Exploring Procedure-based Management Reasoning: A Case of Tension Pneumothorax

by

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DEDICATION

To my partner, Lori, who is my far better half. Someone who believes in me far more than I believe in myself and puts up with my ridiculous ideas.

Thank my children, Jo and Nora, for their unconditional love and bearing with me as I learn how to be a parent.

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ABSTRACT

Exploring Procedure-based Management Reasoning: A Case of Tension Pneumothorax

Raj Singaraju, Master of Health Professions Education, 2022

Thesis directed by: Steven J Durning, MD PhD, Director, Center for Health Professions Education, Uniformed Services University of the Health Sciences in Bethesda, MD

Background

Management reasoning has not been widely explored but likely requires broader abilities than diagnostic reasoning. An enhanced understanding of management reasoning could improve medical education and patient care. We conducted a novel exploratory study to gain further insights into procedure-based management reasoning which has not been empirically explored in prior investigations.

Research Question

We conducted an exploratory study to investigate procedure-based clinical reasoning to gain further insights into this phenomenon. More specifically, what clinical reasoning tasks underpin a physician's management of tension pneumothorax during acute decompensation?

Study Design and Methods

Participant physicians managed a simulated patient who acutely decompensates in a team-based, time-pressured, live scenario. Immediately following the scenario, physicians performed a think-aloud protocol by watching video recordings of their performance and narrating their reflections in real-time. Verbatim transcripts of the think-aloud protocol were inductively coded using a constant comparative method and evaluated for themes.

Results

We recruited 19 physicians for this study. Fifteen physicians were from internal medicine, one from family medicine, and three from general surgery. Recognizing that diagnostic and management reasoning intertwine, this paper focuses on management reasoning's unique characteristics. We found three categories of management reasoning (consistent with situated cognition's factors) with eight subthemes. These include Patient factors: Acuity and Preferences; Physician factors: Recognized Errors, Anxiety, Confidence, Monitoring, and Decision to Treat; and one Environment factor: Resources.

Interpretation

Our findings on procedure-based management reasoning are consistent with Situation Awareness and Situated Cognition theories and the extant work on management reasoning, demonstrating that it is inherently complex and contextually bound (situated). Unique to this study, all physicians demonstrated anticipatory behavior, indicating that attaining competency in procedural management likely requires anticipatory skills. Physicians also expressed concerns about making mistakes, potentially resulting from the scenario's emphasis on a procedure and our physicians' having less expertise with the treatment of tension pneumothorax.

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CHAPTER 1: INTRODUCTION

Background

Clinical reasoning is the task by which practitioners make and justify clinical decisions.[1] Researchers typically divide this task into diagnostic and management reasoning. Practitioners assign a diagnostic label to patients' constellations of signs and symptoms in the former.[2,3] Alternatively, management reasoning is more nebulous. Management reasoning describes how health care workers make clinical decisions about treatment, monitoring, and resource allocation.[2] Because diagnoses can be established as correct or incorrect, much of medical education's work to date on understanding clinical reasoning concentrates on diagnostic reasoning.[4] However, diagnosing patients is only half the job and maybe not even half. Physicians are paid to diagnose and treat patients, with cure often as the primary objective. Physicians not only prescribe medications they may be tasked with performing procedures. Improved understanding of procedure-based management reasoning could improve clinical reasoning teaching and assessments and reduce medical errors.

Literature Review

We define clinical reasoning as a task "that enables practitioners to take wise action, meaning to take the best-justified action in a specific context."[5] Similarly, we define diagnostic reasoning as the steps up to and including labeling of diseases for a "constellation of signs, symptoms, and test results that are unified into a solution at a single point in time."[3] The extant work demonstrates that diagnostic reasoning is a non-linear cognitive process governed by context specificity, cognitive load theory, and dual-processing models.[2,6] Management reasoning is taught and assessed as a cognitive task similar to diagnostic reasoning, but researchers have not widely explored management reasoning in empirical contexts.[1] To our knowledge,

procedure-based management reasoning has not been explored in empric studies.

Management reasoning likely requires considerably broader abilities than diagnostic reasoning. While diagnostic reasoning can sometimes be accomplished in the absence of patient context, management reasoning is almost always context-dependent, requiring consideration of the patient and the available resources.[7] Management reasoning is "the process of making decisions about patient management, including choices about treatment, follow-up visits, further testing, procedures and allocation of limited resources."[1] One framework for analyzing management reasoning was proposed in 2013 by Goldszmidt and colleagues.[8] This framework offers 24 clinical reasoning tasks, of which eleven were associated with management reasoning. Four years later, Juma et al. built on this work, which provided validity evidence for the initial 24 tasks and added two more associated with patient prognosis.[6] Improved understanding of management reasoning could improve the training and assessment of health professionals; and patient care by providing insights into error prevention, clinical practice quality improvement, and overuse and appropriate use of diagnostic tests.[1]

Medical errors continue to be a significant cause of death and disability in the United States.[9] More than 400,000 patients experience preventable harm annually, and in-hospital medical errors account for 100,000 deaths and $20 billion a year.[10] Ten percent of patient deaths and 6-17% of in-hospital adverse events occur from diagnostic errors.[11] If the move from diagnostic to management reasoning represents a significant mind shift, then management and diagnostic errors could have different causes.

Given our limited understanding of management reasoning (and even more so for procedure-based management reasoning), it is not surprising that explicit teaching of management reasoning in medicine is also underdeveloped.[12] Educating learners to navigate

medical decisions that account for patient comorbidities, preferences, and access to care are likely teachable but require deliberate practice to master.[12] Improved understanding of management reasoning through controlled investigations would provide empirical data on which to base educational objectives.

