NOTECHS tool (Appendix 3), scoring utterances. They found that higher scores, being proactive, longer and more descriptive, contributed more effectively to situational awareness[64].

4) Decision making

Besides situational awareness, decision making is another important cognitive NTS. Both skills are strongly interconnected and influence one another: appropriate decisions can only be made based on being aware of the situation and vice versa, when teams make decisions and act upon them, a better overall team situation awareness can be conceived[73,76].

None of the articles included in this review conducted an isolated examination of decision making. It was investigated in ten articles; five within existing NTS tools such as NOTSS and/or ANTS, two within self-developed frameworks and two within the broader SEIPS framework. Again, one article used SEIPS, which includes decision making, but did not explicitly mention this NTS.

5) Task management

Task management, incorporated in ANTS and SPLINTS tools for anesthetists and scrub nurses respectively, includes planning and preparing, prioritizing, maintaining standards and coping with pressure[40,42]. It was explored in six articles, which will be discussed later.

6) Teamwork

Teamwork is intricately linked with communication and other NTS essential for effective collaboration[77,78]. Tools such as SPLINTS and ANTS integrate communication and teamwork as integral elements[40,42]. The Team Emergency Assessment Measure (TEAM) tool evaluates leadership, task management and teamwork[79]. Additionally, the SEIPS model incorporates teamwork within its framework, as discussed below. Four articles used SEIPS, while five articles applied NOTSS and/or ANTS. Boet et al. compared conventional tools like NOTECHS or TEAM, with SEIPS, exploring different methodologies to assess teamwork[80].

SEIPS framework – a systems approach

The SEIPS framework is a theoretical model that integrates human factors. Applying a systems approach, it investigates outcomes within their complex socio-technical system, including six interacting categories: people, tasks, tools and technology, organization, internal and external environ-ment. This review focuses on the 'people' category, which includes communication failures, lack of situational awareness, leadership failures (safety threats) and effective communication, good situation awareness and strong leadership (resilience supports)[44]. More detailed information is available in Appendix 3. Boet et al. compared SEIPS with NOTECHS and TEAM, advocating using SEIPS as it facilitates deeper understanding of teamwork processes and provides possibilities for multi-level interventions to enhance teamwork[80].

Additionally, three other studies applied SEIPS to assess NTS. Van Dalen et al. and Kolodzey et al. reported a high prevalence of person-related resilience supports (76% and 65%), but varied in person-related safety threats (70% and 25%, respectively). Both studies illustrate that errors and patient harm can originate from various elements, with individuals playing a crucial role in error prevention[61,67]. Adams-McGavin et al. revealed person-related resilience supports and safety threats of 75% and 68%, respectively[27]. Both van Dalen et al. and Adams-McGavin et al. found that effective communication accounted for 28% of all person-related resilience supports, confirming its importance in error prevention[27,61].

Used validated measurement tools

Seven articles used validated measurement tools to assess NTS, with five studies employing both NOTSS and SPLINTS to explore surgeons' and nurses' NTS. Doyen et al. used the ORBB to record 22 endovascular procedures and scored all elements for NOTSS and SPLINTS, finding high scores for decision making in surgeons and communication and teamwork in nurses[52]. Four other researchers counted and categorized behaviors for all NOTSS and SPLINTS elements, rather than actually scoring them[28,65,66,69]. Nensi et al. recorded 25 hysterectomies and counted only 22 negative behaviors, all of which were exhibited by surgeons, with no instances observed among nurses. Most of these negative behaviors belonged to the NOTSS element 'leadership' (59%)[69]. In contrast, Sharma et al. recorded 144 laparoscopic surgeries, noting 559 negative behaviors, predominantly related to situational awareness in surgeons (54%) and task-management in nurses (44%). The median number of negative behaviors was much lower than the median number of positive behaviors (28 (IQR 15-38) and 40 (IQR 28-118), respectively)[65]. Fecso et al. focused on NTS around errors, events and rectifications in 56 laparoscopic gastric bypasses, using the ORBB. They reported that positive behaviors were mainly related to situational awareness and leadership[28]. Both surgeons and scrub nurses exhibited more positive behaviors immediately after errors, events and before rectifications[28]. Rai et al. recorded 80 urologic cases with the ORBB, focusing on intraoperative adverse events and distractions, noting that 79% of behaviors were positive[66]. Overall, these studies highlight a predominance of positive NTS behaviors in surgical settings[28,52,65,69].

The studies by Rai et al. and Nensi et al. also used ANTS to assess anesthetists' NTS[66,69]. Rai et al. did not differentiate between disciplines[66], while Nensi et al. found that most positive observations pertained to teamwork, with no negative observations for anesthetists[69].

Self-developed frameworks

Three studies used self-developed frameworks to evaluate NTS in surgical settings. Etherington et al. implemented a self-developed framework based on ANTS, but also included communication and leadership, and used SEIPS for intraoperative distractions. They reported that anesthetists displayed mainly positive behaviors (94%), mostly regarding situational awareness. Negative behaviors were primarily related to task management. Positive NTS behaviors remained high, even during distractions[63].

