How Can Educators Use Simulation Applications to Teach and Assess Surgical Judgment?

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Abstract

Surgical simulation applications have been largely limited to the acquisition and assessment of technical skills. Current teaching and assessment of surgical judgment is nonsystematic and prone to error. Interest in methods to enhance the acquisition and assessment of knowledge-based (judgment) skills for intraoperative decision making has led to the application of cognitive task analysis (CTA) and human error assessment to facilitate this process. CTA-based delineation of the steps and hazards of a surgical procedure creates a structured process to teach and assess expert surgical judgment and improves trainees’ operative planning, hazard recognition, error prevention, and error recovery when coupled with low-fidelity, synthesized simulation models for open and laparoscopic surgery. Web-based simulation applications facilitate curricular learning (rules-guided skills), allow cognitive rehearsal of procedures, and are accessible independent of location and time. Simulation applicationsthat facilitate the assessment and learning of expert intraoperative judgment should include a consensus-derived outline based on CTA of the operative steps and potential points of risk for each surgical procedure; the ability to detect the situational awareness of the performer and the options considered to avoid error at critical steps; an assessment (scoring) of options considered or attempted; immediate evaluation feedback to inform improved performance; and a program of deliberate practice in which progressively more challenging scenarios can be introduced, based on the trainee’s demonstrated skills. High-fidelity simulators currently lack these essential components, and future simulation-assisted teaching and assessment of surgical judgment skills are likely to employ low-fidelity simulators coupled to Web-based instruction.

The apprenticeship model of surgical education is being transformed by new technology and by the need to objectively assess and confirm the competence of trainees. Medical educators in general, and surgical educators in particular, have become increasingly interested in gaining a better understanding of what constitutes expert judgment, so as to apply teaching methods that enhance the acquisition of this important component of competence and expertise.

Simulation models, techniques, and applications have become increasingly popular in surgical training. 1–4 Although simulation applications have demonstrated their value in technical skill acquisition and team building, they have not yet fulfilled their potential role in the attainment of (expert) surgical judgment.

Therefore, in this article I explore some of the recent findings of educational psychologists on what constitutes expert judgment and review how surgical investigators are applying the principles of cognitive task analysis (CTA) and a form of error analysis referred to as human reliability assessment to uncover characteristics of expert judgment in the performance of surgical procedures. I then examine how existing and future simulation models may be applied to teach, learn, and assess expert judgment in surgeons and surgical trainees.

What Is Expert Judgment?

In the field of cognitive psychology, experts are defined as individuals capable of a variety of advanced skills, including constant, rapid, accurate, effective diagnosis and solving of complex problems. They are able to quickly apply domain-specific rules about the condition or problem at hand and maintain an awareness of the consequences of the application of problem-solving strategies. Novices, in contrast, have severe limitations on conscious processing but develop expertise through a lengthy regimen of motivated, deliberate practice. Deliberate practice can lead to expert performance when highly challenging increases in the demands and difficulty of tasks are accompanied by constant corrective feedback. Job experience is not necessarily deliberate practice if it lacks progressive and varied challenges.

Educational psychologists often refer to the Dreyfus and Dreyfus5 model of staged acquisition of expertise, which includes (1) novice, (2) advanced beginner, (3) competence, (4) proficiency, and (5) expertise. The five stages of this progression mirror the five levels of surgical training—that is, (1) student or postgraduate year 1, (2) postgraduate year 2, (3) postgraduate years 3 and 4, (4) chief resident, and (5) fellow or attending—during which progressive phases of learning occur. Skill-guided learning results in knowing how, rule-guided learning results in knowing...
that, and experience-guided learning results in knowing when to do or not to do something, or when to alter the plan or procedure. Furthermore, the development and display of automatic use of a behavior or technique without reflective effort, or automaticity, increases with each stage of development.3

Purposeful, goal-directed behavior incorporates both automatic, nonanalytic behavior and mentally effortful, analytic behavior, in varying proportions.10 Expertise is characterized by effective interfacing between these two modes of behavior.11 Nonanalytic capacity develops as a result of scripting and scenarios related to pattern recognition. When conducting an interventional procedure, the experienced individual performs the routine steps comprising the basic elements of the procedure with some level of attention but without analysis. This automatic processing requires less attentional capacity which, in the expert, frees up cognitive resources to invest in risk awareness, problem solving, and anticipating the results of the intervention. The individual who makes exclusive use of nonanalytic resources and automatic processes is unlikely to manage novel or unusual situations expertly and has been defined by Bereiter and Scardamalia10 as the “experienced non-expert.”