Theoretical Framework

This study explores management reasoning as a cognitive task through think-aloud transcripts from a team-based live simulation scenario of a military-relevant trauma.[13] The study anticipates that participants will engage in goal setting, strategic planning, metacognitive monitoring, and causal attributions.[1] Given the potential for management reasoning to be an iterative process, we chose a time-pressured scenario.[7] We also minimized acceptable performance variability by selecting a casualty with one accepted solution by Advanced Trauma Life Support (ATLS) guidelines.[14]

We anticipate that management reasoning requires cognitive functions seen in prior clinical reasoning studies.[15] Like diagnostic reasoning, we expect procedure-based management reasoning to be a non-linear cognitive process influenced by context.[2,3,6] We also expect management reasoning to require situational awareness and perception and action functions. Existing ideas of clinical reasoning help explain these complex interactions and will likely play roles in explaining procedure-based management reasoning.

Situated Cognition theory supposes that all knowledge is bound within cultural, physical, and social constructs. In medicine, Situated Cognition theory explains how learning and performance occur within clinical encounters and how clinical situations can be broken into factors: physician, patient, and environment.[8,16] These factors provide a useful framework for understanding the complex interactions in clinical encounters, e.g., how a physician on 24-hour

call reads a patient chart and interviews a patient to arrive at a diagnosis. Examples of physician factors include sleepiness, burnout, expertise, and cognitive load; patient factors include presentation complexity, diagnostic suggestion, and language proficiency; and examples of encounter factors include appointment length, setting, and the functionality of health records.[16] We anticipate that procedure-based management reasoning nearly always requires consideration of the patient and the available resources, making it context-dependent.[8]

Endsley's Situational Awareness (SA) theory explains how participants perceive their physical environment over time and align these observations with anticipating future states. Endsley uses models of SA to describe progression to expertise and defines three levels of situational awareness. Level 1 SA describes the ability to perceive relevant environmental information, while Level 2 SA assigns significance and meaning to these perceptions.[15] The last level, Level 3 SA, describes the ability to predict future events from the perceived environment.[15] As with Situated Cognition, these levels of awareness incorporate factors that affect the person taking action, the provider.[17]

Research Question

We conducted an exploratory study to investigate procedure-based clinical reasoning to gain further insights into this phenomenon. More specifically, what clinical reasoning tasks underpin a physician's management of tension pneumothorax during acute decompensation?

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CHAPTER 2: EXPLORING PROCEDURE-BASED MANAGEMENT REASONING: A CASE OF TENSION PNEUMOTHORAX

Abstract

Purpose. Management reasoning has not been widely explored but likely requires broader abilities than diagnostic reasoning. An enhanced understanding of management reasoning could improve medical education and patient care. We conducted a novel exploratory study to gain further insights into procedure-based management reasoning.

Methods. Participant physicians managed a simulated patient who acutely decompensates in a team-based, time-pressured, live scenario. Immediately following the scenario, physicians perform a think-aloud protocol by watching video recordings of their performance and narrating their reflections in real-time. Verbatim transcripts of the think-aloud protocol were inductively coded using a constant comparative method and evaluated for themes.

Results. We recruited 19 physicians (15 internal medicine, one family medicine, and three general surgery) for this study. Recognizing that diagnostic and management reasoning intertwine, this paper focuses on management reasoning's characteristics. We developed three categories of management reasoning factors with eight subthemes. These are Patient factors: Acuity and Preferences; Physician factors: Recognized Errors, Anxiety, Confidence, Monitoring, and Decision to Treat; and one Environment factor: Resources.

Conclusion. Our findings on procedure-based management reasoning are consistent with Situation Awareness and Situated Cognition models and the extant work on management reasoning, demonstrating that management is inherently complex and contextually bound (situated). Unique to this study, all physicians demonstrated anticipatory behavior in all thematic

groups, indicating that attaining competency in procedural management likely requires anticipatory skills. Physicians also expressed concerns about making mistakes, potentially resulting from the scenario's emphasis on a procedure and our physicians' having less expertise with the treatment of tension pneumothorax.

Introduction

Clinical reasoning describes the cognitive tasks by which practitioners arrive at diagnostic and therapeutic decisions, and researchers typically divide clinical reasoning into diagnostic and management reasoning.[2] Diagnostic reasoning assigns labels to patients' constellations of signs and symptoms. Extant work demonstrates that diagnostic reasoning is a non-linear cognitive process influenced by context (e.g., situation specifics), cognitive load (i.e., physician's mental effort), and dual-process theory (e.g., fast and slow thinking).[2,3,6] Alternatively, our understanding of management reasoning remains limited. An enhanced understanding of management reasoning could profoundly improve medical education and patient care.

Researchers have not widely explored management reasoning. Goldszmidt and colleagues proposed a framework that offers 24 clinical reasoning tasks, of which eleven were associated with management reasoning.[6] Four years later, Juma et al. provided validity evidence for the initial tasks and added two more associated with patient prognosis.[1] These two studies form the extant work on management reasoning.

Patient management is typically taught and assessed as a cognitive task similar to diagnostic reasoning.[1] Management reasoning involves "choices about treatment, follow-up visits, further testing, and allocation of limited resources."[1] Educating learners to navigate management reasoning that accounts for patient comorbidities, preferences, and access to care are likely teachable, and instruction in these tasks could improve patient outcomes.[12] More than 400,000 patients experience in-hospital preventable harm annually, including 100,000 deaths.[9,10] Management reasoning's contribution to medical errors remains unknown but is likely significant since diagnostic errors account for 6-17% of these.[11]

As with other clinical tasks, time is likely a critical component of management reasoning. Appropriate patient management requires continuous monitoring and adjustment of plans.[4] Clinical tasks involve iterative processes that practitioners cycle through, acquiring new information, testing hypotheses, providing treatments, and observing outcomes.[18] The iterative nature of clinical reasoning can often be more evident in time-pressured settings that condense cycle times, like emergency departments and intensive care units.[8] More empiric investigations of the situated and temporal nature of management reasoning would improve our understanding of the task and provide data on which to base educational initiatives.

Therefore, we conducted a novel exploratory study to gain further insights into procedure-based management reasoning by creating a time pressure scenario that elucidated the iterative thought processes underpinning medical management.[2]

Methods

Physicians

We invited all resident and attending physicians in the Internal Medicine (IM), family medicine, and surgery specialties via e-mail from the Uniformed Services University of the Health Sciences and Walter Reed National Military Medical Center to participate. No incentives were provided, and there were no exclusion criteria. The Institutional Review Boards from both facilities approved the protocol.