Incze et al. adapted existing tools like NOTSS and NOTECHS to assess teamwork, identifying six critical themes and sixteen sub-themes of NTS. They counted behaviors during moments of uncertainty, noting that some teamwork skills, such as leadership by surgeons, were consistently demonstrated. Other skills, like backup behavior by nurses, increased, while situational awareness decreased during adverse events. This study highlighted how anesthetists, surgeons and nurses uniquely contribute to teamwork and adapt their behavior during different scenarios[68].

Next, Sexton et al. focused on teamwork. They illustrated that more anticipated requests resulted in reduced operative times, with anticipated requests taking almost five times less time to complete (5.3 seconds versus 25.6 seconds)[62]. The study also showed that unfamiliar teams encountered more inconveniences, leading to longer surgery times. A positive relationship was observed between anticipation ratios, non-verbal requests, and cognitive load, suggesting that in environments with higher anticipation, there's a greater reliance on nonverbal communication, requiring greater mutual understanding and situational awareness; which can contribute to higher cognitive loads within the team[62].

Other non-technical skills

Included articles identified eight NTS that were explicitly mentioned, of which six were very common. Two articles identified coordination, however a strong intertwining of communication and coordination was suggested by both research groups, as they appear to be mutually reinforcing skills[57,68]. As mentioned above, anticipation was identified as a separate NTS only once by Sexton et al[62].

Discussion

The use of video recordings in the OR to assess NTS, offers valuable insights that could contribute to enhancing patient safety. This scoping review has demonstrated the extent of studies exploring this innovative observational method, shedding light on various aspects of NTS and their assessment tools.

Important NTS in the OR

This review identified eight NTS across 24 articles, with communication being the most commonly observed NTS. Effective communication is crucial, as poor team communication significantly correlates with postoperative complications and contributes to 50% of all medical errors[13,81]. Skills such as stress and fatigue management were scarcely mentioned despite their impact on both technical skills and NTS in the OR[22]. Other NTS, such as empathy and vigilance are mentioned neither, because they are not easily identifiable unless exceptionally conspicuous[24,82]. Several studies reported subtle NTS, such as speaking up[72], coping with pressure, training, directing and supporting others[51]. These can be considered as subcategories of broader domains like communication, teamwork or leadership. Therefore, this review did not count them as separate entities. Additionally, there is a significant overlap among larger NTS categories. Effective teamwork relies on communication, leadership, situational awareness and task management[77,78]. Good leadership encompasses communication and decision making, which is linked to situational awareness[76]. Improved situational awareness enhances anticipation[65] and increases OR efficiency and teamwork[62]. This overlap among NTS must be considered when interpreting and comparing NTS literature.

Shift in observational methods

This review demonstrated an increase in the number of publications using medical video recordings as an observational method to study NTS. Conventional direct observation in the OR has evolved towards the use of video recordings, highlighting several advantages. Video recordings provide comprehensive and objective documentation of surgical procedures and team interactions, surpassing the limitations of human memory and attention span. For instance, Wauben et al. found significant differences between procedural notes in medical records and objectively analyzed video data[83]. Video recordings also allow for repeated analysis, enabling researchers to explore intricate details and subtle nuances of NTS[84]. Several errors and near misses, unnoticed in direct observations, are identifiable in recordings as early indicators of latent conditions[85]. Additionally, video recordings reduce observer bias by allowing multiple reviewers to independently analyze the same footage, enhancing assessment reliability. This approach supports the involvement of professionals from various fields, including psychologists, clinicians, human factor specialists and nurses, each contributing unique perspectives. Overall, adopting video recordings for assessing NTS in the OR marks a significant methodological advancement, facilitating more accurate and detailed evaluations of surgical performance. Furthermore, sophisticated systems like the ORBB are increasingly used. Looking ahead, the integration of artificial intelligence for automatic analysis holds the potential to further enhance these observational practices[86].

Video recording beyond direct NTS assessment

This review specifically focused on the direct assessment of NTS in the OR, but video recordings offer broader possibilities[87].They can generate performance reports including video fragments, rating scales scores or other relevant information. Such reports can guide postoperative team debriefings and provide structured feedback, as demonstrated by van Dalen et al., potentially improving individual and team behaviors[61].

Additionally, some studies used video recordings to assess compliance with a preoperative checklist like the WHO Surgical Safety Checklist[88-91]. Recordings can highlight checklist elements with low compliance and identify factors leading to reduced quality. For example, Al Abbas et al. reported significant improvements in checklist compliance and quality following a policy change[91]. Several studies investigated specific behaviors such as surgeons' gaze[92], anesthetists' reaction time to alarms[93] and looking behavior at the monitor and patient charts[94]. Recording these behaviors may help to identify potential distractions and guide initiatives to improve situational awareness. Research combining video recordings with other technologies, like physiological data from special shirts with built-in sensors, can evaluate the relationship between heart rate variability – as proxy for stress or cognitive load – and technical surgical performance[95] or dynamic changes during surgery[96]. Stress may adversely impact decision making[87,97,98] and team performance[87,99,100]. Several articles focused on flowdisruptions and distractions, such as alarms, music, irrelevant conversations, and device-related problems. These disruptions significantly impact workflow, efficiency and NTS[27,39,61,63,65,66,69]. For example, Weldon et al. demonstrated that music increased repeated requests, impairing communication[101], while Tscholl et al. suggested that unnecessary alarms cause alarm fatigue and impair situational awareness[102]. These disruptions can affect NTS, workflow processes[103] and potentially increase the risk of medical errors[104]. Video recordings also can be used to provide real-time feedback, enhancing situation awareness. For instance, Lane et al. used a mobile application to stream multiple live surgeries to anesthetists' personal devices, enabling detailed awareness of ongoing events[105].

