When surgeons face intraoperative challenges: a naturalistic model of surgical decision making

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Abstract

BACKGROUND—Surgery is an environment in which being an expert requires the ability to manage the unexpected. This feature has necessitated a shift in surgical decision-making research. The present study explores the processes by which surgeons assess and respond to nonroutine challenges in the operating room.

METHODS—We used a grounded theory methodology supported on intraoperative observations and postoperative interviews with 7 faculty surgeons from various specialties. A total of 32 cases were purposively sampled to compile a dataset of challenging situations.

RESULTS—Thematic data analysis yielded 3 main themes that were linked in a cyclic model: assessing the situation, the reconciliation cycle, and implementing the planned course of action. These elements were connected through 2 points of transition (ie, active and confirmatory reconciliation), during which time the surgeons continue to act although they may change the course of their action.

CONCLUSIONS—The proposed model builds on existing theories of naturalistic decision making from other high-stakes environments. This model elaborates on a theoretic language that accounts for the unique aspects of surgery, making it useful for teaching in the operating room.

Keywords

Intraoperative challenges; Decision making; Reconciliation

Surgery has grown increasingly complex in recent years, becoming an environment in which being an expert is characterized by an ability to manage the unexpected. This evolution has created new opportunities to explore decision making in surgery. Contemporary research has started to move away from a focus on understanding routine problem-solving patterns in the face of common problems^{1–4} and toward a more nuanced understanding of the dynamic

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process of decision making in nonroutine situations in order to prepare surgeons to meet uncertainty with flexibility and innovation.^{5,6}

The present study sought to further the understanding of surgical decision making during challenging situations by exploring the processes by which experts assess and respond to nonroutine challenges. This understanding is necessary to ensure that training and assessment respond to the unique challenges of decision making during nonroutine situations.

Research about intraoperative decision-making has traditionally followed 3 different approaches: (1) the feasibility of deconstructing and explicitly identifying decision-making tasks and influences for a given procedure,^{1,2} (2) the prevalence of “intuitive” and “analytic” decision-making strategies faced by surgeons in challenging situations,^{7,8} and (3) the cognitive shift that occurs when surgical experts anticipate a challenging intraoperative situation.^{9–12} The following section reviews studies from each of the 3 aspects in an attempt to describe the overall context in which the present study is located.

A task deconstruction approach to decision-making activities has been shown to be effective for training essential decisions during laparoscopic surgery. Jacklin et al¹ followed a cognitive task analysis approach to deconstruct the standard decision-making tasks associated with laparoscopic cholecystectomy. By interviewing surgeons about a hypothetical patient, Jacklin et al found that experienced surgeons predominantly use 2 decision-making strategies when dealing with routine decisions. For decisions involving a higher degree of uncertainty (eg, deciding whether the patient should be operated on or not according to the patient’s symptoms), surgeons relied more on their intuition and experience, whereas for routine decisions related to implementing the standard surgical technique (eg, deciding whether to use a bag to extract the gallbladder or not), a rule-based approach was more commonly used. Following a similar goal and using an observational approach, Sarker et al² proposed a systems-based approach to task deconstruction that resulted in a psychomotor surgical dynamic decision-making model. Such a model constitutes a useful resource for scientists to identify the situational elements at play when surgeons confront intraoperative decisions.

The process of understanding how surgeons implement a decision in the operating room should involve a notion of the types of isolated decision-making tasks as well as an understanding of the kinds of decision-making strategies. This knowledge may be particularly helpful to surgeon-educators as they work to develop the decision-making capacity of surgical trainees and junior colleagues. Flin et al⁷ and Pauley et al⁸ identified 2 prevalent types of decision-making strategies used in surgery: intuitive and analytic. Using a naturalistic approach, Flin and Pauley et al described surgical decision making as a 2-stage process composed of situation assessment and the selection of a decision strategy. Furthermore, Flin et al⁷ expanded on the latter element to describe 4 main decision strategies from the aviation literature (ie, intuitive, rule based, analytic, and creative) and the circumstances in which they may be used in surgery. Using Flin et al’s model in combination with the critical decision method, Pauley et al⁸ analyzed surgeons’ recall of surgical cases. They found that intuitive thinking, (ie, a solution is quickly recalled from a

previous encounter with a similar situation) and analytic thinking (ie, comparing between options) are the most prevalent strategies used to make intraoperative decisions during both elective and emergency procedures. By including elective and emergency procedures, Flin et al's work begins to suggest that it may be important to differentiate between routine and challenging cases as suggested by a recent review.¹³

