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Situational Awareness in Anesthesiology

by

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A THESIS

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Abstract

This study was designed to explore how a community of anesthesiologists understood situational awareness (SA), and their thoughts on how it was learned, taught, and assessed. Eighteen anesthesiologists participated in semi-structured interviews. Constructivist grounded theory techniques were used in a thematic analysis of interview transcripts, with group meetings held to develop emerging themes. Respondents displayed an understanding of SA using both clinical and everyday life examples. SA was felt to be important but formal definitions of SA were lacking and SA was not explicitly discussed. SA was learned informally through increasing independence, role-modeling, and reflection on errors, and formally through simulation. Respondents did teach about SA but found it difficult to give meaningful feedback to trainees. Although acknowledgement of SA may be evolving, it appeared that SA was a crucial but tacit concept for the anesthesiologists in this study. Faculty development is required to improve teaching and assessment of SA.

Preface

A version of Chapter 4, entitled "Exploring anesthesiologists' understanding of situational awareness: a qualitative study," has been published in the Canadian Journal of Anesthesia. This chapter is reprinted with permission from Springer Publishing (http://www.springer.com/us/).

Contributions of Authors

Dr. Jocelyn Lockyer: academic supervisor, guided the conceptualization and design of the project, supervised semi-structured interviews, assisted in thematic analysis of interview data, co-authored the manuscript, reviewed and edited thesis and manuscript.

Dr. Rachel Ellaway: guided the conceptualization and design of the project, assisted in thematic analysis of interview data, co-authored the manuscript, reviewed and edited thesis and manuscript.

Dr. Rosaleen Chun: guided the conceptualization and design of the project, assisted in thematic analysis of interview data, co-authored the manuscript, reviewed and edited thesis and manuscript.

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I would also like to thank my friends and colleagues in the Department of Community Health Sciences for their support and advice. I am lucky to have come to know and work with some exceptional medical educators and researchers.

Dedication

I would like to dedicate this thesis to my husband Aaron. Your love and support have kept me going, and you are the kind of medical educator I aspire to be. I would not have finished this work without you cheering me on.

To my daughters, Maya and Kate, I love you more than I can say. This thesis is also dedicated to you.

To my parents, Margaret and Rick, who have always believed in me, I dedicate this thesis to you too.

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List of Symbols, Abbreviations and Nomenclature

Abbreviation	Definition
ACH	Alberta Children's Hospital
AHS	Alberta Health Services
ANTS	Anaesthetists' Non-Technical Skills
ANTS-AP	Anaesthetists' Non-Technical Skills for Anaesthetic Practitioners
CBME	Competency-Based Medical Education
CGT	Constructivist Grounded Theory
CRM	Crisis Resource Management
FMC	Foothills Medical Centre
IMG	International Medical Graduate
JH	Julia Haber
JL	Jocelyn Lockyer
NOTSS	Non-Technical Skills for Surgeons
NTS	Non-Technical Skills
PLC	Peter Lougheed Centre
RC	Rosaleen Chun
RCPSC	Royal College of Physicians and Surgeons of Canada
RE	Rachel Ellaway
RGH	Rockyview General Hospital
SA	Situational or Situation Awareness
SAGAT	Situation Awareness Global Assessment Technique
SART	Situation Awareness Rating Technique
SHC	South Health Campus
SPLINTS	Scrub Practitioners' List of Intra-operative Non-Technical Skills
TSAGAT	Team Situation Awareness Global Assessment Technique

Epigraph

Anticipating problems and figuring out how to solve them is actually the opposite of worrying: it's productive. Likewise, coming up with a plan of action isn't a waste of time if it gives you peace of mind. While it's true that you may wind up being ready for something that never happens, if the stakes are at all high, it's worth it.

- Col. Chris Hadfield, An Astronaut's Guide to Life on Earth

Chapter One: Introduction

1.1 Overview

Anesthesiology is a complex and dynamic medical specialty that requires sustained vigilance on the part of the practitioner, along with the execution of a variety of cognitive and procedural tasks. Anesthesiologists obtain information that is relevant to patient care from multiple sources, and are continually required to make decisions with potentially life-threatening consequences during evolving clinical scenarios. The operating room offers many distractions: the beeping of patient monitoring equipment, the clanging of surgical instruments, the ringing of phones and the sometimes noisy discussion between surgeon, nurse, and anesthesiologist over the operative field. These distractions, combined with the need to perform manual tasks (like the insertion of arterial lines and the programming of infusion pumps) and the demand of mental exercises (like the calculation of drug doses and the scanning of monitors) can overwhelm even an experienced anesthesiologist's ability to gather and process information about a patient. The capacity to notice what is happening with a patient, within a specific context and at a given time, and to integrate that information with underlying medical knowledge and experience, can be termed "situational awareness."

Situation or situational awareness (SA) has been defined as "the perception of elements of the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future."[1] This concept of "knowing what is going on around you"[1] has been emphasized for decades in aviation and military settings[2]; more recently the

concept of SA has been addressed within the medical profession and specifically within anesthesiology.[3, 4]

Although the importance of non-technical skills (NTS) like SA in anesthesiology has been acknowledged, there is little known about how anesthesiologists conceptualize SA, particularly those anesthesiologists who work clinically and teach trainees (residents and medical students). Furthermore, little is known about how anesthesiologists themselves learned SA, and how they approach teaching and assessment of SA in their trainees.

1.2 Study rationale and purpose

SA is an important but incompletely understood concept in anesthesiology. The objective of this study was to explore how anesthesiologists involved in teaching in a particular clinical context understood SA, as well as how they felt they had personally learned it, and how they approached teaching and assessing it in others.

1.3 Thesis structure

This manuscript-based thesis contains five chapters. In Chapter 2, I review the literature in order to provide some background on the origins of the term SA, as well as the current state of knowledge and research related to how SA is learned, taught and assessed. In Chapter 3, I present the methods used in this study, included the rationale for choosing the methods, the process of data collection and a detailed description of the qualitative data analysis. Chapter 4 outlines my results as presented in a manuscript accepted for publication in the Canadian Journal of Anesthesia, entitled "Exploring anesthesiologists' understanding of situational awareness: a

qualitative study." Finally, in chapter 5 I discuss the study findings in light of the current literature, and offer some conclusions based on these findings.

Chapter Two: Literature Review

This chapter will introduce the reader to the literature on SA within the fields of human factors and psychology, and, most importantly, within medicine and anesthesiology. The origins of the term SA are discussed, as well as the various definitions and types of SA presented within the literature. I will discuss the relevance of SA to anesthesiology and patient safety, along with research on how SA may be learned, taught and assessed. The chapter closes with research questions stemming from the gaps in our knowledge surrounding SA.

2.1 The concept of SA

2.1.1 Origins of the term SA

Humans have likely always needed an awareness of their environmental surroundings in order to make decisions, however the term "SA" is thought to have originated within the context of World War I military aviation.[5, 6] Specifically, fighter pilots expressed "the importance of gaining awareness of the enemy before the enemy gained a similar awareness."[5, 6] Interest in SA as a crucial concept within both commercial and military aviation continued, with research and publication of scholarly work related to SA escalating in the late 1980s and early 1990s.[7-11] In particular, the work of Endsley in developing a three-stage model of SA has influenced the directions of SA research.[1, 9] The applicability of the concept of SA to other domains such as medicine has also increased over time, reflected in the growing attention being paid to SA as a contributor to patient safety and error prevention.[12, 13] While the term SA has become more commonly used by researchers in human factors, psychology, aviation and medicine, there is continuing debate surrounding the actual meaning of the term.[14-16]

2.1.2 Definitions of SA

The precise language used to define SA varies between different authors and research teams, and multiple definitions of SA exist within the literature.[5, 17] Most simply, SA can be considered to mean "knowing what is going on around you,"[1] or having "appropriate awareness of a situation."[18] Some definitions of SA focus on the product of SA.[5] For example, Endsley [8(p.97)] stated:

> "SA is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and a projection of their status in the near future"