In summary, video recording in the OR offers extensive potential. It enables direct evaluation of NTS, provides data on potential flowdisruptions, distractions and compliance with safety protocols. It supports improvement initiatives, educational objectives and may guide postoperative debriefings, all likely contributing to patient safety.

Barriers: legal aspects, ethics and logistics

Using medical video recordings in the OR requires careful considerations of legal and ethical issues. Bleakley et al. noted that recorded medical errors could be used as evidence, raising several questions[55]. Should videotapes be used as evidence if a medical error occurs? How long should videotapes be stored and where? Who has access and deletion authority? Are videotapes part of the patient records if patients are identifiable? Can patients review their tape even if no incidents occurred? These inquiries highlight a multitude of legal and ethical issues, influenced by the regional healthcare systems and legal models.

Most included articles were American, adhering to the Health Insurance Portability and Accountability Act, while European studies complied with the General Data Protection Regulation[106]. National laws, hospital protocols and the study's focus must be considered as well. For example, studies focusing on staff communication during non-identifiable moments differ from those involving patient identification and exposure. Some studies did not require patient consent due to exclusion from the video field[94] or because all patient data was automatically anonymized[95].

A Belgian study on the ORBB emphasized creating a secure environment by informing all key stakeholders of the hospital early-on since early stakeholder involvement is crucial to stimulate acceptance. Information sessions and meetings with the hospitals' board of directors, workforce unions and head of the various departments should be organized, discussing the potential benefits and organizational aspects. All team members expected to participate in ORBB-procedures should have the opportunity during multiple structured information sessions to ask questions or raise concerns[107]. Schijven et al. reported that for recordings aimed at improving care and self-reflection, data should not to be traceable to patients. Privacy-enhancing methods like anonymization, facial blurring, and voice distortion are important and do not compromise information quality. Recordings should not be retained longer than necessary[108].

Logistical considerations should include technological and infrastructural requirements. Well-suited audio-video equipment must be purchased and installed in a non-intrusive position to capture relevant footage. Team members should be informed and should know how and when to start and stop recordings to ensure smooth implementation.

Staff and patients' perceptions on video recording in the OR

The acceptance of video recording technologies in clinical settings varies among healthcare professionals. A Canadian study surveyed 43 staff members prior to ORBB installation, revealing that the majority of staff held positive views on operative recordings, with approximately 70% expressing willingness to receive feedback from recorded procedures. However, imposter syndrome – a psychological phenomenon marked by self-doubt and fear of being exposed as a fraud - moderated this positivity. Individuals experiencing imposter syndrome demonstrated increased concerns about recordings, especially about potential legal repercussions109. Another study surveyed 17 clinicians prior to ORBB implementation and found general consensus that recordings could significantly enhance clinical practice and education. Despite these perceived benefits, clinicians expressed concerns about the recordings' impact on clinical performance. They feared that recording might induce nervousness, alter team dynamics, cause distractions, and create undue pressure. Surgeons, in particular, were anxious about the medicolegal implications, fearing that recorded data could be used against them in legal proceedings, thus escalating their liability[110]. Both articles highlighted staff concerns about recordings potentially being used in court[109,110], but did not discuss potential legal protections. Video footage can benefit medical teams by providing evidence that all necessary precautions were taken to prevent patient harm. Surveys examining staff perceptions before and after implementation could reveal insights into evolving attitudes, potentially revealing decreased resistance and concerns over time.

Patients' perspectives were explored in a study that interviewed 49 patients before elective surgery. Patients recognized several advantages provided by operative recordings, such as enhanced educational quality, improved surgical practice, and increased patient safety. However, they were also concerned about privacy loss. While some believed recordings might discourage unprofessional behavior, others worried that monitoring could cause anxiety among OR staff. Interestingly, up to 88% of patients assumed they had the right to access these recordings, believed they owned them and could use them as medicolegal instruments[111].

Limitations

A limitation of using medical video recordings as an observational method is the potential for a Hawthorne effect, where participants alter their behavior due to the awareness of being observed[112]. This effect may have influenced results in all included articles. However, compared to direct observation, video observation may mitigate the Hawthorne effect, as cameras are generally less intrusive and influence behavior less than human observers[113]. Nevertheless, a potential Hawthorne effect should be considered in all results. Second, this review identified eight NTS discussed across 24 articles and several additional nuanced NTS – such as speaking up, coping with pressure, stress and fatigue – that could be integrated within the discussed NTS. Consequently, these subtle skills were not counted as separate entities. The findings demonstrate a significant overlap and strong connection between different NTS, which should be considered when interpreting results. Furthermore, various assessment tools were discussed, with validated tools like NOTSS, ANTS and SPLINTS frequently used. However, different approaches were noted between studies, such as scoring skills versus counting them. Other validated approaches, like the SEIPS framework or the SLI, were also applied. Additionally, several studies used self-developed assessment tools or approaches, such as a self-developed leadership typologies, communication typologies, BARS and questionnaires. These approaches add complexity to comparative analysis due to their heterogeneity. Next, tools like NOTSS, ANTS and SPLINTS are designed for discipline-specific assessment. However, by generating a final global score, opportunities to explore relationships between sub-teams or different members within a discipline are limited. Furthermore, counting certain behaviors does not inherently indicate the effectiveness or appropriateness of these actions. Simply quantifying behaviors without assessing their quality or context may fail to provide a thorough understanding on team performance or patient outcomes. Finally, most studies focused on identifying, counting and/or rating NTS without proposing substantive quality improvement initiatives based on their findings. One notable exception involved the study by van Dalen et al., who used a performance report generated from the recordings and used this to guide postoperative team debriefings[61]. Team debriefings have been shown to identify and address safety issues – new, recurring or unrecognized– and drive quality improvement initiatives[114,115].