One aspect of differentiating decision making between routine and nonroutine moments during a procedure is the way surgeons are able to anticipate that they are approaching a challenging moment in the surgery. This cognitive shift has been described by Moulton et al^{9–11} as the “slowing down when you should” phenomenon. Through the use of observational and interview data, Moulton's model of surgical expertise identifies 2 types of initiators for this transition: proactively planned “slowing down” moments, which can be predicted, and situationally responsive “slowing down” moments, which are triggered by unexpected events and are therefore unpredictable. Moulton et al's contributions have been pivotal in advancing the understanding of how a surgeon recognizes the advent of an upcoming challenging moment.

In summary, previous research has established several facts that further the understanding about surgical decision making including the feasibility of deconstructing and identifying decision-making tasks and influences, the prevalence of both intuitive and analytic strategies depending on the decision-making context, and the existence of a cognitive shift that takes place when surgeons anticipate an intraoperative challenge. Our research seeks to complement these important advances by addressing the ways in which a surgeon creates an understanding of the situation and then generates and implements a solution to the challenge, particularly by describing the process of creating, choosing, or adapting situationally responsive options.

Methods

A grounded theory methodology was used in support of our goal of developing theory in an area about which little is known.¹⁴ This approach¹⁵ was selected because it affords a means to explore how and why specific decisions were made by the surgeons. As a qualitative research methodology, the constructivist grounded theory allowed us to engage in the exploration of the tacit knowledge that arises from the surgeons' reflections on their internal cognitive processes about their approach to decision making in the operating room. In this way, we were able to explore the nature of perceived challenges as expressed by the participating surgeons rather than dictating a particular definition of “challenge,” which may not reflect their experience or opinions.

Informed by the postobservation interview technique critical decision method (CDM),¹⁶ observational and interview data were collected to capture moments of surgical challenge for 32 surgical cases between May 2011 and February 2012. This is a methodology prevalent in naturalistic studies of expert decision making and used to gather retrospective accounts of challenging incidents.¹⁶

Sample

Our work is guided by the overall qualitative research aims to provide rich descriptions of a situation to contribute to the theoretical understanding of a phenomenon or process.¹⁷ With this aim in mind, we engaged in theoretical sampling wherein data are collected and analyzed concurrently with new cases sampled to elaborate or fill gaps in the evolving analysis.

Participating surgeons were sampled purposively to include rich informants with a variety of levels of experience (ie, 5 to 20 years) in a variety of surgical specialties (ie, general surgery, orthopedic surgery, cardiac surgery [2], urology, vascular surgery, and neurosurgery). A total of 32 cases were purposively sampled to compile a dataset of challenging situations; participating surgeons preselected cases and notified 1 of the authors (S.M.C.) when a case was booked that they predicted would be challenging. “Intraoperative challenges” were defined as situations that surgeons predicted would require important judgment calls from their part to decide the proper course of an operation. Other “challenging” factors such as poor teamwork, distractions, equipment failures, and so on were not included in our definition of an “intraoperative challenging situation.”

Data collection

Each case was observed by a nonsurgeon (S.M.C.) who has a Ph.D. in engineering and postdoctoral training in surgical education and is an experienced surgical observer with 7 years of experience observing surgical cases in the operating room and interviewing surgeons for research purposes. Observational field notes were taken regarding specific utterances from surgeons and other health care professionals, general conversations in the operating room, and actions and interactions between staff members relating to the surgery. These field notes were used in combination with a semistructured interview guide to tailor a specific postsurgery interview with the surgeon of each observed case. The purpose of the interview was to explore the surgeon’s behaviors and reflections on dealing with challenging intraoperative moments. Interviews took place immediately after each observed procedure.

