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Identification of Meaningful Data for Providing Real-Time Intraoperative Feedback in Laparoscopic Surgery Using Delphi Analysis

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Abstract

Background. Surgeons are at risk of being overwhelmed with information while performing surgery. Initiatives focusing on the use of medical data in the operating room are on the rise. Currently, these initiatives require postprocessing of data. Although highly informative, data cannot be used to influence preventable error in real time. Ideally, feedback is provided preemptive. *Aims*. First, to identify which information is considered to be relevant for real-time feedback during laparoscopic surgery according to surgeons. Second, to identify the optimal routing for providing such feedback, and third, to decide on optimal timing for feedback to alarm users during laparoscopic surgery. *Methods*. A Delphi study of 3 iterations was conducted within the Amsterdam UMC, location AMC. A total of 25 surgeons and surgical residents performing laparoscopy were surveyed using 5-point Likert scales. Consensus was obtained when 80% of answers fitted the same answering category. *Results*. Delphi round 1 resulted in 198 unique ideas within 5 scenarios. After round 3, consensus was obtained on 102 items. Feedback most relevant during laparoscopic surgery refers to equipment like the gas insufflator, diathermy, and suction device. Feedback should be delivered via an additional monitor. Surgeons want to be instantly alarmed about aberrations in patients' vital parameters or combinations of vital parameters, preferably via a designated section on a monitor in their field of vision. *Conclusions*. Surgeons performing laparoscopy are uniform in their opinion that they need to be alarmed immediately when patients' vital parameters are becoming aberrant. Surgeons state that information regarding supporting equipment is best displayed on an additional monitor.

Keywords

laparoscopy, laparoscopic surgery, real-time, feedback, Delphi

Background

Surgical safety is a topic of high interest in both practicing surgery as in surgical research.[1-4] Recognizing adverse events when they occur is crucial to safeguard surgical outcome. Preventing such adverse events is believed to impact surgical safety even more.[5-9] From the literature, it is known that adverse events usually do not result from one isolated intraoperative event.[1,10] During surgery, there often is a cascade with several erroneous decisions or actions lining up before a situation evolves into an adverse event.[9] In some cases, corrective actions or even sheer luck may result in resilience, where events pass without doing harm to the patient. These events are characterized as "near misses."[1] It is key that the surgeon is aware of being in an erroneous cascade to prevent near misses leading up to an adverse event.[11-13] There are different approaches on how to improve awareness, thereby increasing surgical safety. For example, training in simulative settings focusing on knowledge, skill, procedural routine, and situational awareness.[14] Upcoming is the use of video recordings or outcome reports from video systems and integrated medical data recorders,

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whether or not in combination with structural debriefing.[2,15] Although very useful, simulative settings involving multiple parameters and team members are quite incidental, logistically challenging, and may not prepare for many unforeseen situations.[16,17] The use of debriefing methods suffers inevitably from a delay between the actual occurrence of an event and the delivery of feedback.

The operating room (OR) is a highly demanding and dynamic environment. Contemporary OR's are packed with technology and advanced equipment to support surgical routine. Patient parameters are continuously monitored in an effort to improve safety and early intervention by anesthesiologists, surgeons, and other operating team members. With the introduction and maturation of minimally invasive surgery (MIS), even more technology and equipment were introduced to the OR. During surgery, all this equipment is producing various continuous data streams generating a multitude of signals aimed at providing continuous feedback to the members of the operating team. Although not intended, signals from such systems combined with chatter from colleagues and information presented on equipment monitors may be perceived as distracting rather than alarming. Indeed, relevant information is at risk of not being captured by the surgeon or members of the OR team at all, a phenomenon referred to as inattentional blindness. Even if signals are perceived, they may be subconsciously ignored.[18-22] Presenting irrelevant data or presenting signals at the wrong time is potentially dangerous, as it may result in negligence of such feedback. Presenting a signal too early may result in annoyance and is at higher risk of being ignored by the surgeon. Presenting an alarm too late might not leave enough options to exit an erroneous cascade, therefore timing of a signal is key.[19,23]

The aim of this study was not to introduce new technology but to explore which feedback signals generated by existing technology are deemed relevant by surgeons. Furthermore, we aim to explore when and how to present these signals best in order to interrupt an unwanted chain of events that may lead to an unwanted situation or outcome. Literature search on the topic outlined failed to generate data to answer the question above. The Delphi method was chosen, as it is a well-known method to generate consensus among peers when literature search fails to generate sufficient data to be critically appraised and without the risk of social bias that may occur in a consensus meeting or debate. Research questions were: (1) which feedback signals are preferred by laparoscopic surgeons with varying levels of experience, suitable for intraoperative real-time feedback? (2) what is the optimal timing for feedback to alarm users during surgery? and (3) what is the optimal routing for such feedback?