Procedures

Physicians managed a patient as they acutely decompensate in a team-based, time-pressured, simulated scenario which we believe is optimal for exploring management reasoning in medicine. We selected a diagnosis with one accepted solution by Advanced Trauma Life

Support (ATLS) guidelines to minimize acceptable performance variability.[14] This solution requires physicians to perform one of two procedures to treat the patient.

Scenario

In the scenario, participating physicians encountered a Simulated Patient (SP), portrayed by a trained actor, who was recently admitted for cellulitis and is unknown to the physician. The scenario begins after the SP sustains a fall and strikes their chest on a toilet. Simulated care team staff phoned the physicians to inform them of the fall and requested the physician evaluate the SP. Physicians could then ask the care team questions over the phone before interacting with the patient and care team at the bedside.[13]

A few minutes after the physician arrives at the bedside, the SP decompensates as a tension pneumothorax develops. A combination of shock and lack of hemithorax breath sounds (via an AURiS simulation stethoscope) steers the physicians to the diagnosis of pneumothorax or hemothorax, both of which have the same management under ATLS guidelines.[14]

If physicians wish to perform the procedure, the care team introduces a TraumaMan surgical simulator that supports a thoracotomy.[13] To the maximum extent possible, each physician confronts the same encounter. The SP and ancillary staff provide the same medical and social history, and the encountered environment and SP's objective findings are the same. The scenario was run in real-time, and physicians were instructed to treat the scenario as if it was an actual clinical encounter. When physicians were uncertain about what to do, the simulated care team nurse would cue the physicians to minimize disruptions. Similarly, the simulation stethoscope aims to minimize confounders by limiting diagnostic uncertainty.[13]

Think-Aloud

We explored management reasoning by analyzing transcripts from a think-aloud protocol. Physicians watched video recordings of their performance immediately afterward and narrated their reflections in real-time (Figure 1). This protocol is a standard technique that captures physicians' mental states, unconstrained thought processes, and details temporal reasoning sequences.[2,19,20] Trained research assistants prompted physicians to "think-aloud" if they did not speak for more than five seconds. These think-alouds were audio-recorded and transcribed verbatim, excluding ahs, ums, and pauses.

Analysis

Two authors (RS, SJD) analyzed the transcripts and inductively coded them using a constant comparative method in NVivo 12 Plus.[2] RS inductively coded transcripts and reviewed the coded narratives and codebook with SJD after every five codings. RS recoded previously coded narratives if changes to the codebook were made. Recoding ensured that all the transcripts were coded with a consistent schema. Based on our interpretive work and our recognition that hospital management of tension pneumothorax requires macrocognitive functions that intertwine contextual factors and management and diagnostic reasoning, we developed three categories of factors: patient, physician, and environment.[15] In this paper, we focus on management reasoning's unique characteristics.

Results

We recruited 19 physicians, five females (26%) and 14 males (74%), for this study. The study population included 14 residents (74%) and five attendings (26%). The mean times since

medical school graduation was 21 years and three years for attendings and residents, respectively. Fifteen physicians (79%) were from IM, one (5%) from family medicine, and (16%) three from general surgery. We reached saturation after coding ten transcripts but coded all 17. We identified eight management reasoning themes. These themes coalesced around Situated Cognition's categories of provider, the patient, or the encounter setting, shown in Table 1 and described below.[21]

Provider Factors

We identified five provider factors in management reasoning, three related to self-judgments (*Recognized Errors, Anxiety,* and *Confidence*) and two about assessment of the ongoing situation (*Continuous Monitoring* and *Decision to Treat*). We describe each below.

Recognized Errors

Recognized errors are medical mistakes physicians discovered while reflecting on their performance during their think-aloud. Errors took three forms: missed steps in treatment, inadequate data gathering, and improper resource management. *Missteps* included failure to initiate treatment or perform a procedure.

> *"Oh! I didn't put oxygen on him either. Goodness." (IM Resident 2)*

Physicians also noted they did not gather sufficient *data,* including patient histories, performing a physical exam maneuver, placing the patient on a monitor, or ordering objective studies like X-rays or electrocardiograms.

"allergies is one thing I should have asked before I started giving medications." (IM Resident 4)

Resource errors included not seeking additional resources to facilitate treatment.

"When his blood pressure was dropping, the one thing that I probably would have done in retrospect is to activate the code team." (IM Attending 2)

Anxiety

Anxiety is the physician's worry about secondary harms to themselves or the patient during management. This theme encompassed *self-harm* fears and was principally concerned with patient-to-provider disease transmission,

"I wouldn't necessarily put on gloves quite frankly if this was truly life-threatening." (Surgery Attending 2)

This theme also includes concerns about causing a medical error during a *procedure* which could harm the patient,

"I want to be somewhat cognizant of infection control." (IM Resident 5)

or the possibility of harm from a treatment's secondary effects,

"I don't want to depress his respiratory function by giving him pain control." (Surgery Resident)

Confidence

Personal *Confidence* was the provider's self-assurance in their abilities to perform a specific task. This theme centered on providers' ability to conduct exams and perform procedures. There were three subthemes, and the first was lack of *experience*.