This postobservation interview technique follows the CDM.¹⁶ This technique was particularly effective in response to the high-risk, high-complexity nature of the medium to long surgical procedures (ie, 4 to 14 hours) observed. During longer procedures, many challenging and uncertain moments may occur, and the surgeon is sometimes unable to describe all of them within the context of the situation. Observation-informed probes allowed the surgeon to expand and further reflect on the details of the situation beyond what was described in the initial recalling of the moment. Because field notes were used to inform the postsurgery interview, only interview data were analyzed in the CDM method.¹⁶

Data analysis

Following grounded theory principles, data collection and analysis proceeded iteratively to allow theoretical sampling to saturation. Data collection continued until theoretical saturation was reached (ie, when no new conceptual insights were generated from additional data).¹⁵ Constant comparative techniques for thematic coding were used.¹⁵ Thematic coding began with open coding, capturing each instance of consideration and decision making

related to surgical challenges. Focused coding was then performed to concentrate on intraoperative processes. These codes were then grouped into broader yet still specific categories reflective of recursive themes. The entire research team received these thematic categories and definitions, discussed their resonance with the data, and proceeded to independently create models using the categories that originated from the focused coding. The members of the research team then met to compare the models they independently created. This comparison served to highlight differences and similarities between the models, which were discussed and reconciled between the entire research team. A model was decided on between all team members, and the categories were refined as necessary to reflect their role in the overall model. The data were then recoded using these refined categories as a guide. Discrepant instances were searched for and discussed between 2 members of the research team (S.M.C. and M.V.). The revised model was returned to the entire team, who discussed and agreed on its credibility and resonance with the data and their personal experiences as surgeons. Rigor was ensured by following established qualitative criteria including independent scrutiny, member checking through respondent feedback,^{18,19} method and theory triangulation,^{20,21} and the formation of an audit trail of the analytic process.²²

Results

Nonroutine decision making was observed at least once in each of the purposively sampled cases. During interviews, surgeons were able to provide rich reflections of the nuances surrounding those nonroutine decisions. Thematic data analysis yielded 3 main themes that were linked in a cyclic model of decision making during challenging surgery. The model consists of 3 elements (ie, assessing the situation, reconciliation cycle, and implementing the planned course of action) and 2 points of transition during which time the surgeons continue to act although they may change the course of their action (Fig. 1).

The proposed model uses the premise, which was commonly expressed by participants, that surgeons begin each surgery with a planned course of action and continue to revise that planned course of action throughout the surgery in response to emerging information and the perceived level of difficulty. We refer to the “planned course of action” as any action that was created and decided on before execution. Planned courses of action may include the detailed preoperative plans designed for elective procedures, the minimal plans created for emergency procedures, and evolving intraoperative plans for each small stage of the operation. The proposed model is framed as a cycle through which surgeons may travel many times over the course of a surgery, especially if that surgery is challenging. The cycle may be traveled during each different stage of the surgery or several times within the same stage if challenges arise. A surgical “stage” is idiosyncratically defined by each surgeon and may be specific to the procedure being performed.

Elements of the model

Although this model separates the steps of assessing, reconciling, and implementing for purposes of clarity, analysis indicates that these steps may often overlap; this overlapping is reflected in the iterative transition phases. The proposed model begins with a preoperative

plan formed before the surgeon enters the operating room and informed by all the information available before the surgery. For elective surgeries, this might include clinic visits, imaging, the opinion of colleagues, and research the surgeon has performed. For surgeons performing emergency surgeries, less information may be available, but our interviews indicate that a preoperative plan is still made and that plan takes into consideration all the information available at the time. As 1 participant explained about an elective surgery, “I spent a lot of time reviewing the imaging with the radiologist to ensure that what we were planning to do was even technically possible...I talked to a colleague who does the same kind of surgery as me and suggested to them the approach I was planning to take and said ‘can you look at the imaging and do you think it’s reasonable what I’m planning to do?’” (case 27).