Alternatively, definitions may focus on the process of SA,[5] as in the definitions provided by Bedny and Meister[19(p.71)] and by Smith and Hancock,[18(p.145)] respectively:

> "SA is the conscious dynamic reflection on the situation by an individual…which enables individuals to develop mental models of external events"

> "SA is the invariant in the agent-environment system that generates the momentary knowledge and behavior required to attain the goals specified by an arbiter of performance in the environment"

Despite the ongoing debate regarding which particular definition is most valid, it may be argued that "there is no correct or absolute level of description of either awareness or the situation; rather … descriptions should be tailored pragmatically to facilitate the development of design, training or selection solutions."[16(p.44)] Endsley's 3 level model (perception, comprehension, projection) offers a "functional model for assessing different degrees of insight in a pragmatic

manner"[5] and is the "most widely known account of SA."[20, 21] This particular definition features prominently in the medical human factors literature, particularly within the specialty of anesthesiology.[22-24]

SA is critically important in anesthesiology because practitioners must continually make decisions and complete time-sensitive tasks in a dynamic environment. An illustrative example regarding a specific anesthesiology case would be as follows. A patient with a past history of a deep venous thrombosis, obesity and smoking is having a laparoscopic removal of an ectopic pregnancy. The anesthesiologist notes that the patient's heart rate increases and the blood pressure decreases suddenly during the surgical procedure (I: perception). However, the anesthesiologist also notes that there is no excessive blood loss from observing the surgical field and suction canisters, and there is no evidence of anaphylaxis or anesthetic overdose. Taking the patient's medical history into account, along with the observed changes in vital signs, the anesthesiologist wonders if the patient might have a pulmonary embolus (II: comprehension). The anesthesiologist asks a colleague to perform a transesophageal echocardiogram, which shows acute right heart failure, and evidence of a clot in the pulmonary artery. With the working diagnosis of a pulmonary embolus, the anesthesiologist anticipates that the patient's clinical status will continue to deteriorate (III: projection), and calls for help to prepare infusions to support the patient's blood pressure, consults the ICU, and informs the surgeon, requesting that the surgery be completed as quickly as possible. This example demonstrates that SA is required at all levels of Endsley's model to safely care for the patient in an evolving clinical situation.

2.1.3 Types of SA

SA is sometimes understood as an individual matter,[21, 23] sometimes as a group or team matter,[10, 23, 25, 26] and sometimes as something distributed between human and non-human subsystems.[27, 28] The earliest focus in the literature was on individual SA, and its "acquisition and maintenance… from the point of view of individual operators in complex systems."[21] Spatial and perceptual skills are examples of individual characteristics which have been found to correlate with SA.[25] Even though medical professionals rarely work in isolation within the healthcare system, it is still important to consider SA at the level of the individual. Teaching programs and assessment tools for SA have most often been focused on individual performance.[29] Although there is increased interest in team SA, it is still at the level of the individual that medical professionals are selected, taught and evaluated for competence, and therefore a focus on individual SA is relevant and necessary.

Team SA has been defined as "the degree to which every team member possesses the SA required for his or her responsibilities."[9] If team members are able to communicate and share their mental models in a given clinical situation, it is neither necessary nor practical for everyone to be completely aware of what everyone else is thinking or doing.[10, 30] Shared SA has been defined as "the degree to which team members have the same SA on shared SA requirements,"[9] and this shared SA will influence clinical outcomes for patients being cared for in a team environment.[23] One example of individuals sharing their SA with the team is the pre-operative World Health Organization surgical safety checklist where the surgeon, anesthesiologist, nurses and patient all share their knowledge, questions and concerns in order to assist in planning and anticipation of any issues that may arise during the procedure.[23, 31, 32]

2.1.4 Evolution of the concept of SA in anesthesiology

Gaba et al.[3] were among the first to emphasize the importance of SA in anesthesiology practice, having extrapolated many SA-related concepts from aviation to anesthesiology. Having also introduced the idea of "Crisis Resource Management" (CRM) to anesthesiologists (based on the "Crew Resource Management" principles used in pilot and aircraft crew training), Gaba et al.[3] emphasized the role of SA in anesthesiology practice at a time when high-fidelity simulation was just beginning to be used in medical training.

Non-technical skills have been defined as the "cognitive and interpersonal skills that complement an individual's clinical knowledge"[33]; SA is recognized as an important component of NTS.[33] The Anaesthetists' Non-Technical Skills (ANTS) behavioural marker system was developed in the early 2000s, as a collaborative effort between industrial psychologists and anesthesiologists.[4, 34] This project was the first of its kind to describe and codify the cognitive processes of practicing anesthesiologists. The researchers developed a system to evaluate 4 key NTS (task management, team working, decision making and SA) and focused on observable behaviours. The elements of the SA category include "gathering information," "recognizing and understanding," and "anticipating," which reflected Endsley's 3-level model of SA.[35] The ANTS system has been used widely in anesthesiology,[22, 36, 37] and modified for other specialties,[38, 39] to assess NTS both in clinical and simulation environments.

Interest in SA as a key NTS in anesthesiology has continued throughout the last decade. There are several reviews of the topic, and discussions of various SA frameworks,[23, 27] and studies that

link the concept to medical error and patient safety outcomes within the specialty.[40] In a qualitative study exploring excellence in anesthesiologists, Smith et al.[41] found that "being situationally aware" was one of the characteristics of an excellent anesthesiologist. Despite the academic interest in the topic, it is unclear how a prototypical clinical anesthesiologist conceptualizes SA in their own work and that of their colleagues, or how they teach or assess it.

2.1.5 Significance of SA

It is well recognized that lapses in SA contribute to errors in many professions including aviation, air traffic control, and offshore oil drilling.[42] There is growing evidence that a lack of SA is related to critical incidents and poor outcomes in health care settings.[40, 43-46] One study focusing on death due to error in orthopedic surgery found that 44% of the events were considered related to NTS errors, of which 52% were classified as deficiencies in SA.[45] Deficiencies in SA were also determined to be responsible for almost half of the deaths due to NTS errors in a three-year study in Japan.[46] Deficiencies in SA were noted in more than 80% of intensive care and anesthesiology critical incidents, most of which occurred at the level of perception (level I) and comprehension (level II), according to Endsley's model.[40] Evidence that links problems with SA to poor patient outcomes provides a compelling reason to further study this phenomenon, and indicates that the concept of SA has not only theoretical but practical significance.

2.2 Research in SA

2.2.1 Understanding SA

The fact that many different definitions of SA exist reflects a degree of confusion around what

SA actually means.[11] Indeed, since the mid-1990s, several authors have posited that SA as a concept is "too subjective, too intuitive, and lack[s] a coherent definition."[5-7, 14] As recently as 2010, SA was identified by the Royal College of Physicians and Surgeons of Canada (RCPSC) as the "most important and least understood human factor in healthcare."[12] Similarly, the term SA is not "prevalent or well understood in the nursing lexicon."[47] In studies that focus on the teaching or assessment of SA in the medical sphere, there has been little exploration of how participants formulate their own personal definitions of SA,[48, 49] although some studies (especially in the nursing profession) have tried to explore how SA was understood by healthcare professionals.[50, 51]

The expert reviews of SA in anesthesiology within the literature focus on explicit, codified knowledge of SA - that is, the knowledge that is "subject to quality control by editors, peer review and debate and … given status by incorporation into educational programmes"[52(p.114)] - rather than personal knowledge of SA, which Eraut defines as "the cognitive resource which a person brings to a situation that enables them to think and perform."[52(p.114)] Personal knowledge can be either tacit or explicit, and is context-dependent.[52] SA is likely still a tacit concept in anesthesiology, a type of "intuitive expert knowing."[53]

Discipline-specific review papers discussing the concept of SA have often utilized specific clinical examples or case studies to explain the meaning of SA.[3, 11, 23] Concrete examples may make the concept of SA more accessible to the reader, especially if framed within language and context familiar to a specific profession or discipline. The use of examples from everyday life can be a compelling way to promote understanding, and this has been encouraged within the

context of anesthesiology education.[54] Examples may be positive (i.e. the participant exhibited a good level of SA) or, as is more often the case in critical incident analysis, negative (i.e. a lack of SA contributed in some way to a poor outcome).[16] The use of examples to illustrate SA within a clinical situation also highlights that context is important in understanding SA.[20]