> *"I'm trying to remember everything in the moment." (IM Resident 2)*

Second is the perceived need for *oversight*:

> *"One of my hesitations here was also that in real life, I've never done one of those. So, I would have had to call my senior." (IM Resident 3)*

The third subtheme was the need to *focus*:

> *"Things are going downhill really fast. So, I'm trying to collect myself a little bit." (IM Resident 2)*

Continuous Monitoring

Continuous Monitoring was defined as the physician's ongoing evaluation of the patient and consisted of three subthemes: acute changes in the patient's medical condition, sensory feedback during procedures, and assessment of treatment efficacy. Evaluations of *efficacy* occurred after physicians attempted to relieve the tension pneumothorax:

> *"it's still very tenuous overall. Just have to continually reassess him and make sure I'm not missing anything else." (IM Resident 7)*

Sensory procedural *feedback* was principally tactile and auditory during thoracostomy:

"I put in the needle in the appropriate place and got a whoosh of air." (Surgery Resident)

Finally, all physicians continuously monitored patients for *acute changes* in their condition:

"Still want to make sure there is a pulse." (IM Resident 7)

Decision to Treat

The *Decision to Treat* was when the physician decided to initiate a specific therapy. Physicians focused on two areas, the *treatment* itself and ensuring *preconditions* for treatment were met. A treatment example includes,

"I don't think at this point, clinically it needs to be addressed immediately." (Surgery Attending 2)

Confirming the *preconditions* were met included verifying landmarks, access to the necessary equipment, and, as in this example, administering anesthesia:

"So, I'll just use a lot of local and just go ahead and do the procedure without systemic sedation or pain control. And from here on out it's pretty much, I'm only thinking about the technical aspects of doing the chest tube." (Surgery Resident)

Patient Factors

We identified two patient-related factors, *Acuity* and *Perceived Preferences*, further described below.

Acuity

Patient Acuity pertained to the patient's changing hemodynamic and mental status and appeared to result in the subthemes of *Prioritizing* tasks and *Urgency* of action. Prioritizing was the relative importance of cognitive decisions physicians assign tasks in the narratives. Throughout the scenario, physicians appeared to continuously cycle through prioritizing data gathering, ordering the differential diagnosis, and management decisions:

> *So I feel like a code is still a reasonable call at that point? Right now trying to figure out his stability. Like if I need to be doing chest compressions or like immediately, Not sure which, so keep saying both. Because I'm not going to do either of them. So, yeah. Other things. Like at this point could have been trying to get ready for blood. (IM Resident 8)*

Discussions about the speed of actions indicate *Urgency*:

> *"I'm probably just going to do this right away versus waiting for help." (Surgery Resident)*

Patients' acuity influenced both the differential diagnosis and management. Discussions of time highlight this duality, where physicians tied elapsed time to the probability of a diagnosis, e.g., how long the patient was immobilized as a risk for pulmonary embolism. Physicians similarly evaluated elapsed time in management:

> *"My thought process, I think, was to treat versus not to treat this tachycardia. Because at this point, I'm still not necessarily, you*

know, assuming he's going to crash or assuming he's going to… this guy's going to be headed towards the ICU-level care shortly. (IM Resident 4)"

Physicians began assessing *Patient Acuity* at the outset of the scenario and appeared to return to the theme throughout the encounter:

"So just walking in the room, he looks pretty good. He's able to talk to me, I know his air-- I'm assessing his ABCs, his airway's intact, and he seems to be breathing okay. His vital signs indicated he didn't really have any evidence of hemodynamic instability." (Surgery Resident)

Perceived preferences

Perceived patient *Preferences* were what the physician understood the patient's desires to be. These preferences often drew on cultural and legal norms for patient care. Included in patient preferences are three subthemes. First, perceived *societal* norms centered on patient comfort and modesty:

"I'm just trying to re-drape the patient for his own comfort." (IM Resident 2)

The second patient preference subtheme was developing *rapport* with the patient:

"I'm trying to figure out what direction to take this interview and thought I would let him talk and tell me what he wants to focus." (IM Resident 11)

The last subtheme is informed *consent*:

> *"I can take a little bit of time to explain to him what's going on. The whole idea of informed consent." (Surgery Attending 2)*

Environmental Factors

Finally, we found one environmental factor, *Resources*, discussed here.

Resources

Resources are the materials, staff, and other assets needed to manage patients. We found four subthemes of resources: equipment, care level, skill, and personnel.

Personnel described the interactions between physicians and the care team, including direct communication of management decisions and thoughts about communicating decisions to the care team. Management communication includes gathering subjective and objective data for the physician, the need for additional personnel, and communicating future care needs.

> *"Then communicating to the next team member what just happened kind of quickly." (IM Resident 5)*

Skill refers to the physicians' need for a specific clinical competency. In this scenario, physicians sought people who could perform thoracostomies or thoracotomies:

> *"Somebody knows how to do a chest tube quicker than I could do it." (IM Attending 1)*

Care Level refers to in-hospital nursing monitoring level, for example, the Intensive Care Unit (ICU) and the Medical Ward:

"He's definitely going to go to the ICU." (IM Resident 1)

Lastly, *Equipment* refers to medical instruments or diagnostic tools, and this is a typical narrative example:

"Have the crash cart close by." (IM Resident 7)

Discussion

Our assessment of management reasoning through think-alouds revealed clinical reasoning processes related to providers, patients, and the environment, as Situated Cognition would predict. This study minimizes diagnostic variability by placing all physicians in the same simulated clinical environment. Our simulation also stretches physicians' skills (three-quarters residents and 95% in primary care) by presenting an infrequently encountered diagnosis. This is also the first management reasoning study requiring a procedure for appropriate treatment, and the first study presenting physicians with a single diagnosis with one accepted solution. This novel approach offers important insights into the understudied phenomenon of management reasoning.

To begin, as with other domains like chess, where successful players predict the consequences across a series of actions, our physicians demonstrated anticipatory behavior. For instance, *Physician Anxieties* anticipated medical mistakes, and physicians assessed their *Confidence* as they anticipated the skills needed to perform tasks. Similarly, *Patient Acuity* and *Resources* themes revealed that physicians predicted management steps and environmental needs, respectively. Therefore, attaining competency in medical management likely requires anticipatory skills, which have educational implications.