Future perspectives

Medical video recording has proven to be a valuable observational tool within the OR. Insights from these recordings should be leveraged for local quality improvement initiatives. Performance reports derived from these recordings could guide regular debriefings, potentially moderated by human factor specialists or psychologists. Authentic video footage could enrich educational programs, guide morbidity and mortality meetings and enhance training sessions and simulation exercises, contributing to improved NTS in future cases. Identifying positive behaviors is as important as identifying negative ones. Emphasizing 'what goes well' and under what conditions, may play a key role in quality improvement initiatives. Additionally, identifying distractions and disruptions that adversely impact NTS is crucial. Such insights can guide the optimization of hospital protocols, OR layout, infrastructure, instrument design, and overall resource management. It is essential to evaluate the impact of these quality improvement measures on primary outcomes for both patients and healthcare providers through subsequent analysis of new video recordings. Future research should focus on overcoming barriers to implement medical video recordings and explore staff and patient perceptions towards video recording within Belgian hospitals. The healthcare sector often lacks a culture of open error reporting and learning from mistakes, a practice well-established in other high-risk industries like aviation. To maximize the potential of medical video recording, it is imperative to transition from a culture of blame towards a robust safety culture. This shift would promote open discussion about errors and near-misses without fear of punishment, fostering an environment where continuous improvement in patient safety is prioritized. Finally, to establish a true safety climate, continuous assessment should be integrated into the standard of care, conducted around the clock, during both elective and emergency surgical procedures.

Conclusion

This scoping review conducted a comprehensive search of the current literature on the assessment of NTS in the OR using medical video recordings. Incorporating analysis from 24 articles, this review identified eight NTS. Communication, leadership, situational awareness and teamwork were identified as key NTS. This study also revealed a diverse array of validated and non-validated assessment tools, including broader frameworks applying a more systems-based approach. This notable heterogeneity in tools and approaches suggests a need for greater standardization in the field. While medical video recordings have been shown to offer valuable insights and numerous potential benefits, they also pose legal, ethical and logistical challenges. Further research might gain insights in how to overcome these challenges. Overall, this review highlights a growing interest and recognition among researchers in this particular field, however further research is needed to discover how observed results and findings can be translated to quality improvement initiatives that may ultimately improve patient safety.

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References

1. Wang Y, Eldridge N, Metersky ML, et al. National trends in patient safety for four common conditions, 2005-2011. New England Journal of Medicine. 2014;370(4):341-51.
2. Makary MA, Daniel M. Medical error-the third leading cause of death in the US. Bmj. 2016;353:i2139.
3. Zegers M, de Bruijne MC, Wagner C, et al. Adverse events and potentially preventable deaths in Dutch hospitals: results of a retrospective patient record review study. Qual Saf Health Care. 2009;18(4):297-302.
4. Brennan TA, Leape LL, Laird NM, et al. Incidence of adverse events and negligence in hospitalized patients. Results of the Harvard Medical Practice Study I. N Engl J Med. 1991;324(6):370-6.
5. de Vries EN, Ramrattan MA, Smorenburg SM, Gouma DJ, Boermeester MA. The incidence and nature of in-hospital adverse events: a systematic review. Qual Saf Health Care. 2008;17(3):216-23.
6. Bates DW, Levine DM, Salmasian H, et al. The Safety of Inpatient Health Care. N Engl J Med. 2023;388(2):142-53.
7. Flin R, Yule S, McKenzie L, Paterson-Brown S, Maran N. Attitudes to teamwork and safety in the operating theatre. Surgeon. 2006;4(3):145-51.
8. Zegers M, de Bruijne MC, de Keizer B, et al. The incidence, root-causes, and outcomes of adverse events in surgical units: implication for potential prevention strategies. Patient Saf Surg. 2011;5:13.
9. Gawande AA, Thomas EJ, Zinner MJ, Brennan TA. The incidence and nature of surgical adverse events in Colorado and Utah in 1992. Surgery. 1999;126(1):66-75.
10. Anderson O, Davis R, Hanna GB, Vincent CA. Surgical adverse events: a systematic review. Am J Surg. 2013;206(2):253-62.
11. Institute of Medicine Committee on Quality of Health Care in A. To Err is Human: Builing a Safer Health System. In: Kohn LT, Corrigan JM, Donaldson MS, editors. To Err is Human: Building a Safer Health System. Washington (DC): National Academies Press (US)Copyright 2000 by the National Academy of Sciences. All rights reserved.; 2000.