Methods

Delphi Method

The Delphi method was first developed by the Research and Development (RAND) corporation in 1948.[24-27] The Delphi method can be used as a forecasting tool for trends in technology and science. Delphi methodology may find use in situations where no historical data exist, or when new influencing factors are expected that are not incorporated in the past data. Respondents are allowed to react and assess differing viewpoints. A fundamental characteristic is the anonymous nature of a Delphi study, ensuring that there is not one single dominant group member, influencing other panelists.[28]

Study Design

Delphi studies can consist of questionnaires in a predefined number of rounds, or until a predefined stop criterion (such as the preset level of consensus or stability of results) is achieved. For this study, a predefined number of 3 rounds were set. A predefined number of 3 iterations were chosen as the literature shows this is generally sufficient for achieving consensus and adding more rounds may result in sample fatigue.[28-31] Authors felt it was important to clearly state the expected investment of time for all participants to minimize the risk of dropping out.

Selection of Panelists

A cross-sectional study was conducted in the Amsterdam University Medical Centers (Amsterdam UMC), location AMC. Equipment used when performing MIS produces many feedback signals. Therefore, this study focuses on laparoscopic surgery. Delphi methodology requires a panel of informed individuals who are often called experts. Yet, all participants should bring their own perspective on the discussed subject.[31,32] A total of 33 laparoscopic surgeons and surgical residents with varying levels of experience in laparoscopic surgery within the departments of urology, gynecology, and surgery were found eligible for participation in the Delphi panel. Varying levels of experience were chosen since this reflects daily surgical routine and because varying experience may influence the type and need for information or feedback. Respondents were recruited from the departments of urology, gynecology, and surgery to ensure heterogeneity amongst panelists.[28,33] Medical Ethics Committee approval was not needed, since the study does not involve patients, and all panelists were laparoscopic surgeons participating on a voluntary base.

Scenarios

Prior to the start of this study, a pilot questionnaire for the Delphi process was tested in a research surgical focus group. Situational surgical context was deemed crucial when constructing the Delphi questionnaires. In order to provide such context, 5 different scenarios reflecting realistic situations in the OR were defined to capture specific needs for those situations.

In the first scenario, nothing unusual is going on in the OR, described as the "flow" working scenario. The primary surgeon is performing laparoscopic surgery without a problem. Information from the electronic patient record (EPR), from the surgical equipment (like the gas insufflator and light source), and information from the monitoring of patient parameters are available to the primary surgeon, however not always directly in line of sight. Interaction with the equipment is mitigated via third-person interaction. Laparoscopic surgeons were questioned on what information would be relevant for them and via what medium optimally presented for the particular situation. The need for information is likely to change when an acute situation occurs in the OR. This is reflected in the second scenario, described as the "disturbance" working scenario.

In the third scenario, just as in the first, nothing unusual is going on either. But in this scenario, the surgeons can operate the computer, monitors, and surgical equipment themselves, while preserving sterility and without getting away from the patient using wearable technology such as a head-mounted display. This scenario is dubbed as the "hands-free" working scenario. This situation is not possible in many ORs but was deliberately chosen to help speculate surgeons on their preferences.

In the fourth scenario, panelists are asked to freely elaborate on information they would consider relevant without any limitations; the "visionary" working scenario. In the fifth and final scenario, the panelists were asked how they would prefer to receive feedback, the "preference" working scenario. In all scenarios, panelists were questioned on all 3 research questions (feedback signal, timing, and routing). The 5 working scenarios "flow," "disturbance," "hands-free," "visionary," and "preference" are available in Online Appendix 1. All scenarios were presented as written text to the panelists using an electronic survey tool.

Materials

Electronic surveys were sent to eligible panelists using SurveyMonkey (SurveyMonkey.com; SurveyMonkey® LLC, Palo Alto, California), which allows for one entrance per candidate. This online survey tool was compliant with our center's privacy legislation, as the study was completed before the General Data Protection Regulation (GDPR) became effective. All data were collected and analyzed using the Statistical Package for the Social Sciences version 25 (Armonk, New York, USA).

