Defining critical and non-critical moments in the operating room: a modified Delphi consensus study

La définition des moments critiques et non critiques en salle d'opération : une étude de consensus Delphi modifiée

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Abstract

Background While the operating room (OR) has significantly benefited from aviation strategies to improve safety, the rate of avoidable human errors remains relatively high. One key aviation strategy that has yet to be formally established in the OR is the “sterile cockpit” rule, which prohibits all non-essential behaviours during critical moments of a flight. Applying this rule to the OR may enhance patient safety, but the critical moments of surgery need to be defined first.

Methods This study used a modified Delphi methodology to determine critical moments during surgery according to OR team members across institutions, professions, and specialties. Analysis occurred after each round. The stopping criterion was consensus on 80% of survey items

or no change in the mean score for any individual item between two consecutive rounds.

Results The first round included 304 respondents. Of these, 115 completed the second-round survey, and 75 completed all three rounds (27 nurses, 29 anesthesiologists, 19 surgeons). Critical moments obtained by consensus were: induction of anesthesia; emergence from anesthesia; preoperative briefing; final counts at the end of the procedure; anesthesiologist- or surgeon-relevant intraoperative event; handovers; procedure-specific high-risk surgical moments; crisis resource management situations; medication and equipment preparation; and key medication administration.

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Conclusions *By defining the most critical moments of surgery, future research can determine the relative importance of behaviour and actions at each stage and target interventions to these stages.*

Résumé

Contexte *Alors que la salle d'opération (SOP) bénéficie considérablement des stratégies de l'aviation pour améliorer la sécurité, le taux d'erreurs humaines évitables y demeure relativement élevé. L'une des stratégies clés de l'aviation qui doit encore être mise en place de manière formelle en SOP est la règle de la « cabine de pilotage stérile », qui interdit tout comportement non essentiel pendant les moments critiques d'un vol. L'application de cette règle à la SOP pourrait améliorer la sécurité des patients, mais les moments critiques d'une chirurgie doivent d'abord être définis.*

Méthode *Cette étude a utilisé une méthodologie Delphi modifiée afin de déterminer les moments critiques pendant une chirurgie selon les membres des équipes de SOP en provenance de différentes institutions, professions et spécialités. Une analyse a eu lieu après chaque itération. Le critère d'arrêt était un consensus sur 80 % des items du sondage ou aucun changement dans la note moyenne obtenue pour n'importe quel item individuel entre deux itérations consécutives.*

Résultats *La première série a inclus 304 répondants. Parmi ceux-ci, 115 ont complété le deuxième sondage, et 75 ont complété les trois séries de questions (27 infirmiers/infirmières, 29 anesthésiologistes, 19 chirurgiens/chirurgiennes). Les moments critiques retenus par consensus étaient : l'induction de l'anesthésie; l'émergence de l'anesthésie; le temps d'arrêt préopératoire; les décomptes finaux à la fin de l'intervention; les événements peropératoires importants pour l'anesthésiologiste ou le chirurgien; les transferts; les moments chirurgicaux à risque élevé spécifiques à l'intervention; les situations de gestion de crise des ressources; la préparation des médicaments et du matériel; et l'administration de médicaments clés.*

Conclusion *En définissant les moments les plus critiques de la chirurgie, les recherches futures pourront déterminer l'importance relative des comportements et des actes à chaque étape et cibler les interventions en fonction de ces étapes.*

from these advances (e.g., crew resource management, team training, use of checklists, simulation), the rate of avoidable errors during surgery remains relatively high.^{1,4-6} Most of these errors are preventable and related to human performance factors such as teamwork.⁶⁻⁹ Effective teamwork depends on observable behaviours and clinicians' perceptions.^{10,11} Research has identified tensions between anesthesiologists, nurses, and surgeons that arise from various misperceptions and conflicting professional priorities.¹²⁻¹⁷ This can interfere with the development of a shared mental model (i.e., a common understanding of the situation, treatment plan, and individual roles),^{12,13} which is essential for effective and efficient team performance.¹⁴ It is therefore necessary to explore additional strategies that can be adapted to the OR. These strategies should be determined by the team members.