SA has also been understood as a differentiating factor on the continuum of expertise.[2, 50] Whereas in novices, SA is often "demanding, frequently incomplete, and erroneous"[2] due to their limited attention and working memory, it tends to be "fast….effortless and more complete"[2] in experts because of existing schemas and mental models, along with increased automaticity of processes and the existence of learned behaviours to improve SA.[2] Experts tend to pay more attention to context than do novices in the same situation.[1] However, it is important to note that SA ability in experts is domain specific, and not necessarily transferable to other contexts.[2] Exactly how these experts evolve in their learning of SA is still the subject of study.[2]

2.2.2 Learning SA

Certain cognitive abilities (working memory capacity, general intelligence, time sharing ability, perceptual-motor ability and visual-recognition ability) have been identified as predictors of SA ability.[55, 56] SA skills vary between individuals based on their "innate abilities, experience and training."[9] SA training (including training in attention management strategies and part-task training) may improve skills in task management, comprehension development, projection and contingency planning, information seeking and self-checking.[29, 55] Nevertheless, it remains "unclear how and to what extent relevant skills for the development of SA are acquired."[23]

Furthermore, we understand little about how practicing anesthesiologists feel they learned SA, when this learning occurred, or how deliberately it happened.

Learning has been defined as "the process whereby knowledge is acquired."[52] Much of the learning that occurs in the workplace happens informally and leads to the acquisition of tacit knowledge.[52] While simulation has been shown to be a useful tool to formally address SA teaching,[57, 58] much of the learning of NTS in the clinical environment could be considered both informal and tacit.[52, 59] One example of tacit learning of SA in the workplace is through the process of preceptor role-modeling.[60]

In addition to being relevant to the understanding of SA, context is also important regarding the learning of SA. The concept of "situated learning" is applicable, in that "learning is always situated in a particular context which comprises not only a location and a set of activities in which knowledge either contributes or is embedded but also a set of social relations which give rise to those activities."[52] The teaching of SA is also context-dependent, and is considered below.

2.2.3 Teaching SA

There are many examples of attempts to teach SA within various disciplines reported in the medical education literature, and both didactic and simulation-based curricula for teaching SA have been studied.[61-64] There is evidence to show that training medical students and residents in CRM principles can improve their NTS performance.[65, 66] Critical incident review, morbidity and mortality case conferences, and (legal) closed claims discussions have been utilized to

highlight the role of SA in the context of medical error prevention and patient safety.[20]

The tacit nature of certain concepts makes them difficult to teach.[67] Collins developed the "cognitive apprenticeship" model, which describes teaching through modeling, coaching, scaffolding, articulation, reflection and exploration.[67, 68] This model emphasizes that tacit thinking processes must be made visible, while also recognizing the value of situating "abstract tasks in authentic contexts."[67] The cognitive apprenticeship model has been used to guide debriefing to teach SA to pilots.[69] The model has been described as a useful guide for medical educators,[68, 70, 71] and has been found to be reflective of aspects of how surgeons teach intraoperatively.[72]

A number of approaches to teaching SA skills in anesthesiology have been suggested, including: practicing scanning behaviours; training in attention allocation and multitasking through the use of games and simulation; using exercises in pattern matching, classroom based teaching, computer-based training, simulation, and the use of virtual environments.[3, 23, 57] Approaches to teaching SA in other medical specialties, including surgery and critical care, have included the use of classroom-based techniques, small group sessions, simulation, and coaching, as well as a focus on "slowing down" moments in surgery.[61-63, 73-75]

Despite these many suggestions, it is unclear how the teaching of SA actually happens *in situ* within anesthesiology settings. While there is value in considering the formalized curricula and courses targeting SA teaching, the nature of practice-based approaches to teaching SA in anesthesiology is not well understood and deserves further study.

2.2.4 Assessing SA

Standard setting for assessment of SA can be difficult because, not only is it difficult to know what constitutes an "adequate amount" of SA for a given situation, "it is a significant challenge to define the achievable ideal" SA.[76] Endsley argues that "there is really no set threshold of SA that can guarantee a level of performance," but that efforts to train and assess SA are important because "as the level of SA possessed by an individual increases, the probability of making good decisions and performing well also increases."[1(p.27)] While SA may involve cognitive processes that cannot be observed directly,[42] various techniques and behavioural markers can be employed in the clinical environment or in simulated scenarios to assess SA. These techniques are discussed below.

Endsley developed the "Situation Awareness Global Assessment Tool" (SAGAT) which utilizes pauses during a scenario (often during simulations), at which time the participant is asked specific questions to assess the knowledge gathered from the scenario, the comprehension of the situation, and the prediction of potential anticipated events.[77] For example, in a scenario involving a septic patient, the high-fidelity simulator will be paused and the monitoring screen temporarily blacked out, while the participant is asked 1) "What was the last measured blood pressure?"; 2) "What is the likely cause of the current abnormal vital signs?"; and 3) "What will likely happen to the blood pressure and heart rate in the near future if no treatment is instituted?"

Several studies have used the SAGAT to evaluate individual and team SA.[49, 63, 78, 79] The tool can help to evaluate changes in an individual's SA during the progression of a scenario.

However, one particular disadvantage of the tool is that it requires the participant to stop mid-scenario to answer a series of probing questions, which may be impractical in actual patient care scenarios.

The "Situation Awareness Rating Technique" (SART), which uses a self-rating scale to evaluate SA during a task, was designed by Taylor.[77] Practitioners score themselves on attentional demand, attentional supply and understanding after completion of a task, and no interruptions are required.[80] Ideally the SART score is combined with some measure of actual performance, since one of the disadvantages of the tool is that it is relies on subjective self-scoring, and operators may not be aware of their own lack of SA.[80]

Ratings of individual SA form part of the ANTS behavioural marker system (described previously), which has been used in both simulated and real clinical environments.[34, 81] Raters create a numerical score (0-4) based on their observation of participants' behaviours related to gathering information, recognizing/understanding, and anticipating. However, raters need to be trained to use the system in order to generate valid data, and this training tends to be time-consuming and resource-intensive.[81, 82]

While the creation and evaluation of SA assessment tools has been an active area of research, there has been little study of whether (and in what ways) SA is being assessed on a day-to-day basis in the clinical environment, the quality of these assessments, or the consequences of the ratings generated by these assessments.

2.3 Summary

While the thinking about SA in both medical and non-medical contexts has evolved over the last 20 years, many questions remain. Despite the abundance of publications presenting various definitions and models of SA, the concept is still incompletely understood and our knowledge of how clinical anesthesiologists conceptualize SA is lacking. Although we do understand some of the factors involved in learning SA, we do not have a clear sense of how practitioners perceive their own SA abilities to have developed. Much of the research into SA in healthcare has focused on possible teaching and assessment methods, techniques, or tools.[58, 83, 84] However, in examining these more formalized programs, we have failed to ask the question of how and whether the concept is being taught "at the ground level," and we do not yet understand the consequences of such assessments. These issues become particularly important in this era of competency-based medical education (CBME), where there is a growing expectation of explicit evaluation and repeated observations to show that residents have achieved an acceptable level of performance in skills both technical and non-technical.[85]

In order to address these gaps in our knowledge, I posed the following questions:

1. How do anesthesiologists understand the concept of SA?
2. How did anesthesiologists learn SA?
3. What do anesthesiologists think about how SA is currently taught and assessed?

The next chapter will present the methods used to attempt to answer my research questions, along with a discussion of the rationale for choosing the methods, and a detailed description of how the data was collected and analyzed.

Chapter Three: Methods

This chapter will present the methods I used to explore the research questions. I will discuss the qualitative research approach undertaken, along with the specific data analysis techniques used in the thematic analysis of the interview data. Details regarding the setting and context of the research, along with information about the study population, are provided. I will also discuss measures taken to increase the rigor in this qualitative research project.