Delphi Round 1

First, an email was sent out to all laparoscopic operating surgeons from the departments of urology, gynecology, and surgery to invite surgeons becoming a panelist for this study. An email with an electronic link to the first questionnaire was sent out to the panelists who agreed to participate. The first questionnaire consisted of demographic questions and mainly unstructured open questions to generate ideas on the 3 topics: (1) feedback signals suitable for real-time feedback, (2) timing of feedback, and (3) routing of feedback. Surgeons were presented with the 5 earlier described scenarios. All answers were analyzed and filtered by one researcher (MJ) to identify all unique ideas. In addition, a categorical analysis was performed to determine top 3 of most valuable feedback signals.

Delphi Round 2

The second round consisted of closed questions, where panelists were asked to rate generated results from their unique answers resulting from the previous round on a 5-point Likert scale.[34] A 5-point Likert scale is often used in Delphi methodology.[29,35] In this study, a 9-point Likert scale was considered too broad, resulting in a widespread of answers, and a 3-point Likert scale, on the other hand, was considered too narrow. Answers were rated in terms of likelihood, convenience, and timing, ranging from 1 (very unlikely, very inconvenient, and direct) to 5 (very likely, very convenient, and as late as possible). Ideas were matched to the scenario where the idea was generated in the first round. When 80% of all answers were in either category 1 (Likert scores 1 and 2 combined) or category 3 (Likert scores 4 and 5 combined), consensus was considered obtained and items did not return in the Delphi round.

Delphi Round 3

In the third and final iteration, panelists were again asked to rate the previously generated ideas on a 5-point Likert scale, with distribution of answers from the second round visible. Only items where no prior consensus was achieved were presented.

Data Analysis

Descriptive statistics were performed for demographic data. The level of agreement between participants was calculated using agreement percentages. More than 80% on the 5-point Likert scale in the top or bottom 2 measures was considered as consensus obtained.[36] To evaluate group stability and progress of group stability when rounds evolved, intraclass correlation coefficients (ICCs) were calculated per scenario.

Results

Panelists

Laparoscopic surgeons and surgical residents with varying levels of experience from the departments of urology, gynecology, and surgery were approached. Of the 33 surgeons found eligible candidates for this Delphi panel, 25 surgeons agreed to participate in this Delphi study and received the link to the digital survey of Delphi round 1. When a participant did not complete a round, a reminder was sent regularly. A participant was only approached again for the next round, when the previous round was completed. The participants registered as medical specialist had 12.9 (SD 10.8) working years of experience on average after their surgical registration. The majority of all participants performed 50-100 endoscopic procedures as primary surgeon annually. Participant demographics are displayed in Table 1.

Delphi Round 1

In round 1, 25 panelists were surveyed, of whom 15 panelists completed the survey, resulting in a response rate (RR) of 60%. A total of 198 unique ideas were identified. All unique ideas in their original scenario are provided in Online Appendix 2. Categorical analysis revealed the following categories of feedback signals resulting from data streams: ideas on imaging, correspondence, equipment, patient record, intraoperative parameters, distractions, and alarms. The distribution of ideas is displayed in Table 2.

Delphi Round 2

All 198 ideas generated in the first round were presented to the 15 panelists who completed Delphi round 1 in the second round. Twelve panelists completed Delphi round 2 (overall RR 48%). Consensus was obtained in a total of 63 items. These items did not return in the third Delphi round. For an overview of ideas, items where consensus was reached and their distribution see Figure 1.

Six items were dismissed because >80% of panelists indicated that an item was not feasible. Of the 57 items where positive consensus was obtained in Delphi round 2, panelists achieved a 100% consensus on 14 items. In the "disturbance working scenario," all surveyed gynecologists indicated they want to know whether their patients want (more) children. Furthermore, all panelists want open communication with the anesthesiologist and nurses in this scenario. In the "visionary working scenario," all panelists indicated to want information about blood loss and all gynecologists indicated they want to look back on their last self-performed transvaginal ultrasound when possible. In the "preference working scenario," all the panelists indicated that they want to be alarmed about unusual settings of the OR equipment, excessive intra-abdominal pressure, hemodynamic instability, and ventilation problems. Panelists want these alarms early in a potentially erroneous cascade, except for the ventilation problems where no consensus on timing was reached. In 34 items regarding suitable data streams, consensus was obtained, 12 items regarding timing, 1 item regarding routing of feedback, and consensus was reached on 10 items deemed a distraction.

In the "flow working scenario," panelists indicated that they want information coming from the gas insufflator and the diathermy. In the "disturbance working scenario," panelists indicated that they want information on the

Table 1. Panelists Demographics.