12. Suliburk JW, Buck QM, Pirko CJ, et al. Analysis of Human Performance Deficiencies Associated With Surgical Adverse Events. JAMA Network Open. 2019;2(7):e198067-e.
13. Gawande AA, Zinner MJ, Studdert DM, Brennan TA. Analysis of errors reported by surgeons at three teaching hospitals. Surgery. 2003;133(6):614-21.
14. Kable AK, Gibberd RW, Spigelman AD. Adverse events in surgical patients in Australia. Int J Qual Health Care. 2002;14(4):269-76.
15. Hollnagel E. Safer Systems: People Training or System Tuning? Eur J Investig Health Psychol Educ. 2021;11(3):990-8.
16. Cross SRH. The systems approach at the sharp end. Future Healthc J. 2018;5(3):176-80.
17. Carayon P, Xie A, Kianfar S. Human factors and ergonomics as a patient safety practice. BMJ Qual Saf. 2014;23(3):196-205.
18. Brennan P, Jarvis S. Fallibility, performance, patient safety and teamwork: embedding human factors in surgery. Annals of the Royal College of Surgeons of England. 2024;106:102-5.
19. Shouhed D, Gewertz B, Wiegmann D, Catchpole K. Integrating human factors research and surgery: a review. Arch Surg. 2012;147(12):1141-6.
20. Kelly FE, Frerk C, Bailey CR, et al. Implementing human factors in anaesthesia: guidance for clinicians, departments and hospitals: Guidelines from the Difficult Airway Society and the Association of Anaesthetists: Guidelines from the Difficult Airway Society and the Association of Anaesthetists. Anaesthesia. 2023;78(4):458-78.
21. Reason J. Human error: models and management. Bmj. 2000;320(7237):768-70.
22. Flin R, O'Connor P. Safety at the sharp end: a guide to non-technical skills: CRC Press; 2017.
23. Hearns S. Peak Performance Under Pressure: Lessons from a Helicopter Rescue Doctor. 2020.
24. Flin R, Patey R, Glavin R, Maran N. Anaesthetists' non-technical skills. Br J Anaesth. 2010;105(1):38-44.
25. Brennan P, Oeppen R. The role of human factors in improving patient safety. Trends in Urology & Men's Health. 2022;13:30-3.
26. Prineas S, Mosier K, Mirko C, Guicciardi S. Non-technical Skills in Healthcare. In: Donaldson L, Ricciardi W, Sheridan S, Tartaglia R, editors. Textbook of Patient Safety and Clinical Risk Management. Cham (CH): Springer Copyright 2021, The Author(s). 2021. p. 413-34.
27. Adams-McGavin RC, Jung JJ, van Dalen A, Grantcharov TP, Schijven MP. System Factors Affecting Patient Safety in the OR: An Analysis of Safety Threats and Resiliency. Ann Surg. 2021;274(1):114-9.
28. Fecso AB, Kuzulugil SS, Babaoglu C, Bener AB, Grantcharov TP. Relationship between intraoperative non-technical performance and technical events in bariatric surgery. Br J Surg. 2018;105(8):1044-50.
29. Gordon M. Non-technical skills training to enhance patient safety. Clin Teach. 2013;10(3):170-5.
30. Mishra A, Catchpole K, Dale T, McCulloch P. The influence of non-technical performance on technical outcome in laparoscopic cholecystectomy. Surgical endoscopy. 2008;22:68-73.
31. Hull L, Arora S, Aggarwal R, Darzi A, Vincent C, Sevdalis N. The impact of nontechnical skills on technical performance in surgery: a systematic review. J Am Coll Surg. 2012;214(2):214-30.
32. Rosendal AA, Sloth SB, Rölfing JD, Bie M, Jensen RD. Technical, Non-Technical, or Both? A Scoping Review of Skills in Simulation-Based Surgical Training. Journal of Surgical Education. 2023;80(5):731-49.
33. McCulloch P, Mishra A, Handa A, Dale T, Hirst G, Catchpole K. The effects of aviation-style non-technical skills training on technical performance and outcome in the operating theatre. Qual Saf Health Care. 2009;18(2):109-15.