In Bereiter and Scardamalia’s schema,10 the experienced nonexpert will adapt the present problem to known solutions rather than adapting new solutions to the present problem. Such individuals are otherwise known as technicians “who perform well on routine problems by unreflectively and automatically applying standard assumptions and techniques,” but they do “not display creativity in finding solutions to ill-defined or unusual problems.” Exports “identify the subtle complexities of situations”; through an effortful process, they develop a deeper understanding of the problem and arrive at a better solution that avoids error and a poor outcome.10

Lack of situational awareness leads to errors in judgment: An action decision may be correct for the perceived circumstance but result in error because the actual situation is not as perceived.12,13 (A common example of such an error in general surgery is the bile duct injury that occurs during “routine” laparoscopic cholecystectomy.) Experts may devolve or revert into experienced nonexperts through burnout, disillusionment, or complacency as well as through fatigue, physiologic (e.g., hypoglycemia) or pharmacologic (e.g., alcohol) effects, or excessive anxiety.14–16 In addition, cognitive capacity is limited at any moment in time: The need to perform multiple tasks simultaneously (i.e., technical tasks that demand effortful performance on top of analyzing and being cognitively aware of situational complexities) can result in a failure of performance.17,18

According to Schön,19 experts typically demonstrate three characteristics in action: knowing-in-action (automatic know-how), reflection-in-action (ability to improvise), and reflection-on-action (post hoc reasoning about the experience, which informs future performance). Moulton et al20 state that the expert engages automatic resources in action and uses the cognitive resources that thereby become available to continuously evaluate the situation, assessing how effectively his or her automatic resources are functioning; he or she is able to recognize when it is necessary to “slow down,” that is, when to engage in more effortful, analytic behavior. The experienced nonexpert, however, may not invest these additional cognitive resources and may fail to recognize when it is necessary to slow down. In surgery, we teach this conversion from routine technical behavior to analytic, reflective behavior by slowing or stopping the progress of an operation to focus on analysis of the hazard risk when we encounter a critical point. Or, as one professor of surgery once explained to me, “the secret of being a good surgeon is knowing when to speed up, and knowing when to slow down.”20

Experts demonstrate the ability to deal with uncertainty by naming (observing and/or recognizing the unusual or abnormal) and framing an abnormal situation correctly (understanding the significance of the recognized abnormality).19,21 Therefore, an important characteristic of expert judgment is slowing down when it is necessary “to take the time to ensure that the muddy problems of practice will be correctly named and framed.”9 This transition from automatic, nonreflective activities to cognitive awareness and analysis becomes routinized with increasing experience, such that the expert surgeon may be only minimally aware of when he or she shifts from one mode to the other.3

To understand the process of slowing down, Moulton et al22 interviewed 28 surgeons who were regarded as experts. The surgeons were asked to recall moments when an error occurred in the course of an operation and they found themselves saying, “I can’t believe I just did that,” and to reflect on how those moments informed their subsequent approaches to similar problems. The surgeons acknowledged the role that slowing down plays in exercising analytic tools and expertise. Their comments enabled the investigators to identify planned and unplanned initiators of as well as inhibitors of the transition (slowing down) to a more effortful, analytic mode of behavior. Planned initiators included operative procedure-specific steps and patient-specific abnormalities that were identified in advance, whereas unplanned initiators resulted from situation-specific events, such as complications or events that required a deviation from the operative plan. Factors inhibiting or impairing the transition included physical factors such as fatigue, personality factors such as overconfidence, and situational factors such as difficulties in team management and communication, competing cognitive input (e.g., chatter among team members, loud music), and time constraints (e.g., “I’ve got to be at a meeting with the chairman/dean in 10 minutes”).

An inherent part of expert judgment, therefore, appears to be the transition from routine, automated processes to focused, analytic behavior, characterized by slowing down at critical decision points.3,22 Slowing down allows the expert surgeon to engage in analysis, teaching, and self-reflection, which enhances patient safety. A surgeon’s failure to transition from automatic/routine to attentive/more effortful modes of function (due to lack of situational awareness) can lead to surgical error and patient harm. Over time, and with experience, this transition itself becomes automated or routinized and requires less effort (and time), which frees up
more cognitive capacity for expanded situational awareness, self-awareness, reflection, and innovation, leading to improved outcomes.23

To summarize, expert judgment consists of superior problem-solving skills, which the expert invokes at appropriate points of increased risk during a procedure. These skills are observable as transitions from routine, automatic technical behavior to deliberate, analytical, reflective behavior. Do we as educators identify this behavior as characteristic of expert judgment when we see it? And how do we know if a trainee’s (slowing-down) transitions are occurring at appropriate times and for the right reasons?