Assessing the situation—With the preoperative plan in mind, the surgeon begins the surgery by assessing the situation, remaining alert for information that indicates potential challenges to the preoperative plan. The assessment of the situation also involves interpreting available information to determine whether challenges anticipated in the previous stage may arise or not or if there is any indication of previously unanticipated challenges. Based on the interpretation of intraoperative information and the comparison with the existing planned course of action, the surgeon may choose to adjust the current planned course of action, moving into the reconciliation cycle to make this decision. The following explanation shows how the planned course of action may change once the intraoperative situation is assessed, necessitating the creation of a new plan: “There was a hernia around the colon and we were going to close that defect in the muscle and then place a mesh around it, but when we got there, there was no bridge in the muscle where the colon came out and where the hernia was and since there is no bridge and it was all a big hole, it just seemed to make more sense to remake the stoma and then reposition it rather than repair the old defect” (case 1).

Reconciliation cycle—The reconciliation cycle is characterized as a continuous, iterative process of gaining information; weighing the information found against what is expected or typical and against the planned course of action; and thinking ahead, projecting future steps of the operation and again reconsidering the planned course of action to determine if this is still the best way to proceed.

Gaining information: During surgery, information may be gained through a variety of means. Sources of information may include other people present in the operating room as described by 1 participant, “There’s a fair bit of collective experience in the room separate from me” (case 31), or from nonhuman sources in the operating room (eg, “I know from my previous experiences that I have to rely on the fluoro a lot because I don’t see the fracture” [case 9]). Information may be actively sought (eg, asking a question of a colleague, “Dr. X had the ability to watch [the monitor] and assess, so he was in a better position to judge are we in a good location, yes or no” [case 22]). Information may be actively sought using visual or haptic senses to determine anatomic information (eg, “We had to use special retraction sutures to pull the fat away so that we could actually see [the artery]” [case 30]). Information may also be perceived without active seeking through the process of monitoring

conditions in the operating room such as “you have to interpret all the cues that the nurses are giving you and the perfusionist” (case 28). Many surgeons spoke of the ways in which they gained information they were not explicitly seeking by remaining observant while acting (eg, by noticing anatomic changes, “we saw inflammation between the pulmonary artery and the aorta and that immediately told us we had to slow down” [case 28]).

Weighing information: While conducting the surgery, the surgeon receives a large amount of information and must simultaneously interpret this information while acting and deciding on future action. The surgeons might weigh new information against other sources of information, past experiences, and prior knowledge about this surgery obtained earlier in the surgery or preoperatively as shown by the following example: “I had doubts, based on all our imaging, that we were going to be able to remove the tumor. Our approach was just to kind of slowly work at the periphery to the central part of it and just dig it piece by piece and bit by bit until we could really make a judgement call as to whether it was mobile enough to be removed or not” (case 20). While receiving and interpreting this information, the surgeon is also weighing that information against what the expected findings were in order to determine whether the existing course of action is still satisfactory. The surgeon may find things as expected and choose to continue on with the planned course of action (eg, “I knew that harvesting his artery underneath the ribs was not going to be easy because his chest was very barrel-chested and his lungs were smoker’s lungs. We were confronted with challenges as expected.” [case 10]). Alternatively, the surgeon may encounter something that was unexpected while planning this course of action and decide to change the plan, “I opened [the left heart artery] at the point where on the angiogram it predicted free of disease. It was rock hard. I had to extend the opening further distally, further beyond, to the second piece of vein to that diseased artery” (case 30).

Projecting future steps: In this process of reconciling new information with previous information and expected information, the surgeon also anticipates future findings and challenges, projecting a few steps further in the surgery to anticipate possible challenges such as, “In an operation like this I’m thinking a step or two ahead of what the steps are to try and set up those steps as easily as possible” (case 29). This process of projection is also reconciled with the planned course of action to ensure that the current plan remains satisfactory and that contingencies are considered if unexpected information arises as shown by the following quote: “I kind of have various options in my mind and I see the patterns of what is available and what I have to work with and just one of the options matches that pattern, so I went with it” (case 1). The process of thinking ahead, or projecting, may also include communication with the surgical team to ensure that all members are prepared for what may arise in the future as described by 1 participant, “Before I started I made sure that the nurses had some stitches available that would be the appropriate stitches to use to fix the hole I made if I made a hole” (case 20).