Participant No	Gender	Experience in Years as Registered Specialist	Laparoscopic Procedures/ Year	Year of Residency	No. of Rounds Completed
1	Male	5	50-100	—	3
2	Female	11	50-100	—	3
3	Male	Resident	50-100	5th	1
4	Male	Resident	30-50	6th	1
5	Male	Resident	50-100	6th	3
6	Male	32	>100	—	1
7	Female	18	10-30	—	3
8	Female	8	30-50	—	2
9	Female	5	50-100	—	3
10	Male	8	50-100	—	3
11	Female	32	>100	—	3
12	Male	Resident	50-100	6th	3
13	Female	6	50-100	—	3
14	Male	Resident	30-50	4th	2
15	Female	4	10-30	—	3

Table 2. Results Round 1, Unique Ideas per Questionnaire Item.

Ideas on suitable data streams	N =	Ideas on timing	N =	Ideas on routing	N =
Scenario 1: "Flow Working Scenario"					
Imaging	10	N.A.		General	3
Correspondence	5			Visual	3
Equipment	11				
Patient record	9				
Intraoperative parameters	5				
Scenario 2: "Disturbance Working Scenario"					
Imaging	2	Timing in erroneous cascade	3	General	4
Equipment	9			Visual	5
Patient record	10				
Intraoperative parameters	7				
Scenario 3: "Hands-free Working Scenario"					
Imaging	4	Timing in erroneous cascade	6	General	4
Correspondence	3			Visual	—
Equipment	5			Telemedicine	1
Patient record	5				
Intraoperative parameters	4				
Scenario 4: "Visionary Working Scenario"					
Imaging	11	N.A.		N.A.	
Correspondence	2			N.A.	
Equipment	4			N.A.	
Patient record	2				
Intraoperative parameters	2				
Combinations of parameters	8				
Distractions	12				
Scenario 5: "Preference Working Scenario"					
Alarms	16	Timing in erroneous cascade	17	General	4
				Visual	2
Total	146		26		26

intraoperative patient parameters. Mentioned were "vital parameters not specified otherwise," blood pressure, and heart rate. In this scenario, panelists indicated they prefer to be alarmed on aberrations of these parameters early in a potential erroneous cascade. In the "hands-free working scenario," panelists indicated that they would want information on, and be able to operate, the laparoscopic camera, gas insufflator, diathermy, and desktop computer present in the OR. Regarding timing, panelists indicated they want to be informed early in the potential erroneous cascade and before the situation in the cascade evolves to an urgent situation. In the "visionary working scenario," panelists indicated that they would hands-free interact with ultrasound imaging, diathermy, and gas insufflator. They want to be informed on vital parameters and the interpretation of aberrations in the parameters by the anesthesiologist. The items judged as being a distraction were nonspecific information, information not related to the procedure, and all information that is continuously present was deemed distractions. In the "preference working scenario," panelists reached consensus on 13 different feedback signals and in 8 items also on their corresponding timing. A categorical presentation of items where consensus was reached in this Delphi round is provided in Table 3.

The ICC for the "flow working scenario" was .115, for the "disturbance working scenario" .053; for the "hands-free