How Do We Assess Clinical Judgment?

Classically, attending surgeons’ assessments of whether trainee surgeons possess “good judgment” have been made in a subjective fashion. This approach is problematic because there is potential for bias due to perceived overall performance (the “halo effect”), because teachers have poor insight into their own judgmental processes, and because unstructured global assessments do not provide scope or focus for formative feedback to improve performance.24 Furthermore, in the current surgical training environment, it is rare for a senior surgeon to have extensive one-on-one contact with a trainee so as to determine with confidence the level of judgmental skills the trainee has attained.

Various methods have been developed that attempt to provide an objective and standardized approach to assessing clinical skills. These include the objective structured clinical examination,25 the objective structured assessment of technical skills,26 and the global operative assessment of laparoscopic skills (GOALS),27 which can be modified to a particular procedure, such as groin hernia repair28 or incisional hernia repair.29 Performance scores measured by the GOALS tool correlate highly with performance on a simulator and performance in the operating room, but each of these objective assessment tools places more emphasis on evaluating technical skills than on assessing judgmental ability. Wohaibi et al30 have described an operative assessment tool that uses an 11-point scale to assess cognitive skills and organizational ability (defined as “trouble-shooting ability”) in addition to technical ability and that correlates well with trainee experience and expertise. It is completed jointly by the attending and resident surgeon via a Web-based surgical performance rating system (OpRate) at the completion of each procedure. Validation of this tool’s usefulness in a simulated environment, where trainee awareness, analysis, and decision making can be assessed in isolation, is currently in progress.

The oral examination required for certification by the American Board of Surgery is the prototypical structured model for the assessment of a trainee’s judgment and organizational skills. Many residency training programs have adopted this assessment tool in the form of “mock oral exams” administered to middle- and upper-level residents annually. The oral examination format, however, carries its own set of features that may influence examinee performance, and success on such a high-stakes examination can be affected by the test taker’s anxiety and familiarity with the format. Moreover, in my experience, the oral examination model is not a test of intraoperative situational awareness or decision making but, rather, is heavily weighted toward rules-based facts and algorithms.

Surgical trainees’ awareness of predictable or unpredictable situations that contain hazards and their ability to assess strategies to avoid risk or to alter the operative plan are therefore not measured routinely in a structured, transparent, procedure-specific, instructor-independent manner. To create a tool to measure trainees’ judgment, a codified “best practice” set of behaviors needs to be identified.

Methods to Identify the Essential Elements of Expert Judgment

The difference between skilled, experienced workers (experienced nonexperts) and advanced experts is the ability of the latter to recognize and solve problems. Even the most advanced experts, however, are largely unaware of the automated strategies that guide most of their problem solving.31 One approach to modeling a cognitive system is to trace the problem-solving process to identify points where limited knowledge and resources can lead to breakdowns given the demands of a specific problem.32 CTA is a system of assessing and defining the steps involved in expert task performance. It was developed by industrial psychologists in the 1980s and 1990s to address training needs in industrial, transportation, and military sectors so as to create job expertise in certain complex tasks in a short time frame.33 It has proven to be a successful model for expert training; it has been said that “50 hours of training based on CTA is the equivalent of 5 years of advanced job knowledge.”34 The impetus for the development of CTA was the realization that it takes trainees too long to achieve expertise under the apprenticeship model, which was flawed because situational variations requiring expert judgment happen too infrequently, teaching methods are subjective and imprecise (task teachers do not know how or what to teach), and it is instructor dependent and, therefore, nontransferrable.35

CTA provides a set of methods and techniques that specify the cognitive structures and processes associated with task performance. Or, as Woods36 explained, “Cognitive task analysis is like learning the secret of a magic trick; once you know the trick and know what to look for, you see things you didn’t notice when you didn’t know what to look for.” The CTA process involves interviewing experts to identify a representative sample of domain-specific problems that need to be solved (List 1). The concepts, principles, and practices that characterize expert performance can then be mapped or scripted for teaching and learning by nonexperts (for an example, see Appendix 1). CTA can be laborious because an investigator must interrogate experts who perform the procedure and may need to interrogate other experts who critique the experts who perform the procedure.37