One key strategy from aviation that has yet to be formally established in the OR is the “sterile cockpit” rule.¹⁸ This rule prohibits all non-essential behaviour (e.g., irrelevant communication) during critical moments of a flight, (e.g., when flying at 10,000 feet),¹⁸ and has been shown to greatly enhance aviation safety.¹¹ It has been suggested that applying the sterile cockpit rule to healthcare could have similar benefits for patient safety^{1,4}; however, it is unclear which moments in the OR are the most critical. Defining these moments could facilitate a shared mental model among team members, and inform teamwork and communication-related interventions by specifying the time at which certain behaviours are needed.

Previous studies have identified critical stages of communication for specific procedures (e.g., initiation of cardiopulmonary bypass in cardiac surgery),²⁰ but key operative intervals while the patient is in the OR have not been defined. Critical moments across various surgeries have also not been identified from an interprofessional perspective. This could have important implications for better shared mental models among team members, standardized protocols for teamwork, and safety for patients. For example, there may be certain moments during an operation where closed-loop communication (CLC)²¹⁻²⁵ prevents avoidable errors, and other times when CLC is less important. There could also be moments during an operation when silence is critical for patient safety, and other times when noise (e.g., music, case-irrelevant conversation) does not affect patient safety. Identifying these key times from an interprofessional perspective could help to establish protocols that satisfy all team members and prevent professional “tribalism”.^{23,26}

We aimed to determine critical moments of surgery that are relevant to all professions (nurses, anesthesiologists, surgeons) and applicable to a wide range of procedures.

Many advances in perioperative patient safety have been inspired by other high-risk industries, such as aviation.¹⁻⁴ While the operating room (OR) has significantly benefited

This list can then serve as a starting point for developing interventions and can then be tailored to specific contexts as needed. These findings will inform educational interventions by enabling the most important moments to be targeted and, as a result, optimize teamwork and patient safety in the OR.

Methods

Ethical approval was obtained from the Ottawa Health Sciences Network Research Ethics Board (OHSN-REB 20170877-01H). This study is reported according to the recommendations for Conducting and REporting of DELphi Studies.²⁷ Participants were presented with an informed consent document at the beginning of the survey that explained that they implied their consent by completing the survey.

A modified Delphi method was used to identify critical moments of surgery. Surgery was defined as the period from the patient entering the OR until the patient leaving the OR for postoperative recovery. The Delphi approach is a widely used, rigorous, and accepted method in healthcare for obtaining expert consensus through an iterative ranking process.¹⁰ It obtains consensus among a large, representative number of frontline providers across OR professions.

Voting guide development

The initial Delphi survey was assembled by the team of co-investigators who are researchers and clinicians from nursing, anesthesiology, and surgery. Two members of the research team, a health sociologist (N.E.) and practicing anesthesiologist with expertise in medical education (SB), drafted an initial list of items based on an informal literature review and clinical experience. This list was then shared with a co-investigator team of two registered nurses (J.K., M.C.), one general surgeon and surgical safety researcher (T.G.), one obstetrics and gynecology surgeon and medical education expert (G.P.), one surgical resident (J.J.), and one anesthesia resident (A.C.). Each team member added additional moments based on their perspectives. The survey was then pilot tested with six members of the target population to ensure it was interpreted consistently across respondents and provided enough information for respondents to make informed decisions. Feedback on the wording and understanding of each question was collected and compared, and questions were revised until they were consistently interpreted.

Sample

Our target population included all members of the operative team: circulating and scrub nurses, anesthesiologists, nurse anesthetists, anesthesia assistants, surgeons, physician assistants, and trainees of these professions. We aimed to recruit participants from hospitals internationally across a broad range of surgical specialties. To do so, the study was advertised widely on Twitter. We also implemented a snowball sampling technique to maximize recruitment from other national and international institutions—each participant was allowed to forward the survey to their colleagues. Also, purposive recruitment took place at The Ottawa Hospital, a large academic care centre, through recruitment emails sent to all perioperative departments.