34. Uramatsu M, Fujisawa Y, Mizuno S, Souma T, Komatsubara A, Miki T. Do failures in non-technical skills contribute to fatal medical accidents in Japan? A review of the 2010–2013 national accident reports. BMJ Open. 2017;7(2):e013678.
35. Fukuta D, Iitsuka M. Nontechnical Skills Training and Patient Safety in Undergraduate Nursing Education: A Systematic Review. Teaching and Learning in Nursing. 2018;13(4):233-9.
36. Gillespie BM, Harbeck E, Kang E, et al. Effects of a Brief Team Training Program on Surgical Teams' Nontechnical Skills: An Interrupted Time-Series Study. J Patient Saf. 2021;17(5):e448-e54.
37. Calland JF, Guerlain S, Adams RB, Tribble CG, Foley E, Chekan EG. A systems approach to surgical safety. Surg Endosc. 2002;16(6):1005-14; discussion 15.
38. Sujan M, Lounsbury O, Pickup L, Kaya GK, Earl L, McCulloch P. What kinds of insights do Safety-I and Safety-II approaches provide? A critical reflection on the use of SHERPA and FRAM in healthcare. Safety Science. 2024;173:106450.
39. Santos R, Bakero L, Franco P, Alves C, Fragata I, Fragata J. Characterization of non-technical skills in paediatric cardiac surgery: communication patterns. Eur J Cardiothorac Surg. 2012;41(5):1005-12; discussion 12.
40. Fletcher G, Flin R, McGeorge P, Glavin R, Maran N, Patey R. Anaesthetists' Non-Technical Skills (ANTS): evaluation of a behavioural marker system. Br J Anaesth. 2003;90(5):580-8.
41. Yule S, Flin R, Maran N, Rowley D, Youngson G, Paterson-Brown S. Surgeons' non-technical skills in the operating room: reliability testing of the NOTSS behavior rating system. World J Surg. 2008;32(4):548-56.
42. Mitchell L, Flin R, Yule S, Mitchell J, Coutts K, Youngson G. Evaluation of the Scrub Practitioners' List of Intraoperative Non-Technical Skills system. Int J Nurs Stud. 2012;49(2):201-11.
43. Mishra A, Catchpole K, McCulloch P. The Oxford NOTECHS System: reliability and validity of a tool for measuring teamwork behaviour in the operating theatre. Qual Saf Health Care. 2009;18(2):104-8.
44. Carayon P, Schoofs Hundt A, Karsh BT, et al. Work system design for patient safety: the SEIPS model. Qual Saf Health Care. 2006;15 Suppl 1(Suppl 1):i50-8.
45. Ghiasian L, Hadavandkhani A, Abdolalizadeh P, Janani L, Es'haghi A. Comparison of video-based observation and direct observation for assessing the operative performance of residents undergoing phacoemulsification training. Indian J Ophthalmol. 2021;69(3):574-8.
46. Goldenberg MG, Jung J, Grantcharov TP. Using Data to Enhance Performance and Improve Quality and Safety in Surgery. JAMA Surg. 2017;152(10):972-3.
47. Tricco AC, Lillie E, Zarin W, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med. 2018;169(7):467-73.
48. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Medical Research Methodology. 2018;18(1):143.
49. McHugh ML. Interrater reliability: the kappa statistic. Biochem Med (Zagreb). 2012;22(3):276-82.
50. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan—a web and mobile app for systematic reviews. Systematic Reviews. 2016;5.
51. Parker SH, Flin R, McKinley A, Yule S. Factors influencing surgeons' intraoperative leadership: video analysis of unanticipated events in the operating room. World J Surg. 2014;38(1):4-10.
52. Doyen B, Soenens G, Maurel B, et al. Assessing endovascular team performances in a hybrid room using the Black Box system: a prospective cohort study. J Cardiovasc Surg (Torino). 2023;64(1):82-92.