Throughout this process of the reconciliation cycle, new information is compared with the original plan, and possible future findings are also compared with the existing plan with adjustments made as needed. After the reconciliation cycle, the surgeon may choose to

proceed as planned, or the surgeon may choose to alter or reprioritize the planned courses of action.

Implementing—After confirming or revising the planned course of action, the surgeon begins to implement the planned course of action, again alert for possible challenges throughout this implementation. During implementation, there is an iterative movement between implementing the planned course of action and reconciling new information gained from each step with the planned course of action to ensure that the plan remains satisfactory as the following explanation describes: “It became very clear when we first tried to do some of the maneuvers to mobilize the stomach that the stomach wasn’t going to move and the tumor was near the perforation so that option [initial plan] was not even possible.”

Transitional cycles of the model: active and confirmatory reconciliation

The transition phases are called active reconciliation and confirmatory reconciliation. Both phases represent iterative movements of comparing new information with the planned course of action in an attempt to ensure that the planned course of action is satisfactory. The difference between active and confirmatory reconciliation is that active reconciliation occurs at the beginning of a new stage of the surgery when new information is being uncovered and the planned course of action is more likely to be changed. The plan may be adjusted to ensure that it is technically feasible, will have the best possible outcomes, has a comfortable margin of safety, uses the available human and equipment resources, and is consistent with what the surgeon knows about the patient’s preferences. Confirmatory reconciliation occurs when a plan has been decided on and is being implemented. New information may be obtained during implementation, and the surgeon must remain alert to this possibility and be prepared to adjust the planned course of action to respond to this information in order to ensure that the objective of that stage of the operation is accomplished. When the surgeon is satisfied with the implementation of the miniplan, 1 round of the cycle is complete. The surgeon then transitions to the next stage of the operation and begins the cycle again, assessing the new situation and comparing it against the previously formed miniplan, which takes the place of the preoperative plan in subsequent iterations of the cycle. In this way, the cycle repeats, with each stage informing the subsequent stage. Both the overall plan for the operation and the miniplans evolve as the procedure progresses.

Comments

We were able to observe and explore in interviews the decision-making process of the experienced surgeons in the face of nonroutine problems. Our results echo a process approach to decision making in surgery, which is reflective of the premises of the naturalistic decision-making research tradition.^{23,24} Naturalistic decision making examines the performance of expert practitioners during complex or challenging situations, suggesting that experts seem to take an “intuitive” approach to decision making when facing complex moments. This assertion contrasts with traditional notions of decision making as an educated choice between multiple options.^{25–28}

Based on our observations and interviews, we propose a model of intraoperative decision making that conceptualizes this phenomenon as a continuous cycle. Elements of this

iterative cycle include defining what the problem is, understanding what a reasonable solution would look like, and taking action to reach that goal and evaluating the effects of that action.²⁴ This proposed model shares similarities with Klein's recognition model for decision making by expert firefighters,²⁵ but our model has been constructed to reflect important particularities of the surgical context. Klein's model based on research with firefighters^{24–26} suggests that firefighters used intuitive decision making, generating only a single option instead of comparing 2 or more options. If the course of action seemed appropriate (when mentally simulating the option), then the firefighters would implement that option. If the first strategy was not sufficient, the firefighters would try to modify their chosen option. Klein's approach emphasizes decision processes (ie, characterizing what firefighters actually do when making decisions) rather than focusing on the catalysts of their decisions.²⁴

Although our model also emphasizes processes, it has been adapted to the particular context of surgery, including crucial differences such as (1) the presence of a preoperative plan that is tailored to the specific situation; (2) moderate as well as extreme time pressure, which allows surgeons to engage in a conscious process of gaining and weighing information; and (3) familiarity with both the physical context and the team members before entering the situation (ie, surgeons are familiar with the layout of the operating room, they choose the equipment in advance, they may know who will be the resident or the nurses for the day, and so on).