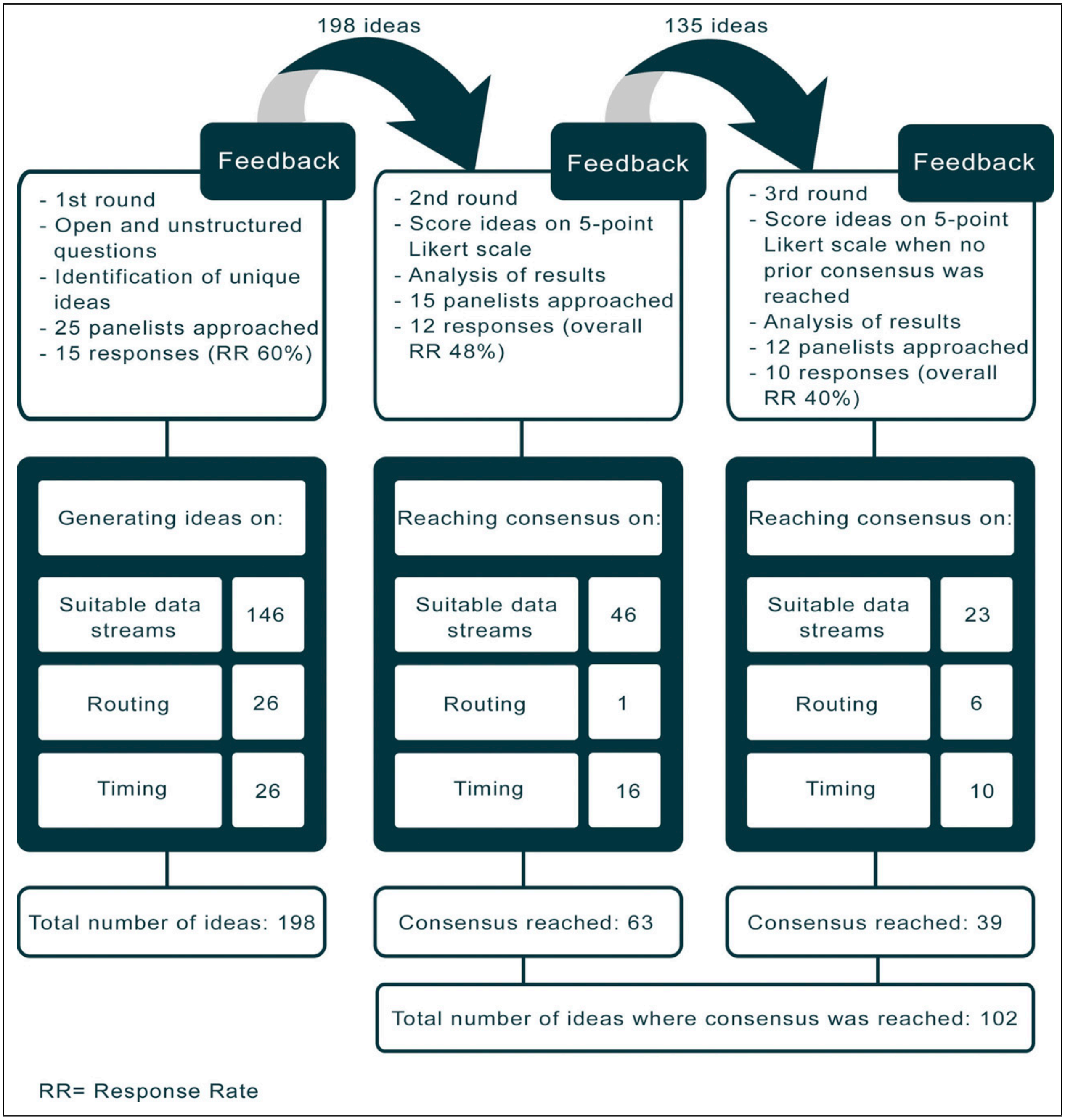

Figure 1. Overview of generated ideas and items where consensus was reached when rounds evolved.

working scenario," the ICC was .099; for the "visionary working scenario," the ICC was .162, and for the "preference working scenario," the ICC was .197. All ICCs indicate poor agreement (<.50). ICCs and evolvement in Delphi round 3 are presented in Table 4.

Delphi Round 3

The remaining 135 items (198 unique ideas minus 63 ideas where prior consensus was reached) were presented to the 12 panelists participating in round 3. Ten panelists completed the final Delphi round (overall RR 40%). Consensus was reached in another 39 items, bringing the total of items where consensus was reached at 102 (Figure 1).

Five items were dismissed in this scenario, since ≥80% of panelists indicated that an item was not feasible. In 34 items, consensus was reached, consensus was reached with the maximum score of 100% in 5 of these items. In additional 7 items regarding timing, 100% agreement was achieved. In the "flow working scenario," all panelists indicated that from

Table 3. Items Where Consensus was Reached in Delphi Round 2.

Scenario 1: "Flow Working Scenario"		
Category		
Data Streams	N =	Ideas
Equipment	2	Gas insufflator and diathermy
Scenario 2: "Disturbance Working Scenario"		
Category		
Data streams	N =	Ideas
Patient record	1	Wish for children
Patient parameters	8	Vital parameters not specified otherwise,[2] blood pressure,[2] heart rate,[2] and blood loss[2]
Timing		
Timing in erroneous cascade	2	Early, before the situation becomes urgent
Routing		
General	1	Open communication between surgeon, anesthesiologist, and nurses
Scenario 3: "Hands-free Working Scenario"		
Category		
Data streams	N =	Ideas
Equipment	4	Operate the laparoscopic camera, operate the gas insufflator, operate the diathermy, or operate the desktop computer
Timing		
Timing in erroneous cascade	2	Early, before the situation becomes urgent
Scenario 4: "Visionary Working Scenario"		
Category		
Data streams	N =	Ideas
Imaging	1	Transvaginal ultrasound
Equipment	3	Diathermy and gas insufflator[2]
Patient parameters	2	Blood loss, combination of blood pressure, heart rate, and interpretation by the anesthesiologist
Distractions	10	All data continuously displayed, vital parameters in a hemodynamic stable patient, laboratory measurements, anesthesiology parameters other than vital parameters, noises/chatter/alarms not direct to the surgeon, ventilation conditions, all nonprocedure specific information, all information not relevant at that time for the specific procedure
Scenario 5: "Preference Working Scenario"		
Category		
Data streams	N =	Ideas
Alarms	13	Presented in Table 4
Timing		
Timing in erroneous cascade	8	Presented in Table 4
Total	57	