In particular, management instruction should reinforce clinical practice microstructures related to anticipatory skills.[22] This could include teaching management problems with multiple acceptable solutions, as seen with managing chronic diseases like hypertension or diabetes. Teaching could also give learners a medical error and ask the learner to recover from the problem, like knicking an artery in surgery or an inappropriate medication administration. Assessing learners' problem representations may facilitate the transition to a competency-based medical curriculum in graduate and undergraduate education by accurately assessing learners' abilities to deal with complex situations in new environments.[23]

Additionally, our findings are consistent with and build on Cook et al.'s management postulates. Narratives from *Physician Confidence, Physician Anxiety, Resources,* and *Patient Preference* themes demonstrate that management reasoning and plans require shared decision making and incorporate clinician, care team, institution, and patient preferences and available resources. Cook et al. also hypothesized that payers would be included in this group, but payers were not included in our scenario. Moreover, our *Physician Monitoring* and *Patient Acuity* themes are consistent with Cook et al.'s supposition that management plans are fluid and require continuous monitoring and adjustment. Taken together, our themes also align with Cook et al.'s view that management is inherently complex and contextually situated.[1]

As with Cook's management postulates, our findings overlap with Juma et al.'s management task framework. Our *Physician Anxiety* theme included Juma's 9th diagnosis task, identifying complications associated with the treatment, and management tasks 14 and 15, considerations of management's impact on comorbid illness and the reverse. Juma's 10th task of response to treatment corresponds with our *Continuous Monitoring* theme, and Juma's 18th task of establishing management plans corresponds with our *Decision to Treat*. Our *Patient Acuity*

theme encompasses Juma's problem framing tasks and management tasks 16, 23, and 24, alternative treatment options, and assessments of patient severity and decision-making capacity. Our *Patient Preferences* encompassed Juma's tasks 11-13, 19, and 20, which include the goals of and psychosocial aspects of care, patient collaboration, and patient education and counseling. Juma's 17th and 21st tasks concerning resource availability and follow-up are included in our theme of *Environmental Resources*. The overlap of Juma's framing and diagnosis task with our management themes is consistent with Juma's finding that the overarching task of establishing management plans requires the integration of framing, diagnosis, and management-specific tasks.[6]

Although there is considerable overlap, there were differences, perhaps due to case variations: Juma et al. reviewed internal medicine admissions, while our case of decompensated pneumothorax would warrant admission to an intensive care unit. Unlike Juma et al.'s, our case also elicited procedure-specific themes, including concerns about disease transmission, landmark identification, and sensory feedback while performing the procedure. Additionally, physicians often focused on missed actions that drove physician composure themes in our think-aloud reflection data.

Physician Confidence may have emerged as a theme because the diagnosis was likely challenging for many of our physicians who do not regularly treat this condition. Our physicians likely lacked schemas (also known as illness scripts) for treating tension pneumothorax proficiently.[24] Thus, our findings suggest that educational activities, like practice with feedback, that can improve learners' illness scripts may be necessary for developing management expertise.[24] Directly observed activities allow educators to reinforce correct actions in various contexts. Assessing learners' representations of situations may also prove an effective way of

tracking management competency because these representations enable learners to cope with complex, context-dependent situations.[23]

Situated Cognition directly correlates with our overarching themes of the patient, provider, and environment, reflecting an intertwining of management and diagnostic reasoning. Providers' assessments of patient acuity simultaneously drive management and the differential diagnosis, and providers continuously and simultaneously revisit their differential diagnosis as they manage their patients. Yet, according to prior Situated Cognition work, patient, provider, and environmental factors can aid or inhibit clinicians in diagnostic reasoning.[21] In this study, a high cognitive load from a diagnosis that stretched our resident (intermediate) physicians as indicated by physicians struggling with SP management.

In addition to Situated Cognition, our results align with several aspects of Endsley's Situational Awareness (SA) model, figure 2. Endsley defines three levels of SA that models progression to expertise. Level 1 describes the ability to perceive relevant environmental information; Level 2 assigns significance and meaning to these perceptions; Level 3 describes the ability to predict future events from the perceived environment.[15] As with Situated Cognition, these Levels of awareness incorporate factors that affect the person taking action, the provider.[17] Endsley's model is useful in understanding our anticipation results.

In our results, physicians demonstrated Level 1 and 2 SA in their Monitoring and Patient Acuity descriptions, and *Provider Anxiety and Confidence* described predictions or concerns about the future. SA Levels 1 and 2 align with our *Recognized Errors* results where physicians did not get enough information or mismanaged their resources. We do not know if concern for errors predisposes physicians to errors or is protective of making errors, but this could be the

work of future studies. Almost 40% of SA errors involve a failure to understand the available information in clinical practice.[25] As a result, SA has educational and safety implications for management reasoning.

Early accurate problem representation during clinical encounters improves diagnosis and may be needed for management. Gruppen et al.'s problem representation model overlaps with our findings by describing an iterative process of evaluation, information gathering, and model refinement.[26] A focus on management problem representation, particularly planning and prediction, may help progress learners towards competence.[15]

Our study had several limitations. Simulation implementation may have affected some physician performance. Physicians noted occasional patient or environmental incongruities between the simulated and natural environment:

> *"I mean, obviously he doesn't have monitors on the way he probably would if he was in the exam room." (Family Medicine Attending)*

These incongruities in the simulation's representative design could impact physician anticipation abilities.[22] Second, this experiment evaluated management reasoning while performing a procedure, and our findings may not translate to other conditions and/or non-procedural settings.

This study of procedure-based management reasoning in a simulation-controlled environment provides insights into the importance of anticipatory behavior to be successful in this domain. This behavior follows with SA and Situated Cognition models with educational implications that teaching management likely requires an emphasis on problem representation.