In view of this, our model characterizes intraoperative decision making as a 3-element cycle with 2 associated transitional processes: active reconciliation and confirmatory reconciliation. The connecting element in the model guiding these transitions is the reconciliation cycle. The reconciliation cycle in our model provides additional granular details about the process that Klein describes in his model²⁵ as mental simulation. Within our reconciliation cycle, we have identified the sources (ie, human and nonhuman) and methods (ie, active information seeking, passive information receiving, and information perceived in the course of acting) by which surgeons gain information from the environment to better conceptualize the problem at hand. Future research will look more deeply at investigating the "reconciliation" phenomenon by describing how the surgeon's knowledge and past experience are combined with information received in the surgical environment to generate an understanding of the situation. One interesting aspect to be considered while further investigating the "reconciliation" phenomenon is the potential differences between less and more experienced surgeons. This will allow us to describe more fully the role of contextual information in the surgeons' decision-making activities in the face of nonroutine problems.

Our work focuses on understanding the internal cognitive processes that guide surgeons as individuals in making decisions during challenging situations. This decision-making process is a complex phenomenon with multiple elements informing or affecting it. However, in order to properly situate such elements within the phenomenon of surgical decision-making, it is important to first describe the tacit knowledge and approaches that surgeons use individually as suggested by this study. As part of our program of research, we are interested in applying a "systems" approach to the study of decision making, and, therefore, future

work will build on our current model to progressively incorporate aspects such as interactions with other elements present in the operating room (eg, other team members, assistive technology, and so on).

In relation to assessing decision-making skills, recent research has generated a number of tools to code and assess nontechnical skills in the operating room: Anesthetists Non Technical Skills (ANTS) for anesthesia and Non Technical Skills for Surgeons (NOTSS), Non Technical Skills (NOTECHS), and revised NOTECHs for surgeons.²⁷ Although the purpose of these tools is to measure social and cognitive skills during live^{28,29} and simulated operations,^{30,31} the assessment is based exclusively on observations, which makes it difficult to capture in detail the phenomenon of surgical decision making as a process. The following questions remain unanswered: What features inform the implementation and revision of decisions? and Do those features present differently during routine surgical cases vs emergency and complicated cases? One way to begin answering these questions is by looking into how surgeons navigate the “reconciliation cycle” described in our model. Features such as the type of information a trainee looks for at a given difficult moment during the surgery and the rationale behind the selection and use of such information may help elaborate what surgical assessors are looking for when they evaluate trainees’ cognitive skills. A recent systematic review has suggested that although most studies in the operating room have looked at routine elective procedures, there may be fundamental differences in nonroutine or challenging settings although this is unclear because of the lack of empiric evidence in the literature.¹³ By focusing on challenging situations, our work may provide preliminary insights into these issues.

Limitations

The main limitations of this study include the recruitment of surgeons from a single educational institution and the reliance on participants’ assessment of anticipated challenges for case selection and on 1 single observer. Moreover, following the tenets of grounded theory research, our sample of surgeons is small and purposefully focused on experienced surgeons and intended for theory building rather than generalization to the entire surgical population. We aimed to guard against hindsight bias that may be linked to the interview method of the CDM by using the observation field notes to inform the postsurgery interviews. Despite these limitations, our work responds to recent claims in the literature for studies of nontechnical skills in surgery that rely on empiric evidence.¹³

Conclusions

Our study adds to the existing literature by providing a model that characterizes the cognitive processes that surgeons engage in to assess and respond to intraoperative challenges. Our model of intraoperative decision making is derived from surgeons’ intraoperative behaviors and postoperative reflections and builds on existing theories of naturalistic decision making from other high-stakes environments. This model also elaborates on a theoretical language that accounts for the unique aspects of the surgical environment. We anticipate that our model will be useful to 2 audiences: (1) decision-making scientists interested in making explicit the tacit approaches to challenging situations

that surgeons use in the operating room; and (2) educators interested in making their decision-making strategies visible as they interact with surgical trainees.

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Figure 1.
A naturalistic model of intraoperative decision making.