CTA has been applied to surgical procedures,35–37 surgical simulation development,38,39 and surgical curriculum development.40 Velmahos et al41 used CTA to analyze the task of central line insertion and identified seven critical steps and the decisions associated with
List 1
Samples of Questions Asked of Experts During Cognitive Task Analysis*

1. What is the goal of this task?
2. What conditions or context must be present to start the task?
3. What is the reason for this task? (What process is at work, what conditions are being classified or changed?)
4. What actions and decisions must be implemented to complete the task?
5. What concepts, processes, or principle knowledge is required to adjust this task to fit novel elements?
6. What equipment and materials are required?
7. What performance standards must be achieved? (e.g., time, accuracy)


Successful performance of the procedure. Sullivan et al48 used CTA to deconstruct the automated and thoughtful skills of experts in percutaneous tracheostomy, revealing multiple steps in the procedure, including key decision points and the cues that inform these decisions. They found that residents trained with a CTA-based curriculum performed better than those trained using standard methods, not only immediately but on reassessment six months later. Using CTA, Jacklin et al37 identified 18 key decision points in the management of gallstone disease and then formed a map of care from the point of initial patient evaluation through recovery from cholecystectomy. To do this, a surgeon and a behavioral psychologist interviewed expert surgeons and characterized decision-making steps and (automated) procedural steps. Although the two interviewers agreed on the definition of the majority of the steps, the surgeon assessed some steps as judgment based, whereas the psychologist graded them as procedure based. This suggests that certain crucial procedural steps, such as dissecting the triangle of Calot and securing the cystic duct, require a combination of technical and judgmental skills. These authors concluded that the concept of surgical competency should be broadened beyond the surgeon’s ability to perform the technical steps of the operation to include his or her ability to make appropriate judgments.

CTA is being applied to an expanding list of surgical procedures so as to define a standard expert method for performing them and the critical decision steps embedded in the expert method.49 As Jacklin et al,49 Pugh et al,49 DaRosa et al,40 and others have pointed out, the involvement of expert surgeons as objective investigators in such efforts is essential for the success of the CTA process.

An alternative method for modeling a complex set of activities that requires expert judgment to avoid harm is to identify the steps of a procedure which contain a high risk of error. Joice et al41 analyzed 200 videotaped laparoscopic cholecystectomies to study the factors contributing to intraoperative errors, using a technique called human reliability analysis (HRA) in which they created a predefined set of error modes (e.g., wrong sequence, wrong instrument, too fast). Most errors were seen in the steps related to identifying the cystic artery (dissecting the triangle of Calot) and securing the cystic duct. The authors concluded that HRA is useful in detecting procedural steps in which errors are commonly encountered and in identifying technical and cognitive remediation approaches. Tang et al42,43 used the same format and an expanded version of HRA, called observational clinical human reliability assessment (OCHRA), to analyze differing techniques used at steps with high risk for error to determine the best (safest) and worst (most error-prone) technical methods of performing a task. These investigators concluded that OCHRA systems should be incorporated into technical training to increase awareness of risk and to identify steps in which decreased speed and increased cognitive resources are required to minimize the chance of error. OCHRA is labor-intensive, however, because professional/expert scoring of each recorded procedure is required. As a result, the method has not gained widespread use.

How Can Simulation Methods Be Applied to Teach, Learn, and Assess Expert Judgment?

Whole-patient (mannequin) simulation models have been used successfully for learning advanced management skills in anesthesia,44-45 emergency medicine and trauma care,46-47 and obstetrical care48 as well as in perioperative surgical care and team building.49 These simulation models focus more on the acquisition of cognitive skills than technical skills, and they successfully engage both experienced practitioners and trainees to sharpen their decision-making and team management skills.

Although attaining expert-level proficiency on a laparoscopic simulator has been shown to result in fewer intraoperative errors,50,51 the currently available high-fidelity surgical simulators do little to help users refine and expand their surgical judgment. This explains, in part, why novices and advanced beginners use such surgical task simulation applications enthusiastically, whereas experts and experienced nonexperts are less motivated to use them.52

Surgical educators and organizations have begun to address the shortcomings of these simulation models by pairing rules-guided learning with technical skill acquisition in a simulated environment. In a study of simulated laparoscopic ventral hernia repair, Pugh et al33 showed that adding instructor feedback on error prevention significantly improved residents’ subsequent intraperformance decision making. In Kohls-Gatzoulis and colleagues’54 study of arthroplasty training, residents who received cognitive skills training in place of some technical skills practice sessions showed improved ability to detect error, plan next steps, and correctly execute the procedure when compared with control group residents who had received only technical instruction.