Tables

	Theme	Description	Example
Physician	Recognized Errors	Missed steps treatments	"Looking back, I should have immediately gotten a needle decompression. I'm just stuck with a pneumothorax as a leading on the differential diagnosis." (IM Resident 4)
		Participants not acquiring enough information	"I should've gotten the chest now, and maybe not been so linear with my approach." (IM Resident 5)
		Mismanagement of medical resources for treatment	"I should have just called for more help right away." (IM Resident 4)
	Anxiety	Disease transmission during patient contact	"I don't know if he's got HIV or hepatitis or anything. So, I just kind of want to, for everybody's protection, it's better to wear gloves." (IM Resident 5)
		Medical error during a procedures	"I'm a little bit less in rush mode. I'm starting to think alright, I'm going to start doing sterile things." (Surgery Resident)
		Secondary treatment effect	"I probably should see what's going on and to make sure that there is no other breathing compromise before I further compromise his breathing with some morphine." (FM Attending)
	Confidence	Lack of task experience	"So moving toward the chest tube placement being set up. At this point, I was kind of freaking out, because I've helped put in many chest tubes; I've never put in one by myself." (IM Resident 4)
		Desire for oversight	"You're going to need a chest tube or potentially an emergent needle that's going to decompress the space, but I don't – I haven't done in years and years. So, I need some help. So, as I'm thinking here, I'm getting a little less comfortable that I'm going to need some help from people more experienced than me." (IM Attending 1)
		Need to focus	"I'm a little bit gathering myself here and taking my time to do the procedure correctly" (Surgery Resident).
	Monitoring	Monitoring for treatment response	"And then I'm like, oh, chest X-ray. Yes. Make sure the lung's reinflated" (IM Resident 2)
		Sensory feedback during procedures	"I can feel the pop, so I know that I'm in the correct space." (IM Resident 2)
		Acute change in patient condition	"So, now I'm checking pulses to see for circulatory system. Cap refill as well, too. And, now, I want to check the cellulitis of the other leg for what he came in for. Now, he's not feeling any pain in it." (IM Resident 2)
	Decision to Treat	Decision to treat	"I'm concerned about a tension pneumo. So I'm going to start oxygen. It's simple things, like get him on some oxygen. He's still kind of responding." (Surgery Resident)
		Verifying landmarks, equipment, and pain control	"So, now, I'm palpating, getting in the landmarks on the dummy. I think everything is good and set. I ask the nurse to get the kit." (IM Resident 2)
Patient	Patient Acuity	Urgency of action	"So at this point, I didn't get the impression, just talking to him, that he was in respiratory distress." (Surgery Attending 2)
		Prioritizing next steps in management.	"I didn't think he was going to need massive resuscitation. I thought what he really just needed was a chest tube correctly placed." (Surgery Resident)
	Preferences	Societal norms of patient modesty and comfort	"I want to sedate this guy just a little bit, just make him comfortable." (Surgery Resident)
		Developing rapport with patients	"Trying to tell him that we care." (IM Resident 6)
		Informed consent and patient autonomy in decision making	"Since he was a little bit more responsive, trying to inform him of what was going on, and kind of plan for my next step." (IM Resident 6)

Environment	Resource	The need for additional personnel	“But it looked like we had all the right support people to help out and get everything with his ICU nurse and the rapid response team and have the crash cart close by.” (IM Resident 7)
		The need for specific skills	“I’m able to tell that I’m not going to be- do the procedure, but he may potentially need a proceduralist.” (IM Resident 8)
		The need for increased monitoring/higher-level care	“I’m like right, we need to go to the ICU and to order the other stuff done.” (IM Resident 5)
		The need for additional equipment	“I just need the objective information with the chest x-ray.” (IM Resident 15)

Table 1: Themes. Internal Medicine (IM), Family Medicine (FM)

Figures

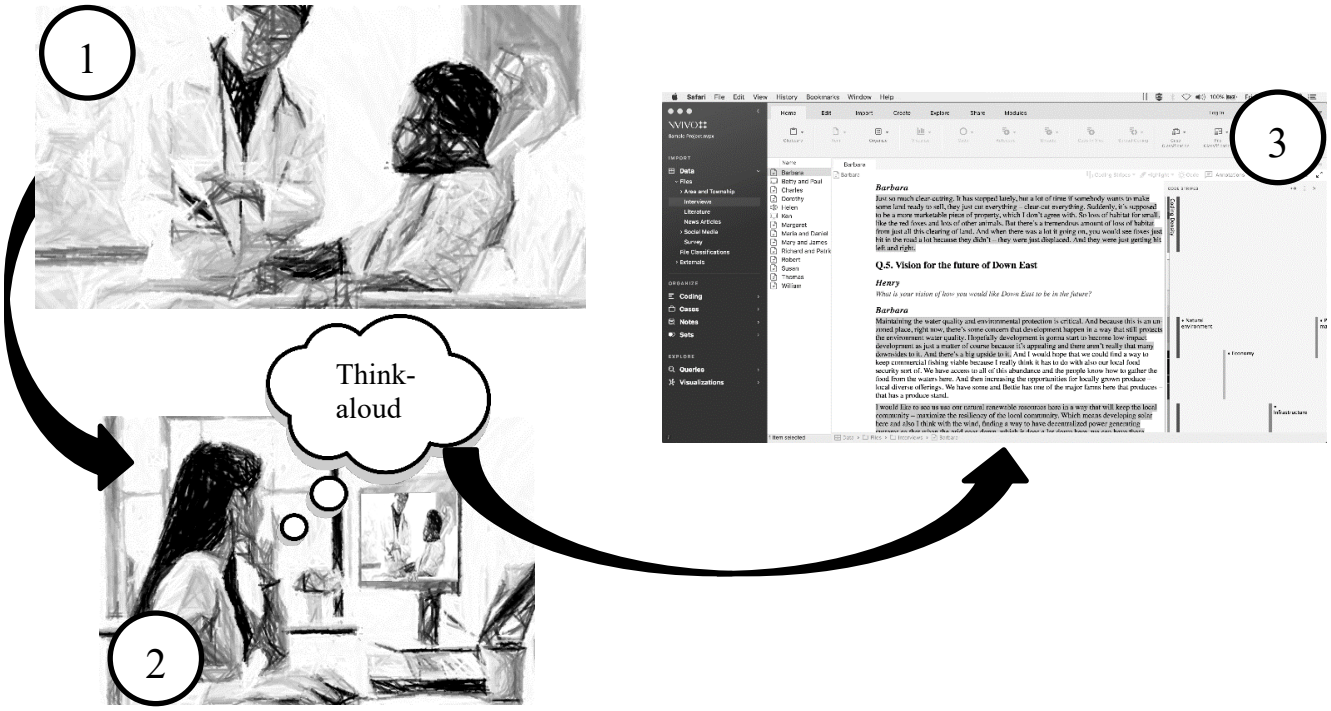

Figure 1: Study Design (1) participate in scenario, (2) participants watch their videotape and perform a think-aloud, and (3) researchers analyze think-aloud data.