3.1 Study design

3.1.1 Overview

Given the research questions of this study and the focus on understanding the views of the research participants regarding SA, I undertook a qualitative study to explore the beliefs and perceptions of a group of anesthesiologists within a single city department. I developed an interview script and conducted a series of one-on-one interviews with the participants. I used a range of constructivist grounded theory techniques in a thematic analysis of the interview transcripts to inductively explore the perspectives and practices related to SA in this group of anesthesiologists.[86] Endsley's 3 level model of SA[9] served as a sensitizing concept[87] which helped to "lay the foundation for the analysis of [the] research data."[87(p.5)] A more detailed discussion of constructivist grounded theory, along with thematic analysis in general, is presented below.

3.1.2 Constructivist grounded theory

As a methodology, grounded theory may be described as a set of research techniques that lead to the generation of conceptual categories, which are then used to create a "unified theoretical explanation" related to the issue being studied.[88] Originally described by Glaser and Strauss, grounded theory allows the development of theory that is "grounded in the data" and not based on pre-conceived hypotheses about the phenomenon under study.[88, 89] The methods used in Glaser and Strauss' grounded theory paradigm included: simultaneous data collection and analysis; the construction of analytic codes and categories from data (not from prior inferences on what the data might reveal); the use of the constant comparative method; progression of theory development during each stage of data collection and analysis; the creation of memos to further build on categories and category relationships; sampling aimed at theory construction; and conducting a literature review after developing the analysis.[88, 90] The modification of classic grounded theory by Charmaz recognizes that the "researcher and participant construct a shared reality,"[91] and is termed constructivist grounded theory (CGT).[89] Charmaz[90] acknowledged that the researcher brings his or her own perspective to the development of theory, and emphasized the importance of "views, values, beliefs, feelings, assumptions and ideologies of individuals," alongside the data collection and analysis, memo-ing and theoretical sampling aspects of grounded theory. CGT has been used to explore topics in medical education,[92] including issues regarding giving and accepting feedback, and learning through clinical work.[93-95]

While I drew on several aspects of CGT in order to inform the collection and analysis of the study data, I do not claim that this was a CGT study.[86, 92] The goal of the study was not to generate a theory about SA,[86] but rather to explore understanding of the concept, and to identify

patterns of thinking and behaviour as a way of informing future practice related to SA within anesthesiology. This reflects a pragmatic stance in the design of the study and an analytical orientation to the broader concept of "thematic analysis".[96]

3.1.3 Thematic analysis

Thematic analysis has been described as "a method for identifying, analyzing and reporting patterns (themes) within data."[97] Although thematic analysis is a relatively flexible method, in that it need not be tied to any particular methodologic framework,[97] it can be considered a rigorous research tool when the analysis is done in a manner that is "deliberate, reflective and thorough."[98] Braun and Clarke[97, 99] have described a six-step process of thematic analysis which includes familiarization with the data, initial coding, searching for themes, reviewing themes, defining and naming themes, and finally writing up the research. The importance of specific themes is not dependent on the simple "prevalence" of a theme within the transcript data, but rather it relates to what the theme contributes to the understanding of the subject of interest.[97]

Thematic analysis describes the "systematic approach for identifying, analysing and reporting patterns - themes - across a dataset."[96(p.178)] As described above, advantages of the method include its flexibility since researchers are not required to adhere to any specific means of data collection or theoretical stance in order to analyze the data, and that it may be used with both small and large datasets.[96] As per Braun and Clarke,[96] weaknesses of the method include limitations in its interpretative power if it is not considered within an existing theoretical framework, along with a lack of guidance for higher level analysis. Regardless, thematic analysis is considered a well-recognized and accessible analytic strategy for qualitative

researchers, especially those with limited qualitative data analysis experience.[96]

3.1.4 Constructivist approach

Braun and Clarke have defined constructivism as a "method which examines the ways in which events, realities, meanings, experiences and so on are the effects of a range of discourses operating within society."[97] I used a constructivist approach in this study as a way of understanding participants' points of view and experiences. The emphasis on constructivism in this study acknowledges the existence of "multiple participant perspectives,"[90] which provides richness and depth to understanding the data obtained from interviews.

3.1.5 Reflexivity

The study team consisted of 4 individuals. Julia Haber (JH) and Rosaleen Chun (RC) are anesthesiologists with an interest in medical education. Rachel Ellaway (RE) and Jocelyn Lockyer (JL) are PhD medical education researchers with extensive qualitative research backgrounds. The different perspectives within the group allowed for broader examination and interpretation of the data.

As an anesthesiologist involved in medical education within the educational and practice community being studied, I had both a professional and, in many cases, a personal relationship with the participants. This "insider status" provided a distinct ethnographic gaze within the study, and allowed a rich discussion to occur, including the use of a common language and an understanding of the jargon within the specialty of anesthesiology, and the implicit acknowledgement that I had shared many of the same training and practice experiences as the

interview participants.

In contrast, as a professional insider, I came to the research with my own ideas and preconceptions about SA and its role in anesthesiology. Charmaz[91] acknowledged that researcher is not an objective being, but brings his or her own biases to the data interpretation. Glaser[91] also acknowledged that research bias is a "variable" incorporated into the constant comparison analysis process. Thus, such bias may be viewed as additive to the study rather than representing a flaw, as long as it is carefully considered and acknowledged.

3.2 Data

3.2.1 Interviews as a method for collecting data

Interviews are commonly used in qualitative research as a means of data collection.[100] Semi-structured interviews are particularly useful in that they allow the researcher to ask specific questions, but the respondents may provide as much detail in their responses as they choose, and the researcher is able to follow up on any discussion points or emerging topics of particular interest.[101] Probes are often used to stimulate discussion around a question or concept within the interview guide. Individual interviews allow the researcher to "delve deeply into social and personal matters" in a manner that group interviews often do not.[101]

Since I was particularly interested in the thoughts and experiences of anesthesiologists relating to their experiences of learning, teaching and assessing SA, semi-structured interviews were useful to allow participants to share their thoughts, stories and examples with me. Interviews were all conducted face-to-face, which allowed me to note non-verbal clues, facial expressions and body

language, providing further information from respondents beyond their spoken words. These non-verbal cues allowed me to ask relevant follow-up questions at the time of the interview, if it appeared that the participant might have further ideas or thoughts to share.

3.2.2 Setting and context of the research

The setting for this project was the Department of Anesthesiology, Alberta Health Services, in Calgary, Alberta. Calgary is the largest city in Alberta, Canada, with an estimated population of 1.2 million.[102] There are 5 major hospitals in Calgary: Foothills Medical Centre (FMC), Rockyview General Hospital (RGH), Peter Lougheed Centre (PLC), South Health Campus (SHC) and the Alberta Children's Hospital (ACH). Each of these hospitals provides anesthesiology care services for general surgery, orthopedics, gynecology, along with some specialized anesthestic services.[103] Further information on each of these sites is presented in Table 1.

Table 1: Calgary Anesthesiology Department Information

Hospital	Special anesthesiology services provided	Number of anesthesiologists
Foothills Medical Centre	Trauma Services, Cardiac Surgery Neurosurgery, Gynecologic Oncology, High Risk Obstetrics, Kidney Tranplant	53
Rockyview General Hospital	Urology, Ophthalmology	39
Peter Lougheed Centre	Vascular Surgery, Bariatric Surgery	34
South Health Campus	Focus on Regional Anesthesia for Orthopedic Procedures	20
Alberta Children's Hospital	Pediatric Anesthesiology	19

At the time the study was undertaken, there were approximately 165 anesthesiologists with staff positions in Calgary.[104] Staff anesthesiologists in Calgary hospitals have clinical appointments via Alberta Health Services (AHS) and are granted an appointment starting at the level of Clinical Assistant Professor, through the University of Calgary. These anesthesiologists all work in urban teaching hospital environments, with a variety of trainees including medical students, anesthesiology residents, and off-service residents. There were approximately 32 residents in the training program at the time the study was carried out.