Estimates of appropriate sample sizes for Delphi processes differ depending on the makeup of the target population. Where participants have similar training and expertise, smaller sample sizes (20–30) can yield stable response characteristics.¹¹ With more heterogeneous groups, evidence suggests that sample sizes over 65 can be treated as normally distributed.¹² Therefore, we aimed to recruit at least 70 participants to complete all rounds. Assuming a conservative 30% response rate at each round, we planned to sample at least 800 healthcare professionals in the first round ($800 \times 0.30 \times 0.30 = 72$). We planned to stop recruitment either after we collected the sample size targeted at each round (round 1: 800; round 2: 240; round 3: 70) or after three months.

Survey administration

Participation in the Delphi process involved three web-based surveys. The research team was blinded to the identity of all participants. Participants were asked to rate listed items (i.e., moments of surgery) on a scale of 1 (least critical) to 5 (most critical). Participants were also able to indicate “unable to judge” if needed. In round 1, participants were invited to suggest additional moments beyond those listed. The stopping criterion for the study was either consensus on 80% of items (defined by the W statistic of < 0.8) or no change in the mean score for any individual operative phase between two consecutive rounds. This resulted in three rounds taking place. Each round of the survey was sent only to those participants who completed the previous round.

Analysis and consensus

Moments for which 75% of participants across professional groups (i.e., all subjects) rated as being “not critical” (i.e.,

Table 1 Demographic characteristics of participants across each round

	<i>n</i> (%) or median [IQR]		
	Round 1 (<i>n</i> =304)	Round 2 (<i>n</i> =115)	Round 3 (<i>n</i> =75)
Profession			
<i>Anesthesia</i>			
Anesthesiologist (physician)	99 (32.6)	39 (33.9)	26 (34.7)
Nurse anesthetist	2 (0.7)	0 (0)	0 (0)
Anesthesia assistant	15 (4.9)	4 (3.5)	3 (4.0)
<i>Surgery</i>			
Surgeon (physician)	81 (26.6)	35 (30.4)	19 (25.3)
<i>Nursing</i>			
Registered nurse	88 (28.9)	33 (28.7)	23 (20.0)
Registered practical nurse	16 (5.3)	4 (3.5)	4 (3.5)
<i>Other</i>	3 (1.0)	0 (0)	0 (0)
Trainee status			
Trainee	61 (20.1)	22 (19.1)	15 (20.0)
Non-trainee	243 (79.9)	93 (80.9)	60 (80.0)
Country in which currently practicing			
Argentina	1 (0.3)	1 (0.3)	0 (0)
Australia	14 (4.6)	8 (6.9)	6 (8.0)
Canada	253 (83.2)	96 (83.5)	61 (81.3)
Egypt	1 (0.3)	0 (0)	0 (0)
Ethiopia	1 (0.3)	0 (0)	0 (0)
France	1 (0.3)	0 (0)	0 (0)
Guatemala	1 (0.3)	0 (0)	0 (0)
Guyana	1 (0.3)	0 (0)	0 (0)
Iran	1 (0.3)	1 (0.3)	1 (1.3)
Nepal	2 (0.7)	1 (0.3)	1 (1.3)
Netherlands	2 (0.7)	1 (0.3)	0 (0)
Saudi Arabia	2 (0.7)	0 (0)	0 (0)
South Africa	1 (0.3)	1 (0.3)	0 (0)
Spain	1 (0.3)	0 (0)	0 (0)
Sweden	2 (0.7)	1 (0.3)	0 (0)
United Kingdom	12 (3.9)	2 (1.7)	2 (2.7)
United States	7 (2.3)	3 (2.6)	3 (4.0)
Zambia	1 (0.3)	0 (0)	0 (0)
Post-training years of experience	8 [3.0-14.3]	9 [3-17]	9.5 [6.5-17.8]
Specialty			
Cardiac	5 (1.6)	4 (3.5)	4 (5.3)
ENT	1 (0.3)	1 (0.9)	1 (1.3)
General	22 (7.2)	10 (8.7)	10 (13.3)
Neurology	2 (0.7)	1 (0.9)	0 (0)
Obstetrics/Gynecology	83 (27.3)	20 (17.4)	18 (24.0)
Ophthalmology	1 (0.3)	1 (0.9)	1 (1.3)
Orthopedic	12 (3.9)	6 (5.2)	3 (4.0)
Pediatrics	2 (0.7)	0 (0)	0 (0)
Plastic	3 (1.0)	0 (0)	0 (0)
Thoracic	8 (2.6)	3 (2.6)	1 (1.3)
Urology	9 (2.9)	4 (3.5)	2 (2.7)
Vascular	2 (0.7)	0 (0)	0 (0)