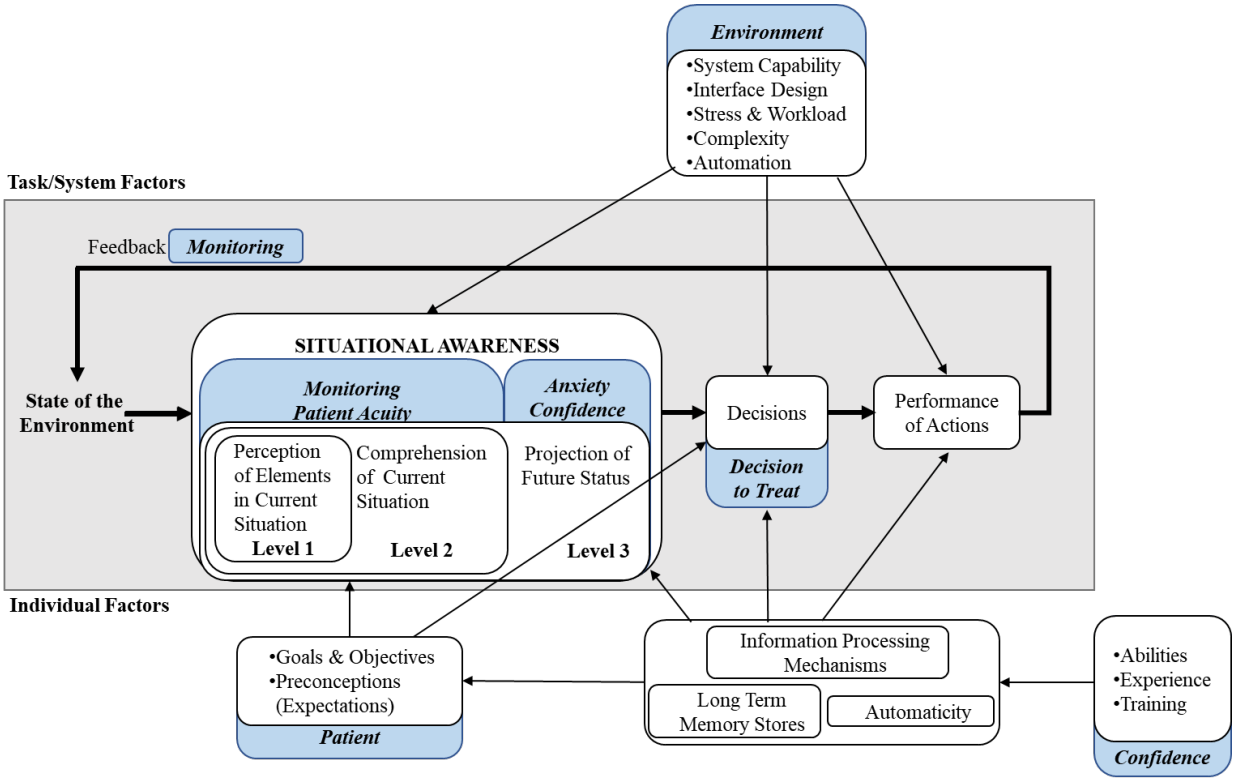

Figure 2: Themes that correlate with Endsley's Situational Awareness Framework. Colored sections are drawn from this study.

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CHAPTER 3: DISCUSSION

Discussion

Management reasoning requires physicians to access medical knowledge and process clinical encounter information to make decisions about testing, treatment, follow-up, procedures and use of limited resources.[1] This study employs a simulation-controlled environment to isolate the management reasoning tasks of procedural-based management reasoning. Our results align with Situational Awareness (SA) and Situation Cognition theories, and uniquely emphasize anticipation. Developing anticipation as a skill in management reasoning has educational implications.

Managing the rapid decompensation as our simulated patient develops a tension pneumothorax requires physicians to anticipate responses based on "partial and probabilistic information."[22] Anticipation skills allow people to predict the consequences in a series of actions, and superior anticipation is long associated with expert performance in multiple domains, from chess to medicine.[15,24] Anticipation is a crucial skill for athletes where rapid movements constrain the amount of time in which athletes can make decisions.[22] In Soccer, opponents trigger the anticipatory responses of goalkeepers' actions: a goalkeeper must decide which were to move to block a penalty shot in less than 400ms.[22] Managing decompensation may require similar levels of SA, but the triggers and expert responses have not been described in the literature. Future investigations could explore these triggers.

Endsley's SA model provides a theoretical construct from which to evaluate our physicians' anticipation needs. Endsley's model describes a three-level progression to expertise, figure 2. SA Level 1 describes the ability to perceive relevant environmental information, Level 2 assigns significance and meaning to these perceptions, and Level 3 describes the ability to

predict future events from the perceived environment.[15] Our physicians displayed SA level 3, anticipation, in all three factors: physician, patient, and environment. Physicians also demonstrated level 1 and 2 SA in their *Monitoring* and *Patient Acuity* descriptions, and Provider *Anxiety* and *Confidence* described predictions or concerns about the future. SA levels 1 and 2 align with our *Recognized Errors* results where physicians did not get enough information or mismanaged their resources. Training in SA could improve medical management.

Current surgical procedural training concentrates on training technical skills over cognitive skills.[27] However, perceptual or judgemental errors cause most surgical errors, not technique errors.[28] Graafland et al. conducted a systematic review of training SA in the operating room and found that crisis training was an acceptable and reliable way of assessing learner SA in minimally invasive surgeries.[28] However, they found no validated means of training SA in open surgeries.[28] Another systematic review by Dedy et al. found two surgical studies that improved SA.[27] A randomized controlled trial by DaRosa et al. that used didactic sessions to educate learners on decision making and error avoidance during laparoscopic surgery improved performance on exams designed to improve interoperative judgment.[29] In another study, Scott et al. conducted a two-day didactic and hands-on training session for trauma management that showed improvement in decision making.[30] Serious games have also been suggested as a means of improving SA.[28] Further research is needed to enhance the SA of learners in procedural training.