the information available from OR equipment like information/settings of the gas insufflator and the settings of the diathermy machine are deemed relevant. Of the available patient parameters, panelists were most interested in the amount of blood loss. In the following "disturbance working scenario," all surveyed panelists indicated that in this situation they prefer feedback via an additional monitor and that feedback should be offered directly. In the

Table 4. Group Stability per Scenario per Round.

	Round 2 (ICCs*)	Round 3 (ICCs)
1. Flow working scenario	.115	.468
2. Disturbance working scenario	.053	.148
3. Hands-free working scenario	.099	.348
4. Visionary working scenario	.162	.228
5. Preference working scenario	.197	.648

*Intraclass correlation coefficients, ICC <.50 = poor, ICC between .50 and .75 = moderate, ICC between .75 and .90 = good, and ICC above .90 = excellent.

"preference working scenario," all panelists indicated that they want to be alarmed of a decreasing or low blood pressure. In the following vital parameters or combinations of vital parameters, all panelists indicated to prefer feedback instantly: when blood pressure is low or decreasing, there is a tachycardia, a combination of a decreasing blood pressure and increasing heart rate, hemodynamic instability, ventilation problems, the loss of pneumoperitoneum, or excessive use of distension medium at hysteroscopy. A distribution of all other items where consensus was reached is visualized in Table 5. ICCs were calculated for round 3 and are displayed in Table 4. Although ICCs were still relatively low, they

Table 5. Items Where Consensus was Reached in Delphi Round 3.

Scenario 1: "Flow Working Scenario"		
Category		
Data Streams	N =	Ideas
Imaging	2	Imaging not specified otherwise, CT-scan images
Equipment	2	Gas insufflator and diathermy
Patient parameters	3	Blood loss,[2] blood pressure, vital parameters not specified otherwise
Routing		
Visual	3	Display on the monitor with the laparoscopic camera feed, display in a separate section of a monitor already in use, or display on an additional monitor
Scenario 2: "Disturbance Working Scenario"		
Category		
Data streams	N =	Ideas
Equipment	2	Information/settings of the gas insufflator[2]
Patient record	1	Do not resuscitate statement
Timing		
Timing in erroneous cascade	1	Direct
Routing		
Visual	2	Display in a separate section of a monitor already in use or display on an additional monitor
Scenario 3: "Hands-free Working Scenario"		
Category		
Routing	N =	Ideas
General	1	Oral feedback by 1 of the nurses
Scenario 4: "Visionary Working Scenario"		
Category		
Data streams	N =	Ideas
Imaging	4	Last preoperative CT-scan images, CT-abdomen, MRI-abdomen, MRI-pelvis
Patient parameters	2	Combination of blood pressure and heart rate, combination of blood pressure, heart rate, and oxygen saturation
Scenario 5: "Preference Working Scenario"		
Category		
Data streams	N =	Ideas
Alarms	3	Decreasing or low blood pressure, tachycardia, low oxygen saturation
Timing		
Timing in erroneous cascade	8	Direct[8]
Total	34	

Table 6. Data Streams Deemed Most Valuable to Surgeons.

Data Stream	Source	Timing
Information/settings from the gas insufflator	Gas insufflator	Early
Information/settings from the diathermy	Diathermy	Early
The amount of blood loss	Suction equipment	Early

Table 7. Feedback Signals from the "Preference Working Scenario" Where Consensus was Reached.