Most of the interactions between anesthesiology staff and residents occur in the setting of the operating room, via the clinical care of patients who require anesthesia for elective or emergent surgery. Opportunities for learning also exist in the pre-operative clinic, acute pain service, and the multi-disciplinary chronic pain clinic. Some of the teaching interactions between staff and residents occur in the classroom setting during the academic half-day and teaching rounds. Additionally, teaching occurs within the simulation environment throughout the 5-year residency.

Staff anesthesiologists in Calgary are physicians who have completed a residency in anesthesiology, and are certified through the Royal College of Physicians and Surgeons of Canada (RCPSC). Some staff anesthesiologists have international training (either residency or fellowship) from other countries such as the United Kingdom and the United States. The majority of Calgary anesthesiologists have completed an anesthesiology residency in Canada. The length of time in anesthesiology practice for individual anesthesiologists in our departments

is highly variable, ranging from the first year after residency/fellowship, to over 30 years of experience.[104]

The culture within each of the hospitals, as well as within Calgary, shapes the environment where the learning and teaching of NTS takes place. Each educational environment within the 17 Canadian anesthesiology residency programs has its unique aspects, but all Canadian anesthesiology residents follow the same national curriculum,[105] and accreditation requirements from the RCPSC ensure that clinical anesthesiology experiences are not vastly different between residency programs.[106] While the findings of my study are intimately linked to the particular research setting, it is possible that they might be generalizable to other teaching centers, especially within Canada.

3.2.3 Data Collection

I developed an interview guide (Appendix A) based on the study research questions and using the sensitizing concept of Endsley's SA model,[87] and this guide was reviewed and iteratively revised by the study team. Probes were created to stimulate discussion between the interviewer and respondent. Questions were open-ended and worded to avoid simple "yes or no" answers. Prior to recruiting the study participants, RE interviewed me using the study guide in a "mock interview" fashion, which provided the opportunity to refine the interview guide questions and to test the probes. This mock interview also offered me the opportunity to more formally answer each of the interview guide questions and to reflexively examine some of my thoughts and biases about SA prior to conducting the interviews myself.

I conducted semi-structured interviews in person with the first 2 interviews also including JL, a qualitative researcher with extensive interviewing experience. Interviews were carried out over 10 months, between January and October 2016. Audio-recordings of the interviews were transcribed verbatim by a third-party professional transcriptionist. All data were anonymized before analysis. Simultaneous data collection and coding were performed (see data analysis section below). The study was based on interviewing 15-20 anesthesiologists, with the final number depending on the point at which thematic saturation (i.e. no new themes emerging from the data) was reached [90, 97, 107, 108]

3.2.4 Participants

Inclusion criteria for interview participants included holding a position as a staff anesthesiologist working at any of the five hospitals in Calgary, and involvement in teaching anesthesiology to medical students and residents. Locum physicians were excluded from the study, as we wished to focus on those anesthesiologists whose experiences were most reflective of the educational culture in Calgary during the study period. I invited, by email, all anesthesiologists who met the inclusion criteria to participate in semi-structured interviews. Additionally, posters approved by the local ethics review board were placed in conspicuous areas (e.g. operating room lounge bulletin boards) during the recruitment period for the study. Interested anesthesiologists contacted me directly to arrange their interview.

Although the demographic characteristics of the initial participants were dependent on those who volunteered to be interviewed, an attempt was made to balance the demographic characteristics

among the interviewees (e.g. sex, teaching site, years in practice) selected from the volunteer pool.

3.3 Data analysis

3.3.1 Analysis of transcript data

I undertook an initial line-by-line coding of the transcripts for calibration purposes for the first 7 interviews. Qualitative data analysis software (NVivo 11 for Mac, QSR International) was used for the coding, as well as to record memos electronically. Prior to the line-by-line coding, I listened again to the audio-recorded interviews. I used a constant comparison method, moving back and forth between interview transcripts and adding codes as ideas and themes emerged from reading the transcribed data. I had several face-to-face meetings with JL (thesis project supervisor), as well as email exchanges and updates on the progress of the interviews during this time period.

Once the initial 7 interviews had been coded, the codebook and all of the transcripts were reviewed by the study team as a whole and changes to the codebook made to reflect ideas and themes that had evolved during the discussion. The original codebook was felt to be overly complex, and the study team suggested collapsing some of the codes into higher-order categories to simplify and refine the coding process.

I then coded the remaining interviews (8-18) and went back and re-coded interviews 1-7. I used an iterative coding process (i.e. I reviewed/further coded transcripts which had previously been coded once more interviews had been performed and new data had been acquired and analyzed).

The study team met frequently during this period of time to discuss emerging ideas and themes related to the data. I continued to create memos about ideas and thoughts that came to mind during the data analysis. I performed queries from time to time (using NVivo) to review quotations from different respondents that were grouped together under one code, in order to help shape my thinking about emerging themes.

3.3.2 Rigor in qualitative research

The idea of rigor in qualitative research relates to the trustworthiness of the work, which incorporates the concepts of credibility, transferability, dependability and confirmability.[109-111] While the notions of reliability and validity can apply to qualitative work, these concepts are considered differently than when used to evaluate quantitative research.[111] The credibility (truth value) and transferability (applicability) of qualitative research may reflect validity, whereas the dependability (consistency) reflects reliability.[111] Morse[110] described possible threats to rigor in qualitative work including the "unstructured process of obtaining data within verbal interaction or observation, the interpretative nature of the analysis, and the subjective nature of data itself." In order to mitigate some of these threats, Morse has suggested strategies to improve validity including: theoretical sampling; peer-reviewing/debriefing during the data analysis process; refinement of the coding system as interviews progress; clarifying researcher bias; member checking; thick description; and triangulation of data.[110] However, the use of these methods is research context-dependent: not all of the strategies are applicable to all qualitative research.

In this study, we developed a coding system/codebook that we reviewed as a study team. Transcripts were coded by more than one individual and we discussed and compared codes

regularly at research meetings. Thick descriptions were obtained from participants, with "overlap of key issues," which contributed to internal reliability.[110] In terms of peer review, two of the research team members were practicing anesthesiologists (JH and RC). Since I did the majority of the coding, RC's review of the data provided an element of peer review in terms of synthesizing the data and "pattern-finding."[110]

With regard to reliability, Morse[110] has stated that "reliability makes replication possible" but that the "process of replication itself destroys induction. Therefore, replication of a project is unnecessary and undesirable in qualitative inquiry." Rather, the focus on reliability in qualitative work should be on the coding process, namely the development of a coding system and inter-coder agreement.[110] The code-book/coding system used in this project was reviewed by the study team, the transcripts coded by more than one member, and agreement regarding coding was discussed in regular meetings. Member-checking during subsequent interviews (ie: asking questions relating findings from earlier interviews to subsequent interview participants to confirm experience or meaning) is another strategy to increase reliability.[110] This type of questioning was employed in the interviews used in this study.[99]

These efforts, made during both the data collection and analysis stages in this work, arguably increased the validity and reliability of the study and contributed to the trustworthiness of our findings.

3.4 Privacy, Confidentiality, and Data Handling

Informed consent was obtained in writing from all participants, and participants were informed prior to the interviews that confidentiality would be maintained. Audio recordings of interviews were transcribed and de-identified, and the audio recordings and printed transcripts kept in a secure location. Electronic copies of the recordings and transcripts were maintained, and these were created as password protected files, on a password-protected laptop. Anonymity was maintained with regards to quotations used in presentations and written publications.

3.5 Ethics approval

This study was approved by the University of Calgary Conjoint Health Research Ethics Board (REB15-1959, December 2015).

3.6 Summary

Semi-structured interviews with Calgary hospital-based anesthesiologists were used to collect data exploring the understanding of SA, along with information about the learning, teaching and assessment of SA. Thematic analysis of interview transcripts using constructivist grounded theory techniques was performed, with discussion of emerging themes occurring at regular study team meetings throughout the research process. The following chapters provide the results of the thematic analysis along with a selection of exemplar quotations illustrating some these key themes.