In cooperation with the Society of American Gastrointestinal and Endoscopic Surgeons, Fried et al55,56 developed the Fundamentals of Laparoscopic Surgery (FLS) course, which emphasizes the attainment of basic laparoscopic skills and understanding. The FLS course includes technical exercises completed on a box-trainer.
To teach and assess more advanced clinical management skills, the Society for Surgery of the Alimentary Tract has partnered with a Web-based education company to develop a "virtual surgical patient" evaluation tool (www.discoursecell.com). They have created a series of clinical scenarios that combine text, static and video imaging, and pull-down data menus that allow the user to determine what information is needed for clinical decision making. The tool assesses the user’s management skills by offering options at key steps in the scenario. The “branching” design allows the user to proceed down paths that may not be correct. At the end of the case, the tool generates a score that reflects the user’s overall proficiency of judgment. This system emphasizes cognitive rather than technical skills, and it can be used to assess the expertise of residents as well as practicing surgeons. Zendejas et al recently reported reductions in patient complications and length of hospital stay following the addition of a simulation-based training protocol that included Web-based cognitive simulation exercises and practice to proficiency on an extraperitoneal hernia simulator.

Web-based and computer software applications have become increasingly popular as a means to teach and learn clinical skills. Cognitive simulation applications are one type of Web-based model in which variations in data in simulated scenarios can be accessed to assess clinical problem-solving behavior. This permits the mapping of the cognitive demands imposed by the situation to assess the response of the problem-solving operator. As described by Windsor, cognitive simulators are Web- or software-based, combine multiple media (text, Internet, audiovisual), use prerendered simulation (video or virtual reality), allow testing of knowledge and decision making, and provide feedback based on relevant metrics. The Web-based Integrated Cognitive Simulator (www.simtics.com) and the software-based SimPraxis trainers (www.redllmainc.com) are two examples of this developing type of simulation that promotes both cognitive rehearsal and technical rehearsal of operative procedures and can be used anytime, by multiple users, close to the operating room in location and time.

Pugh et al have used CTA to adapt box-trainer systems and models of open surgical procedures to assess intraoperative decision making for ventral hernia repair, mediastinal lymphadenectomy, pancreaticojunostomy, and intestinal stoma creation. By combining direct feedback and instruction by expert observers during simulated procedures that are based on CTA-guided procedure analysis, they found that users significantly improved their simulated intraoperative decision making and more correctly performed the simulated procedure. Marshall et al reported a similar application of CTA-based methods to assess and teach the decision-making steps in chest wall tumor resection. Such simulation models allow the instructor to stop the procedure to assess the learner’s cognitive processes and assess his or her situational awareness. Direct interrogation allows the instructor to assess whether a trainee’s slowing down in action is a result of appropriate awareness and analysis or whether it is merely dithering. Immediate, formative feedback from instructors results in improvements in surgical planning, recognition of possible complications, error prevention, and error management.

Cognitive rehearsal of a procedure is used routinely by expert surgeons, but it is more difficult for advanced beginners and inexperienced but technically proficient trainees. Simulation models which promote cognitive rehearsal in addition to technical rehearsal have been shown to improve surgical outcomes. Cognitive rehearsal of an event or procedure can take the form of mental visualization, a technique that has been shown to improve the performance of professional athletes. Mental practice can also take the form of a structured simulation or depiction of a procedure. Arora et al demonstrated that a mental practice protocol significantly improved surgical residents’ performance of simulated surgery or laparoscopic cholecystectomies.

Currently, therefore, the surgical simulation methods that are the most effective for teaching, learning, and assessing the essentials of expert surgical judgment consist of box-trainer and low-fidelity, open-surgery models coupled to Web-based applications that incorporate a programmed map or algorithm of the steps and tasks involved in the correct performance of a procedure. Box-trainer and high-fidelity simulation models have been shown to be equally effective for the acquisition of technical skills in novice trainees, which raises the issue of justifying the high cost of high-fidelity devices. Using box trainers and synthesized open-surgery models to evaluate and teach judgment requires the presence of expert instructors, however, which raises issues of the cost and means to support the instructors’ time commitment. Thus, the challenge for high-fidelity simulator development, as noted by Satava, remains the incorporation of training and assessing judgment, so as to provide skills-based, rules-based, and knowledge-based training that does not require the presence of an instructor.