Table 1 continued

	<i>n</i> (%) or median [IQR]		
	Round 1 (<i>n</i> =304)	Round 2 (<i>n</i> =115)	Round 3 (<i>n</i> =75)
More than one specialty reported	154 (50.7)	65 (56.5)	35 (46.7)

ENT = ear-nose-throat; IQR = interquartile range

a rating of 1 to 3) were removed from subsequent voting and eliminated from the final list of items. Moments for which 80% of participants across professional groups rated as “critical” (i.e., a rating of 4 or 5) were also removed from subsequent voting and automatically included in the final list of items. Items were also included in the final list if they were voted as critical by 80% or more of participants within a professional group and had a mean rating of 4 across all professions. All items were explained to participants in each round. Voting for the second and third rounds included items for which there was no previous consensus as well as new items suggested by participants in the first round.

Similar items suggested by participants were first grouped under common themes by a research team member with relevant OR experience (A.C.) and subsequently verified by remaining team members. The final list of suggested items for inclusion in the second and third rounds was then established through consensus-based discussion. Similar items were grouped in the second round for clarity and to avoid repetition.

For the purposes of the analyses, physician anesthesiologists (both staff and trainees), nurse anesthetists, and anesthesia assistants were grouped under “anesthesia”. Surgical fellows and residents were grouped under “surgery” along with staff surgeons.

Statistical analysis

Data were exported from SurveyMonkey into Microsoft Excel version 16 (Microsoft Corporation, Washington, USA) for calculation of descriptive statistics. Data were presented as frequencies, proportions, mean (standard deviation [SD]), or median [interquartile range (IQR)].

Results

Participants

The first round included 304 respondents. Of these, 115 completed the second-round survey, and 75 completed all three rounds. Of the 75 participants who completed all rounds, 27 (36%) reported their profession as nursing, 29

(39%) as anesthesia, and 19 (25%) as surgery (Table 1). Six countries were represented, with the majority of participants residing in Canada (*n* = 61; 81%) and nearly all participants coming from high-income countries. Most participants reported working in more than one surgical specialty (*n* = 35; 47%). Most participants were not trainees (*n* = 60; 80%) and reported a median [IQR] post-training experience of 9.5 [6.5–17.8] yr.

Round 1 voting

Of the 22 moments listed in the initial survey, eight moments were included in the final list of critical moments and did not need to proceed to second-round voting. Of these eight critical moments, six were rated as 4 or 5 by more than 80% of all participants (Table 2): induction of anesthesia (89%), emergence from anesthesia (84%), a delicate dissection (88%), surgical safety checklist step one (84%), surgeon- or anesthesiologist-relevant intraoperative event (96%), and a call for more help from a team member during a life-threatening emergency (99%). Two of the eight critical moments were included from the first round because they were rated as 4 or 5 by 80% or more of participants within a professional group and had a mean rating of at least 4 across all professions. These were handover between colleagues [84% of nurses and 83% of anesthesia rated critical; mean (SD) rating 4.13 (0.90)] and when a team members make the final count at the end of the surgical procedure [94% of nurses rated critical, mean (SD) rating 4.03 (1.02)].

The moments “surgical skin incision”, “when the surgeon closes skin”, and “when the patient is transferred from the OR table to the bed/stretcher” were removed after round 1 as more than 75% of participants rated them as 3 or lower.