53. Jung JJ, Jüni P, Lebovic G, Grantcharov T. First-year Analysis of the Operating Room Black Box Study. Ann Surg. 2020;271(1):122-7.
54. van Dalen A, Jansen M, van Haperen M, et al. Implementing structured team debriefing using a Black Box in the operating room: surveying team satisfaction. Surg Endosc. 2021;35(3):1406-19.
55. Bleakley A, Allard J, Hobbs A. 'Achieving ensemble': communication in orthopaedic surgical teams and the development of situation awareness--an observational study using live videotaped examples. Adv Health Sci Educ Theory Pract. 2013;18(1):33-56.
56. Frasier LL, Pavuluri Quamme SR, Ma Y, et al. Familiarity and Communication in the Operating Room. J Surg Res. 2019;235:395-403.
57. Ivarsson J, Åberg M. Role of requests and communication breakdowns in the coordination of teamwork: a video-based observational study of hybrid operating rooms. BMJ Open. 2020;10(5):e035194.
58. Emmerton-Coughlin H, Schlachta C, Lingard L. 'The other right': control strategies and the role of language use in laparoscopic training. Med Educ. 2017;51(12):1269-76.
59. Bezemer J, Korkiakangas T, Weldon SM, Kress G, Kneebone R. Unsettled teamwork: communication and learning in the operating theatres of an urban hospital. J Adv Nurs. 2016;72(2):361-72.
60. Raheem S, Ahmed YE, Hussein AA, et al. Variability and interpretation of communication taxonomy during robot-assisted surgery: do we all speak the same language? BJU Int. 2018;122(1):99-105.
61. van Dalen A, Jung JJ, Nieveen van Dijkum EJM, et al. Analyzing and Discussing Human Factors Affecting Surgical Patient Safety Using Innovative Technology: Creating a Safer Operating Culture. J Patient Saf. 2022;18(6):617-23.
62. Sexton K, Johnson A, Gotsch A, Hussein AA, Cavuoto L, Guru KA. Anticipation, teamwork and cognitive load: chasing efficiency during robot-assisted surgery. BMJ Qual Saf. 2018;27(2):148-54.
63. Etherington C, Burns JK, Ghanmi N, et al. Identifying positive and negative use of non-technical skills by anesthesiologists in the clinical operating room: An exploratory descriptive study. Heliyon. 2023;9(3):e14094.
64. Kunkes T, Cavuoto L, Higginbotham J, et al. Influence of hierarchy on risk communication during robot-assisted surgery: a preliminary study. Surg Endosc. 2022;36(5):3087-93.
65. Sharma S, Grantcharov T, Jung JJ. Non-technical skills and device-related interruptions in minimally invasive surgery. Surg Endosc. 2021;35(8):4494-500.
66. Rai A, Beland L, Aro T, Jarrett M, Kavoussi L. Patient Safety in the Operating Room During Urologic Surgery: The OR Black Box Experience. World J Surg. 2021;45(11):3306-12.
67. Kolodzey L, Trbovich P, Kashfi A, Grantcharov TP. System Factors Affecting Intraoperative Risk and Resilience: Applying a Novel Integrated Approach to Study Surgical Performance and Patient Safety. Ann Surg. 2020;272(6):1164-70.
68. Incze T, Pinkney SJ, Li C, et al. Using the Operating Room Black Box to Assess Surgical Team Member Adaptation Under Uncertainty: An Observational Study. Ann Surg. 2024.
69. Nensi A, Palter V, Reed C, et al. Utilizing Black Box Technology to Identify and Describe Intraoperative Delays, Distractions and Threats in the Gynecology OR: A Pilot Study. Journal of Minimally Invasive Gynecology. 2020;27(7, Supplement):S70.
70. Norris S. Multimodal Interaction Analysis. The Encyclopedia of Applied Linguistics. 2020.
71. Rydenfält C, Johansson G, Odenrick P, Åkerman K, Larsson P-A. Distributed leadership in the operating room: a naturalistic observation study. Cognition, Technology & Work. 2015;17(3):451-60.
72. Soenens G, Marchand B, Doyen B, Grantcharov T, Van Herzeele I, Vlerick P. Surgeons' Leadership Style and Team Behavior in the Hybrid Operating Room: Prospective Cohort Study. Ann Surg. 2023;278(1):e5-e12.
73. Endsley M. Endsley, M.R.: Toward a Theory of Situation Awareness in Dynamic Systems. Human Factors Journal 37(1), 32-64. Human Factors: The Journal of the Human Factors and Ergonomics Society. 1995;37:32-64.
74. Hazlehurst B, McMullen CK, Gorman PN. Distributed cognition in the heart room: how situation awareness arises from coordinated communications during cardiac surgery. J Biomed Inform. 2007;40(5):539-51.
75. Guerlain S, Adams RB, Turrentine FB, et al. Assessing team performance in the operating room: development and use of a "black-box" recorder and other tools for the intraoperative environment. J Am Coll Surg. 2005;200(1):29-37.
76. Van de Walle B, Brugghemans B, Comes T. Improving situation awareness in crisis response teams: An experimental analysis of enriched information and centralized coordination. International Journal of Human-Computer Studies. 2016;95:66-79.
77. Nurok M, Sundt TM, 3rd, Frankel A. Teamwork and communication in the operating room: relationship to discrete outcomes and research challenges. Anesthesiol Clin. 2011;29(1):1-11.
78. Hunt EA, Shilkofski NA, Stavroudis TA, Nelson KL. Simulation: translation to improved team performance. Anesthesiol Clin. 2007;25(2):301-19.
79. Cooper S, Cant R, Porter J, et al. Rating medical emergency teamwork performance: development of the Team Emergency Assessment Measure (TEAM). Resuscitation. 2010;81(4):446-52.
80. Boet S, Burns JK, Brehaut J, et al. Analyzing interprofessional teamwork in the operating room: An exploratory observational study using conventional and alternative approaches. J Interprof Care. 2023;37(5):715-24.
81. Mazzocco K, Petitti DB, Fong KT, et al. Surgical team behaviors and patient outcomes. The American Journal of Surgery. 2009;197(5):678-85.
82. Cobianchi L, Dal Mas F, Verde JM, et al. Why non-technical skills matter in surgery. New paradigms for surgical leaders. Discover Health Systems. 2022;1(1):2.
83. Wauben LS, van Grevenstein WM, Goossens RH, van der Meulen FH, Lange JF. Operative notes do not reflect reality in laparoscopic cholecystectomy. Br J Surg. 2011;98(10):1431-6.
84. Bezemer J, Cope A, Korkiakangas T, et al. Microanalysis of video from the operating room: an underused approach to patient safety research. BMJ Qual Saf. 2017;26(7):583-7.
85. Slagle JM, Anders S, Porterfield E, Arnold A, Calderwood C, Weinger MB. Significant Physiological Disturbances Associated With Non-Routine Event Containing and Routine Anesthesia Cases. Journal of patient safety. 2015;11(4):198-203.
86. Cheikh Youssef S, Haram K, Noël J, et al. Evolution of the digital operating room: the place of video technology in surgery. Langenbeck's Archives of Surgery. 2023;408(1):95.
87. Wetzel CM, Kneebone RL, Woloshynowych M, et al. The effects of stress on surgical performance. American journal of surgery. 2006;191(1):5-10.
88. Lingard L, Espin S, Rubin B, et al. Getting teams to talk: development and pilot implementation of a checklist to promote interprofessional communication in the OR. Qual Saf Health Care. 2005;14(5):340-6.
89. Lingard L, Regehr G, Orser B, et al. Evaluation of a Preoperative Checklist and Team Briefing Among Surgeons, Nurses, and Anesthesiologists to Reduce