Challenges and Recommendations

As Spencer stated, “An operation calls for 70–75% decision making and 20–25% dexterity.” Opportunities to assess trainees’ critical decision making are limited in the operating room, however; such assessments are better performed in a simulated surgical environment. For simulation applications to be effective in learners’ acquisition and instructors’ assessment of judgmental or knowledge-based skills, validated cognitive and technical skills criteria need to be codified for each “core” procedure in a surgical curriculum. This is a challenge, however, because no two senior surgeons perform the same operation in exactly the same way. Therefore, check points (e.g., steps with high error risk, key decision points) must be identifiable, and the surgeon’s level of situational awareness needs to be measurable. The response to each critical step must be recorded, scored, and displayed for the instructor to provide corrective feedback and to
inform the trainee’s future decision making. Anomalies due to anatomic or pathologic variations need to be introductible so that the challenges and demands on the user can be increased progressively as skill attainment allows.

The successes reported by some surgical educators who have incorporated these principles into training exercises paired with “homegrown” box trainers and open surgical models indicate that expert judgment is teachable and transferable to trainees outside the operating room. The incorporation of Web-based clinical training sites that permit technical and cognitive rehearsal of procedures is likely to further enhance the transfer of judgmental expertise in the simulated environment. Yet, until high-fidelity simulators incorporate a validated “best practice” for each core procedure with metrics indicating expert performance and a method to score user performance, dedicated surgical teachers will continue to be needed to guarantee trainees’ attainment of expert surgical judgment in the simulated environment.

**Recommended reading:** Readings that may be of value to the interested reader are suggested in Supplemental Digital List 1, available at http://links.lww.com/ACADMED/A91.

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**References**


40. Pugh CM, DaRosa DA, Santacaterina S, Clark RE. Faculty evaluation of simulation-based modules for assessment of


58 Bell RH Jr. Discourse LLC. Personal communication with DK Andersen, September 15, 2011.


Appendix 1
Excerpt of Cognitive Task Analysis Results for Flexor Tendon Repair*

Task 13: Decide if wound needs to be extended AND which method to use AND which direction to extend

Goal: Provide access to operative area without creating excessive scarring

**STEP 1:** Decide if field is adequate to visualize and/or repair tendon
- Does laceration allow visualization of 10 mm of each tendon edge?
  - IF YES, THEN proceed with repair
  - IF NO, THEN extend incision to expose an area where 10 mm of each cut edge can be brought into wound for repair

**STEP 2:** Decide which direction to extend wound by determining likely location of cut tendon edges given mechanism of injury

**STEP 2A:** Decide location of cut tendon edges
- IF digits were in flexion during injury, THEN the distal cut edge will be distal to the injury AND the proximal cut edge will be close to the site of injury
- IF the digits were in extension during injury, THEN the distal cut edge will be close to the site of injury AND the proximal cut edge will be proximal to the site of injury
- IF digits were in neutral during injury, THEN both cut edges will be close to the site of injury

**STEP 2B:** Decide which direction to extend wound
- IF the cut edge is likely distal to the site of injury, THEN extend the incision AND in continuity with most lateral edge of wound
- IF the cut edge is likely proximal to site of injury, THEN extend incision proximally AND in continuity with the most lateral edge of wound

**STEP 3:** Decide between Bruner and midlateral incision, or a combination to extend incision

Goal: Incorporate existing wound into extension to provide area for tendon visualization/repair

**A.** Bruner incision: diagonal incision extending across one phalanx
  - **Advantage:** can easily extend proximally into the palm, provides excellent exposure of flexor sheath as well as digital nerves
  - **Disadvantage:** minimal if you don’t violate tendon sheath, additional sutures

**B.** Midlateral incision: an incision along the midlateral line defined by depth of joint crease with digit in complete flexion
  - **Advantage:** leaves scar on the nontactile area of the finger, less visible scar because it is in area of no tension
  - **Disadvantage:** increase risk of injury to dorsal branch of digital nerve, technically more difficult for exposure, transection of feeding vessel to vincula when elevating neurovascular bundle with skin flap