There were 96 suggestions for additional moments. After grouping similar suggested moments under common themes where appropriate, four new items were developed and included for voting in the second round: medication and equipment preparation; crisis resource management situations; key medication administration; and high-risk surgical procedures/moments. Moving to round 2 voting, the initial phase “a call for help from a team member during a life-threatening emergency” was placed under the

Table 2 Percentage of participants rating moments as critical, across and within professions: round 1*

Surgical phase	All groups (n=300) n (%)	Anesthesia (n=115) n (%)	Surgery (n=81) n (%)	Nursing (n=104) n (%)
Induction of anesthesia	270 (90.0)	115 (100)	58 (71.6)	94 (90.3)
Emergence from anesthesia	254 (84.6)	115 (100)	48 (59.3)	88 (84.6)
Introduction of trocars	184 (61.3)	81 (70.4)	50 (61.7)	53 (51.0)
Surgical skin incision	104 (34.6)	58 (50.4)	19 (23.4)	27 (26.0)
A delicate dissection, for example dissection close to big vessels	266 (88.6)	95 (82.6)	77 (95.1)	91 (87.5)
Surgical safety checklist step 1: preoperative (before patient anesthetized)	255 (85.0)	99 (86.1)	55 (67.9)	98 (94.2)
Surgical safety checklist step 2: surgical time out (after patient anesthetized and before surgical incision)	207 (69.0)	85 (73.9)	38 (46.9)	81 (77.8)
Surgical safety checklist step 3: “debriefing” (at the end of the surgical procedure)	141 (47.0)	52 (45.2)	25 (30.9)	62 (59.6)
Checking of special energy devices or equipment just before using it	145 (48.3)	45 (39.1)	33 (40.7)	65 (62.5)
When team member(s) make(s) the initial count at the beginning of the surgical procedure	178 (59.3)	48 (41.7)	37 (46.6)	91 (87.5)
When patient is positioned	209 (69.6)	83 (72.2)	45 (55.6)	80 (76.9)
Checking of surgical implants	150 (50.0)	39 (33.9)	36 (44.4)	73 (70.2)
Confirming/handing off specimens	149 (49.6)	33 (28.7)	32 (39.5)	82 (78.8)
When team member(s) make(s) the final counts at the end of surgical procedure	215 (71.7)	62 (53.9)	53 (65.4)	98 (94.2)
Any anesthesiologist- or surgeon-relevant intraoperative event (e.g., bleeding, hypotension)	290 (96.6)	112 (97.4)	76 (93.8)	99 (95.2)
Call for more help from an OR team member during a life-threatening emergency	299 (99.6)	115 (100)	80 (98.8)	101 (97.1)
When the surgeon conducts anastomosis (for example visceral or vessel)	169 (56.3)	49 (42.6)	45 (55.6)	73 (70.2)
Time periods with more than 8 personnel in the room	82 (27.3)	30 (26.1)	32 (39.5)	60 (57.7)
When using a stapling device	90 (30.0)	13 (11.3)	21 (25.9)	55 (52.9)
When the surgeon closes skin	54 (18.0)	16 (13.9)	43 (53.1)	30 (28.8)
When patient is transferred from the OR table to the bed/stretcher	123 (41.0)	63 (54.8)	10 (12.3)	50 (48.1)
Handover between colleagues of the same specialty/profession (e.g., nurse to another nurse or anesthesiologist to another anesthesiologist)	232 (77.3)	96 (83.5)	48 (59.3)	87 (83.7)

= Included in final list without further voting. *Critical = rating of 4 or 5 on scale of 1 (least critical) to 5 (most critical)

Anesthesia assistants, nurse anesthetists and physician anesthesiologists were grouped under the profession “anesthesia”

OR = operating room

new item “crisis resource management situations,” defined as active life-threatening emergency situations. Similarly, the initial phase “when the surgeon does a delicate dissection” was subsumed under “high-risk surgical procedures/moments,” defined as risky or challenging aspects of a procedure that are not immediately life threatening.

Round 2 voting

In round 2 (Table 3), participants voted on 14 items. The item “high-risk surgical procedures/moments” was rated as 4 or 5 by 93% of participants. Crisis resource management situations were rated as 4 or 5 by 86% of anesthesiologists and had a mean (SD) rating of 4.18 (1.13) across professions. These two items were included in the final list.