In addition to SA, Situation Cognition serves as a useful theory to analyze our results. Our themes of the patient, provider, and environment directly correlate with Situation Cognition theory as it applies to medicine. In Situated Cognition, physician factors include sleepiness, burnout, expertise, and cognitive load; patient factors include presentation complexity,

diagnostic suggestion, and language proficiency; and examples of encounter factors include appointment length, setting, and the functionality of health records.[16] Cook et al. postulated that management reasoning is nearly always context-dependent, which is consistent with our findings.[8] Physicians displayed consideration for the need for *additional personnel*, *specific skills*, *monitoring/higher-level care*, and *additional equipment*, as *well as patient preferences* and their own *Confidence* and *Anxieties*. These themes and subthemes indicate awareness of the patient context. These results suggest that applying Situation Cognition theory to training programs could improve learner management reasoning.

Educators could structure the curriculum to improve anticipation and judgment skills by drawing on SA and Situated Cognition. Educators could present learners with problems that have multiple accepted solutions and pair these problems with didactic sessions that discuss possible courses of action. This format continues DaRosa et al.'s work that improved judgment.[29] Assessing learners' anticipation in their problem representations may also help educators determine which students will have problems dealing with complex situations in new environments.[23] Following a learner's presentation on a patient, educators could ask learners to predict the hospital course and how to cope with deviations from their predictions. This presentation style would force learners into an iterative anticipatory process of evaluation (predicting outcomes), information gathering (predicting signs and symptoms), and model refinement.[26] Additionally, learners are frequently assessed on the risk procedures pose to patients, e.g., infection and bleeding. Asking learners how to manage a procedure's complications could help train anticipation.

We also recognize that the management of Tension Pneumothorax was a stretch for many of our primary care and resident physicians. These physicians likely experience a high cognitive

load while treating the casualty. Cognitive Load theory applies to medicine by describing working memory's limitations. This theory breaks cognitive loads into three categories: intrinsic loads refer to specific topics, extraneous loads refer to how information is presented to learners, and germane loads deal with how people create long-term memories (schema).[31] In clinical situations, cognitive load theory describes how physicians access schema to describe their clinical encounter. It also explains how physicians interpret the clinical environment and patient information to arrive at diagnosis and management decisions. Cognitive load should be considered when teaching anticipatory behaviors in learners.

Limitation

As noted in Chapter 2, Cook et al. also hypothesized that management reasoning would require a consideration of payers preferences, but payers were not included in our scenario. In addition to being incorporated into the scenario, insurance payer considerations were likely a concern for our physician participants. The Military Healthcare System operates as a single-payer system so that physicians may be less aware of treatment costs than in other settings.[32] However, this scenario also does not lend itself to cost considerations since it has limited treatment options and the patient requires immediate intervention.

Simulation fidelity is a limitation of the study. Fidelity concerns emerge in three ways. First as incongruities in the presentation and the diagnosis: "I don't know if he's trying to stimulate tachypnea, but he seems still comfortable." (IM Attending 2) Second as alterations in management due to the simulation: "I guess that's a little bit unrealistic. If I'm actually doing a decompression, then they're not going to be moving the patient. So, I guess that part's unrealistic." (IM Resident 14) Last are incongruities in what the participant expected to see in the

environment “You know, I mean obviously he doesn’t have monitors on the way he probably would if he was in the exam room. Sometimes, simulations kill me.” (FM Attending)

Fidelity indicates how accurately a simulation represents an event, whereas high fidelity refers to a very realistic representation.[33] High-fidelity simulation is frequently associated with improved learning because it is assumed that higher fidelity is related to the suspension of disbelief and increased engagement.[34] In turn, increased engagement is associated with enhanced learning.[33] However, engagement is not universally defined, conceptualized, or measured in medicine. The Multidimensional Framework (MDF) is helpful in describing simulation fidelity because it describes engagement in behavioral, emotional, and cognitive components.[35] Drawing on the MDF, Padgett defines engagement as: “a context-dependent state of dedicated focus towards a task wherein the learner is involved cognitively, behaviorally, and emotionally.”[33]

Although simulation fidelity was noted by participants, but did not likely affect our management theme data. Based on the Padgett’s definition, we expect the simulation to sufficiently engage participants if it induced appropriate emotional stress, cognitive load, and required metacognition.[33] Physicians noted emotional stress in the *Physician Confidence* and *Anxiety* themes. *Physician Confidence*, particularly the subtheme of *need to focus*, indicated stress on the physicians cognitive load. Physicians displayed metacognition in the *Environment* and *Patient* themes by interacting with care teams, the patient, and examining available resources. Although physicians noted discrepancies, they were able to sufficiently suspend of disbelief to engage with the task.

Military Relevance

This study improves our understanding of management reasoning, which could improve patient care. Patients in the Defense Health Agency (DHA) are victims of the same medical errors civilians are. As with the civilian sector, improved understanding of management reasoning may lead the military to decrease its medical utilization and improve its error prevention and healthcare quality.[1] These would directly benefit patients enrolled under the DHA and reduce costs to the Department of Defense (DoD).

In addition to improvements in patient safety, this study provides some insights into simulation fidelity. The military relies extensively upon high-fidelity simulation training to maintain combat readiness and medical skills. Providing realistic simulations improves clinical reasoning and procedural skills and offers service members a greater array of training options.[36] Live simulations are an integral part of high acuity combat casualty medical training, and the use of these simulations hopes to improve patient outcomes. Unfortunately, the utility of simulation in teaching medical management has not been established, and an improved understanding of clinical reasoning tasks could expand military medical simulations.

Conclusion

This study of procedure-based management reasoning in a simulation-controlled environment provides insights into the militarily relevant topics of patient care, medication education, and simulation fidelity. The unique finding of the study is the need to perform anticipatory behaviors in procedure-based management. This behavior follows with Situation Awareness and Situated Cognition models.

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