Chapter Four: Results

This chapter presents the manuscript entitled "Exploring anesthesiologists' understanding of situational awareness: a qualitative study" (authors: Julia Haber, Rachel Ellaway, Rosaleen Chun, Jocelyn Lockyer). It has been accepted for publication in the Canadian Journal of Anesthesia (estimated date of publication September 2017) and contains the results of the study. It has been re-formatted for this manuscript-based thesis.

4.1 Abstract

Purpose: This study explored how anesthesiologists understand situational awareness (SA), and their thoughts on how SA is learned, taught, and assessed.

Methods: Semi-structured interviews were performed with practicing anesthesiologists involved in teaching. This qualitative study used constructivist grounded theory techniques (i.e. line-by-line coding, memo-ing, and constant comparison) in a thematic analysis of interview transcripts. Group meetings were held to develop and review themes emerging from the data.

Results: 18 anesthesiologists were interviewed. Respondents displayed an understanding of SA using a mixture of clinical and everyday life examples. Despite agreeing on the importance of SA, formal definitions of SA were lacking, and the topic of SA was not made explicit in either their practice or their teaching activities. SA had been learned informally through increasing independence in the clinical context, role-modeling, and reflection on errors, and formally through simulation. Respondents currently taught SA through modeling and discussing scanning behaviours, checklists, verbalization of thought processes, and debriefings. Although trainees'

SA was assessed as part of the decision-making process regarding granting clinical independence, respondents found it difficult to give meaningful feedback on SA to their trainees.

Conclusion: Although SA is an essential concept in anesthesiology, its use remains rather tacit due to the lack of a common operational definition of the term. Faculty development is required to help anesthesiologists more explicitly teach and assess SA in the clinical environment.

4.2 Introduction

Situational (or situation) awareness (SA) has been defined as "the perception of elements of the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future."[1] SA has been recognized as an essential non-technical skill and crisis resource management (CRM) principle in anesthesiology.[3, 4, 23, 112] The concept of SA has been incorporated into the "Anaesthetists' Non-Technical Skills" (ANTS) framework,[22] the CRM objectives of the Canadian National Anesthesiology Curriculum,[105] and the Canadian Guidelines to the Practice of Anesthesia.[113] In addition, SA is specifically identified as part of the CanMEDS 2015 medical expert competencies and milestones.[114]

Although there have been different definitions and examples of SA within anesthesiology, there is little known about how the concept of SA is understood by clinical anesthesiologists.[3, 23, 27] In a needs assessment by the Royal College of Physicians and Surgeons of Canada, SA was identified as the "most important and least understood human factor in healthcare."[12] Discussions of individual SA, team SA and distributed SA can help to create a framework for understanding the concept, but apart from "expert" descriptions of these terms, it is unclear how

the average clinical anesthesiologist relates the term "situation(al) awareness" to their day-to-day practice.[23, 27, 115]

Certain cognitive abilities (e.g., working memory capacity, general intelligence, time sharing ability, perceptual-motor ability and visual-recognition ability) have been identified as predictors of SA ability.[55, 56] SA skills vary a lot between individuals based on their "innate abilities, experience and training."[9] SA training (including training in attention management strategies and part-task training) may improve skills in task management, comprehension development, projection and contingency planning, information seeking and self-checking. [29, 55]

While potentially applicable to anesthesiology, much of the research into learning SA has been borrowed from the aviation industry. The relatively modest literature on SA in medicine has tended to focus on teaching and assessing SA. Approaches to teaching SA skills in anesthesiology include: practicing scanning behaviours; training in attention allocation and multitasking through the use of games and simulation; and exercises in pattern matching, classroom based teaching, computer-based training, simulation, and the use of virtual environments.[3, 23, 57] Approaches to teaching SA in other medical specialties, including surgery and critical care, have included the use of classroom-based techniques, small group sessions, simulation, and coaching, as well as a focus on "slowing down" moments in surgery.[61-63, 73-75]

Ratings of individual anesthesiologist SA form part of the ANTS behavioural marker system, which has been used in both simulated and real clinical environments.[34] Similar behavioural marker systems (based on ANTS) have been developed for other health care providers, since

non-technical skills (including SA) are also felt to be essential in these disciplines. Examples include ANTS-AP for anesthesia assistants;[116] NOTSS for surgeons;[117] and SPLINTS for scrub nurses.[118] The ANTS system evaluates SA at three different levels: Gathering information (level 1: Perception), Recognizing and Understanding (level 2: Comprehension) and Anticipating (level 3: Projection).[1] Other strategies for assessing SA include: variations on the "Situation Awareness Global Assessment Tool" (SAGAT); "Situation Awareness Rating Technique"; and the "Situation Present Assessment Method", mostly within the context of simulation.[49, 57, 58, 79, 119, 120] The SAGAT is a technique developed by Endsley that uses pauses to assess participants' SA about a scenario in real-time (e.g. "Level 1: What is the last recorded blood pressure (BP)?"; "Level 2: What is the likely cause of that BP?"; "Level 3: What will happen to the BP if the patient receives no treatment?").[77] The SAGAT has also been modified to assess SA within a team environment (TSAGAT).[79]

Despite the acknowledged importance of SA as documented in reviews and research, many questions remain. Our study was designed to address the following research questions:

1. How do anesthesiologists understand the concept of SA?
2. How do anesthesiologists learn SA?
3. What do anesthesiologists think about how SA is currently taught and assessed?

4.3 Methods

This qualitative study, approved by the University of Calgary Conjoint Health Research Ethics Board (REB15-1959, December 2015), used constructivist grounded theory techniques with a focus on participant experiences and understanding of SA.[89] A constructivist approach enables

researchers to examine "the ways in which events, realities, meanings, experiences and so on are the effects of a range of discourses operating within society."[97] Constructivist grounded theory techniques (such as line-by-line coding, memo-ing and constant comparison) were used in a thematic analysis of transcripts to afford a broader inductive exploration of Calgary anesthesiologists' SA perspectives and practices.[86]

4.3.1 Data collection

An interview guide (appendix A) was initially developed by one of the authors (JH) based on the study research questions, and then reviewed and revised by the rest of the study team, including the addition of probes for each question to stimulate discussion. Semi-structured interviews were conducted in person by JH with the first 2 interviews also including a qualitative researcher (JL) with extensive interviewing experience. Interviews were carried out over 10 months, between January and October 2016. Audio-recordings of the interviews were transcribed verbatim by a third-party professional transcriptionist. All data were anonymized before analysis. Simultaneous data collection and coding were performed (see data analysis section below). Although our study design was based on an estimated 15-20 interviews, the final number depended upon our reaching thematic saturation in our analyses (i.e. no new themes emerging from the data) [90, 97, 107, 108]

4.3.2 Participants

We sought to interview anesthesiologists who worked at any of the five hospitals in Calgary and who were involved in teaching anesthesiology to medical students and residents. All anesthesiologists who met these criteria were invited by email (by JH) to participate in semi-

structured interviews. Interested anesthesiologists contacted JH directly to arrange a time to be interviewed. During the study period, there were approximately 165 staff anesthesiologists working in Calgary, and approximately 32 trainees in the anesthesia residency program. Although this was in effect a convenience sample, an attempt was made to balance the demographic characteristics among the interviewees (e.g., sex, teaching site, years in practice) selected from the volunteer pool.

4.3.3 Analysis

An initial line-by-line coding of the transcripts for calibration purposes for interviews 1 through 7 was undertaken by JH. Qualitative data analysis software (NVivo 11 for Mac, QSR International, Melbourne, Australia) was used for the coding, as well as to record memos. Once the initial 7 interviews had been coded, the codebook and all of the transcripts were reviewed by the study team as a whole and changes to the codebook made. The remaining interviews (8-18) were coded and interviews 1-7 were re-coded. Coding was performed using an iterative process (i.e. transcripts which had previously been coded were reviewed/further coded once more interviews had been performed and new data acquired and analyzed). The study team met frequently to discuss emerging ideas and themes related to the data.