Round 3 voting

Participants voted on 12 items in round 3 (Table 4). “Key medication administration” was rated as 4 or 5 by 80% of participants. “Medication and equipment preparation” was rated as 4 or 5 by 85% of nursing participants and 86% of anesthesia participants, but only 44% of surgeons. Its mean (SD) score across professions was 4.14 (0.70). Therefore, both of these items were included in the final list of moments.

Three items were rated as 4 or 5 by nursing participants (initial count, when patient is positioned, confirming/handing of specimens) but mean scores across all professions were less than 4 and therefore were excluded (Table 5).

Table 3 Percentage of participants rating moments as critical, across and within professions: Round 2*

Surgical phase	All groups (n=115) %	Anesthesia (n=43) %	Surgery (n=35) %	Nursing (n=37) %
Introduction of trocars	66 (57.4)	28 (65.1)	22 (62.9)	16 (43.2)
Surgical safety checklist step 2: surgical time out (after patient anesthetized and before surgical incision)	71 (61.7)	29 (67.4)	18 (51.4)	24 (64.9)
Surgical safety checklist step 3: “debriefing” (at the end of the surgical procedure)	54 (47.0)	18 (41.9)	15 (42.9)	21 (56.8)
Checking of special energy devices or equipment just before using it	53 (46.1)	11 (25.6)	18 (51.4)	24 (64.9)
When team member(s) make(s) the initial count at the beginning of the surgical procedure	64 (55.7)	17 (39.5)	16 (45.7)	32 (86.5)
When patient is positioned	83 (72.2)	36 (83.7)	20 (57.1)	28 (75.7)
Checking of surgical implants	65 (56.5)	14 (32.6)	20 (57.1)	32 (86.5)
Confirming/handling off specimens	58 (50.4)	13 (30.2)	15 (42.9)	30 (81.1)
High-risk surgical procedures/moments (e.g., moments specific to each procedure that are high risk for failure/consequences/alteration to patient vitals, such as release of vascular clamps, coming off bypass, CO ₂ insufflation; OR moments when changes in surgical plan may occur, such as surgeon converting from minimally invasive to open surgery; when the surgeon conducts anastomosis, such as visceral or vessel)	107 (93.0)	40 (93.0)	35 (100)	33 (89.2)
Time periods with more than 8 personnel in the room	43 (37.4)	9 (20.9)	12 (34.3)	22 (59.4)
When using a stapling device	43 (37.4)	8 (18.6)	14 (40.0)	21 (56.7)
Medication and equipment preparation	79 (68.7)	29 (67.4)	22 (62.9)	28 (75.7)
Crisis resource management situations	84 (73.0)	37 (86.0)	25 (71.4)	23 (62.2)
Key medication administration (e.g., antibiotics, heparin, methylene blue)	71 (61.7)	26 (60.5)	20 (57.1)	25 (67.6)

Anesthesia assistants, nurse anesthetists and physician anesthesiologists were grouped under the profession “anesthesia”.

CO₂ = carbon dioxide; OR = operating room.

Discussion

This study used a modified Delphi consensus process to identify critical moments for patient safety during surgery from an interprofessional perspective. Participants identified ten moments of surgery as critical. These moments could be generalized to most surgical procedures, making them particularly relevant to the study of OR team behaviour and related patient safety outcomes.

Future research can study the impact of particular behaviours and actions during these moments compared with other moments of the procedure. As a result, protocols can be developed that emphasize safety actions that are relevant to all team members at specific times rather than make general recommendations.¹³ Specifying when a behaviour should occur is necessary for effective teamwork, similar to what has been accomplished in other high-risk industries such as aviation and the military. For example, teamwork protocols could specify that CLC be practiced during key medication administration and that case-related conversation be restricted to the final instrument count.