Feedback Signal (%)	Consensus on Timing in Delphi Round 2	Consensus on Timing in Delphi Round 3
Consensus reached in round 2		
1. Excessive intra-abdominal pressure (100)	Early (100)	—
2. Anesthetics wearing off, patient is waking up (80)	Early (90)	—
3. Paralysis is wearing off (80)	No consensus on timing	No consensus on timing
4. Almost out of gas for the insufflator (90)	Early (80)	—
5. Decreasing blood pressure in combination with a high or rising heart rate (80)	No consensus on timing	Early (100)
6. Hemodynamic instability (100)	No consensus on timing	Early (100)
7. Ventilation problems (100)	No consensus on timing	Early (100)
8. Loss of pneumoperitoneum (80)	No consensus on timing	Early (100)
9. Unusual settings of operating theater equipment (e.g., diathermy or the gas insufflator) (100)	Early (80)	—
10. Too much use of distension medium at hysteroscopy (80)	No consensus on timing	Early (100)
11. Impending damage to adjacent organs (90)	Early (90)	—
12. Thermic damage to adjacent organs (90)	Early (100)	—
13. Impending bleeding (90)	Early (90)	—
Consensus reached in round 2		
1. Low or decreasing blood pressure (100)	—	Early (100)
2. Tachycardia (90)	—	Early (100)
3. Low oxygen saturation (90)	—	Early (80)

increased compared to the previous round. The ICC for the "preference working scenario" was .648, indicating a moderate level of group stability.

Generated ideas on preferred feedback signals resulting from the data streams after Delphi round 1 ranged widely, where ideas on routing and timing were fairly consistent in different scenarios and when rounds evolved. After the final Delphi round, a top three of most valuable data streams available in the operating theater and a selection of alarms with corresponding timing clearly stood out. These ideas were mentioned in different scenarios and with the highest level of agreement. The top three of data streams with corresponding timing are presented in Table 6.

Routing of the feedback of these specific data streams was not surveyed. However, all panelists indicated that they want open communication with the surgeon, anesthesiologist, and nurses. From the visual routings of feedback, display on either an additional monitor or in a separate section of a monitor already in use (for example, with the laparoscopic camera feed) was preferred by panelists.

In Delphi round 3, consensus was reached on 3 more items where surgeons want to be alarmed about and their corresponding timing. In the previous Delphi round, consensus was reached on 14 items and consensus on corresponding item was reached in 8 of 14 items. In Delphi round 3, consensus on timing was reached for 5 of the remaining alarms. Results are presented in Table 7.

Discussion

This Delphi analysis identified 198 unique ideas regarding relevant feedback signals, optimal timing, and ideal routing. After 3 Delphi rounds, consensus was obtained in 102 items. From these items, a top three of real-time feedback signals deemed relevant by laparoscopic surgeons could be conducted. These top three consist of information and settings coming from equipment being the gas insufflator and the diathermy and information of blood loss. Even though panelists were presented with a wide variety of scenarios and ideas, consensus was obtained in the majority (102/198) of the items on 3 different topics.

Despite the variety of possibilities resulting from many data sources that arise in laparoscopic surgery, varying surgical professions, and varying levels of experience, surgeons express a clear and uniform vision on what information should be available immediately when operating. This may explain the discrepancy between the high number of ideas where consensus was reached and the relatively low ICCs. Five different scenarios reflecting the situation in the OR were created by the authors of this study to provide context to the panelists. Panelists could reflect upon each questionnaire; no comments on the chosen scenarios were received.

Feedback signals coming from the OR equipment deemed most valuable to surgeons are those that may directly influence their performance or disrupt normal workflow.[37] Surgeons suggested that they should be able to gather information from and operate the gas insufflation and diathermy. Furthermore, surgeons want to have information derived from the suction equipment, since blood loss is related to patient outcome. Normally, the performing surgeon would ask the circulating nurse to adjust levels of the insufflator flow according to the specific procedural needs. This may be a time consuming and in potential frustrating process prone for error due to third person interaction.[19,38,39]

Surgeons want to be *alarmed* about parameters that, if passed unnoticed or noticed late, may result in harm. Aberrations in vital parameters relevant to that patient or combinations of aberrations in parameters are mentioned by panelists. It is not that such information is currently *unavailable* in the endoscopic OR. But merely that information cannot be accessed in the direct line of sight or at hearing distance. Even when such signals are in the immediate perceptive area of the surgeon, they may go by unnoticed if nothing changes in the signal, or when the surgeon is mentally occupied focusing on the primary task: performing surgery.[40] Indeed, when surgeons are in "a flow" state and surgery runs smoothly, displaying signals that do not contain information that needs to be acted upon in the line of sight is unwanted and may be distracting, as indicated by the panelists of this Delphi study. But when information *should be noted and acted upon*, information may now pass unnoticed as it is not in direct focus. Hence, surgeons may be unaware of a deteriorating situation and may therefore be unable to react timely and appropriately. One of the feedback signals suggested frequently to be visually available is timed information about blood loss via the suction device. This is an example of a parameter that is currently available through equipment signaling, however out of sight. As such, the surgeon depends on others to provide this information actively.