Of the four members of the study team consisted, two (JH and RC) are anesthesiologists with an interest in medical education. The other two (RE and JL) are PhD medical education researchers with extensive qualitative research backgrounds. The different perspectives within the group allowed for broader examination and interpretation of the data. The invited participants were all known to JH in a professional capacity.

4.3.4 Qualitative rigor

Rigor in qualitative research relates to the trustworthiness of the work.[110] While the notions of reliability and validity can apply to qualitative work, these concepts are considered differently than when used to evaluate quantitative research.[111] The credibility (truth value) and transferability (applicability) of qualitative research may reflect its validity, whereas the dependability (consistency) reflects its reliability.[111] Strategies our study team used to increase the validity of our research included peer-reviewing/debriefing during the data analysis process; clarifying and unpacking potential researcher biases; refinement of the coding system as interviews progressed; and iterative deliberative development of emerging theories and interpretations of the data.[110] To increase reliability, the code-book/coding system used in this project was reviewed by the study team, the transcripts were coded by more than one member, and agreement regarding coding was established through regular meetings. Longitudinal member-checking during subsequent interviews was another strategy used to increase reliability (i.e. asking questions relating findings from earlier interviews to subsequent interview participants to confirm experience or meaning).[110,99]

4.4 Results

Eighteen anesthesiologists were interviewed for this study, over a period of 10 months. Sixteen participants were initially interviewed, and the sample was then expanded to eighteen to seek greater diversity of opinion. Participant characteristics are described in Table 2.

Table 2: Participant Characteristics

Participant characteristic	**Result**
Sex (M:F)	12:6
Number of years in practice	Range 2-27 years
Number in practice <10 years	8
Number in practice >10 years	10
Practice site	Site 1: 9 (FMC*)
	Site 2: 4 (PLC#)
	Site 3: 2 (RGH|)
	Site 4: 2 (ACH**)
	Site 5: 1 (SHC##)
Canadian Graduate: International Medical Graduate	15 (Canadian): 3 (IMG||)
Length of interviews	Range, 34 - 88 mins Average length, 54 minutes

* Foothills Medical Centre; # Peter Lougheed Centre; | Rockyview General Hospital;

** Alberta Children's Hospital; ## South Health Campus; || International Medical Graduate

The thematic analysis identified many concepts which we grouped within four themes: understanding SA, learning SA, teaching SA, and assessing SA.

4.4.1 Understanding SA

Respondents considered good SA to be a fundamental skill in anesthesiology practice, although many admitted they had not spent much time thinking about the concept prior to the interview.

> "I think it's highly valued and … one of those implicit parts of our culture."
>
> Interview 12

Many respondents were able to describe the concept of SA in the context of the operating room.

> "if we're doing a trauma…patient who's bleeding rapidly, if you've got suddenly a change in your rhythm when you're listening to the pulse oximeter…quickly assimilating all of that information and then making a decision."
>
> Interview 4

Other respondents described SA based in examples from everyday life, such as parenting, team sports, driving and aviation.

> "Driving, for example… You need to be aware of not just keeping your car on the road but … what kind of weather is out there, what are the road conditions … what's happening behind you, what's happening to the side of you and … in your car."
>
> Interview 7

Respondents offered various definitions of the term SA, many of which centered on the gathering of information from various sources within their environment. Many respondents also discussed the interpretation of this information and the anticipation of future events. However, respondents generally expressed a lack of confidence with working definitions of SA as they exist in the literature, and they admitted that SA was not routinely discussed in their work setting.

> "I think it's an easy catchphrase to use. But I don't know …if it's ever been defined to me. And I don't know if anyone's ever defined it in terms of how we teach it or who has it."

Interview 6

Respondents identified different aspects of SA including the need for vigilance, filtering of non-relevant data (information gathering), the importance of clinical context and experience (data interpretation), the need to prepare for and anticipate events (anticipation). There was some discussion of team SA but most respondents focused on individual SA.

Respondents noted various barriers to their day-to-day SA, including excessive noise (e.g. music, non-medical conversations), monitor alarms, personal stressors (e.g. fatigue, hunger, mental distraction), high patient complexity, electronic distractions (e.g. cell phone, OR computer/internet) and the presence of learners. They described strategies to maintain or enhance SA including scanning behaviours (e.g. monitor scan, room scan), the use of checklists/briefings, and frequent self-reflection on performance.

SA was also discussed in terms of emotional intelligence (a type of social intelligence that involves monitoring, discriminating between and using emotions to guide thinking and actions).[121]

" residents that I have come across who lack situational awareness… either they're not vigilant … [or] they don't know how to read non-verbal cues"

Interview 4

A number of respondents thought that "good SA" was a critical way of differentiating novice and expert anesthesiologists.

"maturing from a medical student… to an anaesthesia resident, to an anaesthesia staff person … a lot of what you're doing is developing situational awareness."

Interview 11

4.4.2 Learning SA

Although several anesthesiologists indicated that they had learned about SA through simulation, most participants described having to build SA skills with little educational support, largely through self-reflection around medical errors and near misses. The power of role modeling of SA was also highlighted.

"this is the same as all the other nontechnical skills, like how do you teach professionalism, how do you teach scholarship? … a lot of it is through role modeling"

Interview 8

Respondents noted that some learners have inherently better SA skills than others.

"I think some people are just good at it… they're street smart…they just know what's going on."

Interview 3

However, most respondents agreed that SA was a skill that could be learned.

"I imagine that nature sort of pegs your range. And nurture puts you where you end up finishing up on that range."

Interview 6

Respondents felt that while SA learning in anesthesiology begins at the earliest stages of training, it mainly occurs in senior years (usually postgraduate year three and above).

> "my conversation with an R5 is very different because … I know that they've acquired those skills and that baseline level of functioning … the majority of teaching that I do for an R5 is all about situational awareness actually."
>
> Interview 7

4.4.3 Teaching SA

Respondents felt that SA should be taught. They described using different teaching methods including behavioural teaching around checklists and scanning behaviours, debriefing after errors and near misses, talking aloud, and giving graduated independence to learners.

> "you have to verbalize your thoughts… if you hear silence in the room and suction going and … situational things that tell you that the surgeons are in trouble and you just order four units of blood and you don't verbalize why you've done that then…the opportunity to teach that awareness is lost."
>
> Interview 7

While few respondents used the term "situational awareness" in their teaching, those who had a background in simulation were more likely to use the specific terminology of SA and other CRM principles. While respondents frequently mentioned simulation as a tool to teach SA, they noted that the artificial environment of simulation could not substitute for true clinical experience.

"The problem with simulation …is that it's an artificial situation - as much as we try to make it into a realistic situation, it's not… And you lose a lot of those non-verbal cues … with regards to what … we interpret as important and not"

Interview 4

Several respondents described barriers to teaching, including a limited understanding of how to teach SA, and the time pressure in the operating room. It was felt that faculty development to improve familiarity with SA concepts and teaching methods would be beneficial.

"I think one of the challenges is that we don't think about it, so we don't… deliberately focus on it"

Interview 10

Additionally, respondents described the need to prioritize patient safety rather than allowing residents to learn from errors in SA.

"I don't let [residents] drift too far … versus waiting for them to miss it and then [patients] come to harm and then to teach that point."

Interview 2

4.4.4 Assessment of SA

Our respondents described assessing their trainees' SA using various discrete methods, including direct assessments of information gathering and understanding, discussions of anesthetic plans and anticipated events, and SAGAT-like questioning activities.

"periodically testing them…like what was the last peak airway pressure… what was your respiratory rate? What was your PEEP?"

Interview 4

However, many respondents described using a gestalt evaluation of SA rather than specific techniques, which reflected a focus on their trust in the trainee, and affected decisions about giving the trainee certain levels of responsibility and independence.

"when you're working with a resident…one of the things you…unconsciously determine is… does this individual have good situational awareness for their stage of training? And therefore, am I comfortable with them doing what they're doing? Can I leave the room for this amount of time?"