Although consensus was reached across professions for most moments, there were some which were considered

critical by only one or two professions. Most often, this involved moments rated as critical by nurses (e.g., initial/final counts) but not viewed similarly by physicians, or moments rated as critical by nurses and anesthesia providers (e.g., induction/emergence; medication and equipment preparation), but not viewed similarly by surgeons. It is also interesting to note that a greater proportion of nurses tended to rate each listed item as critical than physicians did. Disagreement among professions about what constitutes a critical moment during surgery could create teamwork and communication issues, subsequently posing risks to patient safety.^{14,15} Educational interventions might therefore focus on establishing a common understanding of critical moments or encouraging an understanding of the perspective of all team members. For example, a phase of surgery that is important for anesthesia or nursing should be viewed as important by all other team members even if they are not directly involved in the specific task. This is key for maintaining situation awareness and team coordination.¹⁶ The list of critical moments developed by this study provides a starting point for teamwork protocols that incorporate the perspective of all team members. Designing an intervention based on moments with interprofessional consensus is a feasible first step toward

Table 4 Percentage of participants rating moments as critical, across and within professions: Round 3*

Surgical phase	All groups (n=75) n (%)	Anesthesia (n=29) n (%)	Surgery (n=19) n (%)	Nursing (n=27) n (%)
Introduction of trocars	50 (67.6)	22 (75.6)	11 (61.1)	16 (59.2)
Surgical safety checklist step 2: surgical time out (after patient anesthetized and before surgical incision)	54 (73.0)	25 (58.6)	11 (61.1)	25 (92.6)
Surgical safety checklist step 3: “debriefing” (at the end of the surgical procedure)	40 (54.1)	11 (37.9)	10 (55.6)	18 (66.7)
Checking of special energy devices or equipment just before using it	36 (48.6)	7 (24.1)	10 (55.6)	18 (66.7)
When team member(s) make(s) the initial count at the beginning of the surgical procedure	43 (58.1)	11 (37.9)	9 (50.0)	23 (85.2)
When patient is positioned	52 (70.3)	18 (62.1)	11 (61.1)	22 (81.2)
Checking of surgical implants	45 (60.1)	12 (41.4)	11 (61.1)	21 (77.8)
Confirming/handing off specimens	48 (64.9)	11 (37.9)	14 (77.8)	22 (81.2)
Time periods with more than 8 personnel in the room	27 (36.5)	7 (24.1)	2 (16.7)	16 (59.3)
When using a stapling device	27 (36.5)	3 (10.3)	8 (44.4)	15 (55.6)
Medication and equipment preparation	57 (77.0)	25 (86.2)	8 (44.4)	23 (85.2)
Key medication administration (e.g., antibiotics, heparin, methylene blue)	59 (80.0)	22 (75.9)	13 (72.2)	23 (85.2)

= Included in final list without further voting. *Critical = rating of 4 or 5 on scale of 1 (least critical) to 5 (most critical).

Anesthesia assistants, nurse anesthetists and physician anesthesiologists were grouped under the profession “anesthesia”.

building shared mental models. It may be important for subsequent work to enhance education around the roles, tasks, and perspectives of each team member so that the entire team is aware of and understands these key elements.

It is interesting to note that only the preoperative briefing (step one) of the surgical safety checklist was considered critical by participants, despite the fact that the checklist is typically implemented as a single intervention (requiring all three steps). The perceived differences in the importance of each step may speak to the variation in compliance often observed in clinical practice.^{17,26,28}

This study has several limitations. First, there was substantial attrition of participants from the first to final round of the survey. There were, however, no systematic differences between participants who completed the study and those who did not, limiting the degree of bias. Responses were, however, largely from high-income countries and may not be generalizable to countries with more limited resources and personnel. It should also be acknowledged that patients did not participate in this study. It is important to obtain patient perceptions in future studies because an increasing number of surgeries are performed while patients are awake. Second, consensus studies are not generally regarded as highly rigorous and should be interpreted in light of this limitation. Still, they can optimally identify areas of focus for future research in ways that are relevant to clinical practice. This is especially true for our study on frontline OR professionals. Future research might leverage existing data collection

technologies such as the OR Black Box^{®29,30} to prospectively study errors and events at the critical moments identified in this study and test the effectiveness of interventions targeting these specific moments. Our results could also help overcome traditional limitations of in-person observation in the OR by informing observers where to direct their attention. Previous studies have shown, for example, that in-person observers tend to focus their attention on the most “action” even though areas of less action may be equally important.³¹ Thus, moments such as “medication and equipment preparation,” which may have been overlooked in previous observational studies, have now been identified as key areas to observe.