Despite the fact that the results presented in this study may not be surprising, suggested feedback signals by our panelists are unavailable for real-time intraoperative feedback to date. The panelists surveyed in this study suggested to provide the feedback on an additional monitor (abdominal and insufflator pressure and blood loss) or the monitor in the direct line of vision when performing surgery (out-of-boundary vital parameters). To view information presented on an additional monitor, the surgeon would have to look away from the surgical area, which is potentially dangerous. In contrast, presenting overly information on the monitor featuring the laparoscopic video feed could be disturbing, impairing the surgeons' view of the surgical area. Therefore, authors suggest to display such information when it is considered outside of normal boundaries but not continuously by default. Another way of routing that was frequently suggested during this Delphi study to provide real-time feedback was to stimulate open and clear communication patterns between operating team members. Although this routing of feedback is independent of technology, it may be vulnerable as it is both human and situation dependent. Especially, when a situation arises when everyone in the OR must maintain their prime focus on the specific task, communication between those persons is known to be under stress.[41,42]

Limitations

In this Delphi study, panelists were asked in an open and unstructured first questionnaire to generate ideas on their ideal routing of feedback. It is likely that panelists who are not aware of the latest technological possibilities have only mentioned ideas that they feel are possible or already familiar to them, leaving out solutions that could in potential also be beneficial, introducing knowledge reporting bias.[43] The nature of the study may not have provided enough opportunity for panelists to elaborate further on the matter, since they were asked to answer on 5-point Likert scales after Delphi round 1. Since this is the first study exploring this topic by our knowledge, we believe the Delphi design is the best method of choice. Since the experts of this Delphi study originate from different specialties and have a varying level of experience, these factors may have influenced results; this variety among panelists however is a key factor when using the Delphi method. Although gynecologists participating in this Delphi study clearly valued transvaginal ultrasound, information regarding hysteroscopy and information about their patient's wish for children no other specialty-dependent differences were found. Experience did not seem to influence how experts participating in this study valued ideas. The number of panelists was considered too small to perform a segmented analysis for residents, fellows, and medical specialists. In this analysis, no differences in preferences resulting from the level of experience were found. This may however be an underestimation of reality. Residents in training may still be in their learning curve and therefore value other information. Furthermore, they may not experience responsibility different because a supervising surgeon may be present during surgery. In the scenarios used, we always survey the panelist as the performing surgeon to minimize this effect.

Although the operating team consists of more members than just the surgeon, in this Delphi study the focus was specifically on the interests of the laparoscopic surgeon. Adding more variety to the panel would have possibly resulted in more opinions and therefore consensus possibly could not have been achieved. Considering the number of laparoscopic surgeons within our center and the time-consuming nature of the questionnaires used for his study, a RR in Delphi round 3 of 40% (n = 10) is acceptable and can serve as a starting point to further explore the topic in additional research.

Conclusions and Recommendations

Surgeons performing laparoscopy who participated in this study were presented with a variety of statements; furthermore, there was a variation of experience among panelists. Despite the variety in statements and experience, panelists are uniform in their opinion that they need to be alarmed immediately when patients' vital parameters are becoming aberrant. The preferred routing of feedback about patient parameters is via a monitor already in use, like the monitor displaying the laparoscopic video feed. Surgeons want to be informed about difficulties with supporting equipment that are a derivative of patient safety, such as the blood loss via the suctioning system or the pressure in the pneumoperitoneum coming from the gas insufflator. Surgeons state that information regarding supporting equipment is best displayed on an additional monitor.

Future Perspectives

Future studies should focus on surgeon and operating team satisfaction presenting them with relevant data for real-time feedback. There should be experiments with the routing of such feedback to create the optimal setting for the surgeon performing laparoscopic surgery. This study indicates that surgeons are interested to operate equipment that is part of their workflow, like the insufflator, diathermy, and laparoscopic camera themselves, while preserving sterility. How to integrate remote control of the equipment present in the OR was out of scope of this study, but according to panelists and authors, worth exploring. This study provides the scientific fundament to initiate further studies researching the optimal setting within the OR.

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Author Contributions

All listed authors can legitimately claim authorship, since they comply with the following statements:
1. Made a substantial contribution to the concept or design of the work or acquisition, analysis, or interpretation of data
2. Drafted the manuscript or revised it critically for important intellectual content
3. Approved the version to be published
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Supplemental Material

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