Failures in Communication. Archives of Surgery. 2008;143(1):12-7.
90. Mejia OAV, Fernandes PMP. Checklists as a central part of surgical safety culture. Sao Paulo Med J. 2022;140(4):515-7.
91. Al Abbas AI, Sankaranarayanan G, Polanco PM, et al. The Operating Room Black Box: Understanding Adherence to Surgical Checklists. Annals of surgery. 2022;276(6):995-1001.
92. Sutton E, Youssef Y, Meenaghan N, et al. Gaze disruptions experienced by the laparoscopic operating surgeon. Surg Endosc. 2010;24(6):1240-4.
93. Schmid F, Goepfert MS, Kuhnt D, et al. The wolf is crying in the operating room: patient monitor and anesthesia workstation alarming patterns during cardiac surgery. Anesth Analg. 2011;112(1):78-83.
94. Ford S, Birmingham E, King A, Lim J, Ansermino JM. At-a-glance monitoring: covert observations of anesthesiologists in the operating room. Anesth Analg. 2010;111(3):653-8.
95. Grantcharov PD, Boillat T, Elkabany S, Wac K, Rivas H. Acute mental stress and surgical performance. BJS Open. 2019;3(1):119-25.
96. Dias RD, Zenati MA, Stevens R, Gabany JM, Yule SJ. Physiological synchronization and entropy as measures of team cognitive load. J Biomed Inform. 2019;96:103250.
97. Wemm SE, Wulfert E. Effects of Acute Stress on Decision Making. Appl Psychophysiol Biofeedback. 2017;42(1):1-12.
98. Morgado P, Sousa N, Cerqueira JJ. The impact of stress in decision making in the context of uncertainty. J Neurosci Res. 2015;93(6):839-47.
99. Driskell JE, Salas E, Johnston J. Does stress lead to a loss of team perspective? Group dynamics: Theory, research, and practice. 1999;3(4):291.
100. Cumming SR, Harris LM. The impact of anxiety on the accuracy of diagnostic decision-making. Stress and Health: Journal of the International Society for the Investigation of Stress. 2001;17(5):281-6.
101. Weldon SM, Korkiakangas T, Bezemer J, Kneebone R. Music and communication in the operating theatre. J Adv Nurs. 2015;71(12):2763-74.
102. Tscholl DW, Handschin L, Rössler J, Weiss M, Spahn DR, Nöthiger CB. It's not you, it's the design - common problems with patient monitoring reported by anesthesiologists: a mixed qualitative and quantitative study. BMC Anesthesiol. 2019;19(1):87.
103. Gillespie BM, Harbeck E, Kang E, Steel C, Fairweather N, Chaboyer W. Correlates of non-technical skills in surgery: a prospective study. BMJ Open. 2017;7(1):e014480.
104. Keogh S, Laski D. A Concern for Intraoperative Distractions and Interference: An Observational Study Identifying, Measuring, and Quantifying Both within the Operating Theatre. Surg Res Pract. 2021;2021:9910290.
105. Lane JS, Sandberg WS, Rothman B. Development and implementation of an integrated mobile situational awareness iPhone application VigiVU™ at an academic medical center. Int J Comput Assist Radiol Surg. 2012;7(5):721-35.
106. Gabrielli M, Valera L, Barrientos M. Audio and panoramic video recording in the operating room: legal and ethical perspectives. J Med Ethics. 2020.
107. Doyen B, Gordon L, Soenens G, et al. Introduction of a surgical Black Box system in a hybrid angiosuite: Challenges and opportunities. Phys Med. 2020;76:77-84.
108. Schijven MP, Legemate DA, Legemaate J. [Video recording and data collection in the operating room: the way to a 'just culture' in the OR]. Ned Tijdschr Geneeskd. 2017;161:D1655.
109. Gordon L, Reed C, Sorensen JL, et al. Perceptions of safety culture and recording in the operating room: understanding barriers to video data capture. Surg Endosc. 2022;36(6):3789-97.
110. Etherington N, Usama A, Patey A, et al. Exploring stakeholder perceptions around implementation of the Operating Room Black Box for patient safety research: A qualitative study using the theoretical domains framework. BMJ Open Quality. 2019;8:e000686.
111. Gallant JN, Brelsford K, Sharma S, Grantcharov T, Langerman A. Patient Perceptions of Audio and Video Recording in the Operating Room. Ann Surg. 2022;276(6):e1057-e63.
112. McCambridge J, Witton J, Elbourne DR. Systematic review of the Hawthorne effect: new concepts are needed to study research participation effects. J Clin Epidemiol. 2014;67(3):267-77.
113. Pringle M, Stewart-Evans C. Does awareness of being video recorded affect doctors' consultation behaviour? Br J Gen Pract. 1990;40(340):455-8.
114. Magill ST, Wang DD, Rutledge WC, et al. Changing Operating Room Culture: Implementation of a Postoperative Debrief and Improved Safety Culture. World Neurosurg. 2017;107:597-603.
115. McGreevy JM, Otten TD. Briefing and debriefing in the operating room using fighter pilot crew resource management. J Am Coll Surg. 2007;205(1):169-76.

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