Our work represents a key step toward improving patient safety in the OR by identifying moments during which to target interventions based on their perceived importance to each of the three main OR professions. Evidence suggests the perceptions of team members are as important to patient safety and teamwork as objectively observed behaviours.^{19,20} For the first time, healthcare providers from each of the core OR professions (nursing, anesthesia, surgery) have been asked to define those moments they perceive as critical. We acknowledge that this “generic” list of critical moments should be tailored to specific surgical specialties and local contexts for implementation. Nevertheless, our list of critical moments provides a starting point for exploring the importance of specific actions and behaviours during

Table 5 Mean scores for surgical moments where consensus was not reached*

Phase	First round Mean (SD)	Second round Mean (SD)	Third round Mean (SD)
Introduction of trocars	3.81 (0.87)	3.74 (1.08)	3.97 (0.85)
Surgical safety checklist step 2: surgical time out (after patient anesthetized and before surgical incision)	3.83 (1.06)	3.69 (1.12)	3.96 (1.04)
Surgical safety checklist step 3: “debriefing” (at the end of the surgical procedure)	3.31 (1.13)	3.29 (1.17)	3.42 (1.20)
Checking of special energy devices or equipment just before using it	3.55 (1.00)	3.43 (1.16)	3.52 (1.04)
When team member(s) make(s) the initial count at the beginning of the surgical procedure	3.72 (1.12)	3.74 (1.19)	NA
When patient is positioned	3.85 (0.95)	3.90 (0.91)	NA
Checking of surgical implants	3.73 (1.05)	3.87 (1.05)	3.94 (1.02)
Confirming/handing off specimens	3.48 (1.17)	3.63 (1.18)	3.94 (0.92)
Time period with more than 8 personnel in the room	3.36 (1.11)	3.19 (1.11)	3.29 (1.03)
When using a stapling device	2.99 (1.17)	3.13 (1.26)	3.41 (1.20)
Medication and equipment preparation	NA	3.94 (1.01)	NA
Crisis resource management situations	NA	4.18 (1.13)	NA
Key medication administration (e.g., antibiotics, heparin, methylene blue)	NA	3.78 (1.07)	NA

*was not voted as “critical” by minimum 80% of participants or as “not critical” by minimum 75% of participants.

NA = not applicable. Item was suggested by first round participants and thus only voted on in second and third rounds; SD = standard deviation

Table 6 Final list of critical moments in the OR

- Induction of anesthesia
- Emergence from anesthesia
- Surgical safety checklist step 1: preoperative (before patient anesthetized)
- When team member(s) make(s) the final counts at the end of surgical procedure
- Any anesthesiologist- or surgeon-relevant intraoperative event (e.g., bleeding, hypotension)
- Handover between colleagues of the same specialty/profession (e.g., nurse to another nurse or anesthesiologist to another anesthesiologist)
- High-risk surgical procedures/moments (e.g., moments specific to each procedure that are high risk for failure/consequences/alteration to patient vitals, such as release of vascular clamps, coming off bypass, CO₂ insufflation; OR moments when changes in surgical plan may occur, such as surgeon converting from minimally invasive to open surgery; when the surgeon conducts anastomosis, such as visceral or vessel; delicate dissection close to big vessels)
- Crisis resource management situations (e.g., call for help from an OR team member during a life-threatening emergency)
- Medication and equipment preparation
- Key medication administration (e.g., antibiotics, heparin, methylene blue)

CO₂ = carbon dioxide; OR = operating room

certain moments in the context of each surgical subspecialty.

Conclusions

We have defined the most critical moments of surgery that require the most focused attention for future patient safety initiatives. Future research can determine the relative importance of behaviour and actions at each stage. This could potentially enhance the effectiveness of future educational interventions, such as the “sterile cockpit rule”, by specifying the times at which certain actions need

to be completed. As a result, interventions to reduce medical errors linked to poor surgical patient outcomes may be greatly enhanced.

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