Interview 11

Respondents highlighted the difficulty of truly assessing SA due to the internal nature of the trainees' thoughts and understanding of events. Some also highlighted that the very act of assessment changed the trainee's SA in situ.

"by the simple fact of asking them about it 'Were you aware of that?' … it changes their… awareness of it or …the way that they would think about it. Simply because you've asked about it."

Interview 7

Respondents noted that they tended to avoid giving feedback about SA as they thought it would be received as personal criticism.

"you're criticizing their cognitive process in some ways, and that cognitive process is not … something that they've learned in residency. It's something that's part of their whole… development."

Interview 15

4.5 Discussion

This is one of the first studies to explore how clinical anesthesiologists understand the concept of SA, how they believe it is learned, and how they approach the teaching and assessment of SA.

We found that SA was not explicitly discussed in the workplace in this community of practice, despite there being a general agreement as to the importance of the concept and the fact that deficiencies in SA were well known to relate to critical incidents in anesthesiology.[40, 46] The expert reviews of SA in anesthesiology within the literature have focused on explicit, codified knowledge of SA; knowledge that is "subject to quality control by editors, peer review and debate and … given status by incorporation into educational programmes."[52] This differs from a more individual and personal knowledge of SA, which Eraut defined as "the cognitive resource which a person brings to a situation that enables them to think and perform."[52] Personal knowledge can be either tacit or explicit, and is context-dependent.[52] SA was likely still a tacit concept in the particular community of practice we engaged, a type of "intuitive expert knowing".[53]

The anesthesiologists within our community of practice considered SA to be relevant to both their clinical and non-clinical lives, and that it was particularly important to their specialty. However, as with the human factors and aviation communities,[7] there was no definitive, easily quoted description of SA and many of the respondents initially struggled with having to verbalize quite how they understood SA. Nevertheless participants were able to articulate, to varying degrees, the importance of gathering, interpreting and anticipating information from the patient and the environment; thus Endsley's 3 level model of SA proved to be a useful, relatable framework that could provide a shared language for these anesthesiologists.[1]

Anesthesiologists described the way that they learned SA as having been heavily influenced by experiential learning during and beyond their training. Progressive clinical independence, role-modeling, self-reflection, and analysis after errors were identified as critical for developing SA in the absence of formalized instruction, although some anesthesiologists had encountered the concept of SA during simulation training. Our findings in that regard align with both experiential and social learning theories, demonstrating the important of practical and collaborative approaches to developing SA.[122]

Respondents discussed different approaches to teaching SA, including using checklists, scanning behaviours, debriefing after errors, and talking-aloud in order to share otherwise tacit knowledge. These approaches to teaching SA have been also been suggested in the literature.[23, 29] Although simulation has been identified by others as a method of teaching SA,[123] our respondents expressed concern regarding the inauthenticity of the simulated environment, with respect to the development of SA skills. It was unclear whether individuals who were familiar with simulation

were better or more explicit teachers of SA in the clinical environment, only that those with simulation experience seemed more familiar with the concept of SA.

Respondents assessed trainees' performance on information gathering, data interpretation, and ability to anticipate future events, an approach which was consistent with Endsley's 3 levels of SA, and the ANTS behavioural marker system evaluation of SA.[9, 22] Assessment of a trainee's SA was seen as a gestalt process, similar to that used in a global-rating type assessment, and the anesthesiologist's impression was used to inform decisions about granting clinical independence to the trainee.

One implication of this study was the apparent need for a commonly used, operational definition of SA for anesthesiology teaching and assessment in the clinical context. Secondly, despite the numerous extant resources related to SA in anesthesiology,[22, 23, 27] there was a clear need for continuing professional development and faculty development that addressed SA issues. Perhaps most importantly, there was an apparent need for more explicit discussion and acknowledgement of SA as a vital skill in anesthesiology practice and education. These discussions should also consider the advantages and disadvantages of using different instructional modalities (such as simulation) to teach and assess trainees' SA.

We acknowledge several limitations in this research. Firstly, the findings are situated within a single community of practice at a specific time, and as such may not be generalizable to all anesthesiology practice contexts. Secondly, our focus was primarily on individual SA, not on team SA or distributed SA.[27] Thirdly, the first author undertook the bulk of the coding for this

study, with the inherent risk of bias related to her previous thinking about SA, knowledge of the literature, and her own clinical and simulation experiences in anesthesiology. However, all research team members reviewed the interview transcripts and performed their own coding of the interviews. Emerging themes and questions were discussed regularly in group meetings. Finally, we acknowledge that the views of learners were not part of this study as only staff anesthesiologists were recruited.

In conclusion, anesthesiologists appeared to understand SA, although a commonly used operational definition was lacking, as was any formal or regular consideration of SA issues. Although SA is clearly relevant and important to our specialty, it remains a somewhat tacit and nebulous concept, and as such it should be discussed, taught, and assessed more explicitly, with particular attention to its practical and collaborative aspects we identified. Our findings reflect Glavin and Flin's discussion of SA as a competency in anesthesiology, in that SA is undoubtedly important, but incompletely acknowledged, and deserves as much as attention as the basic science knowledge required for the medical expert role in anesthesiology.[112]

Chapter Five: Discussion and Conclusions

This chapter will elaborate on the discussion of the study findings presented in Chapter Four. The aim of my research was to explore how anesthesiologists in Calgary understood the concept of SA, and I attempted to gain insight into how they had experienced learning SA, along with how they approached teaching and assessment of SA in trainees. I will discuss the themes and subthemes that emerged from the data analysis related to each of the questions, and will expand on these within the context of the existing medical education literature. I will explore the implications of the study findings, review the strengths and weaknesses of the study, and discuss avenues for possible future research.

5.1 Discussion

SA is linked to performance in complex and dynamic environments[20] and is considered a marker of expertise.[2] There is increasing interest in studying optimal teaching and assessment methods for SA in medical training.[61, 78] However, in the midst of the development of training programs and measurement tools for SA in both clinical and simulated environments, some larger questions have been ignored, namely: how do the physicians responsible for educating medical trainees really understand SA, and how do they pragmatically approach the teaching and assessment of SA? Without knowing how (and whether) anesthesiologists understand SA, and how this influences their teaching and assessment activities, we are missing important information. This study is one of the first to use qualitative methods to explore the perspectives of practicing anesthesiologists.

5.1.1 Understanding SA

Analysis of our interview data revealed that participants felt that SA was an important concept and a valuable skill in anesthesiology, but that they did not explicitly discuss SA in their workplace. They could provide examples of SA from both their professional and personal lives, but lacked confidence in providing a common, working definition of SA. Participants described common barriers to SA along with strategies they used to maintain or increase their SA. SA skill was felt to be a marker of expertise in anesthesiology.

The general agreement regarding the importance of SA in anesthesiology is understandable given that deficiencies in SA are known to relate to critical incidents.[40, 46] Good performance of NTS has been associated with good performance of technical skills in a simulated anesthetic crisis,[124] and better NTS (especially SA) have been associated with fewer surgical errors in the clinical environment.[125, 126] Despite the acknowledged importance of the topic, participants expressed a lack of confidence in providing definitions of SA, but they were able to describe examples which illustrate their understanding of the concept; this likely reflected a "personal knowledge" of SA, indicative of a tacit understanding of SA.[52, 59] Even within the human factors and aviation literature, SA has been described as a "ubiquitous phrase and the frequent topic of research projects even without consensus on its meaning."[7(p.55)] When asked about SA, participants were able to articulate, to varying degrees, the importance of gathering information from the patient and the environment, the necessity of interpreting this information in light of the clinical context, and the significance of being able to anticipate future events. Thus, Endsley's 3 level model of SA appears to be a useful, relatable framework that could provide a shared language for these

anesthesiologists.[1] Endsley's model is commonly cited within the anesthesiology SA literature,[23, 40] but does not yet appear to have entered the collective consciousness of the anesthesiologists in this practice setting. The model represents just one possible theory for conceptualizing SA,[5] but it is one that would likely resonate within this community of anesthesiologists and would likely allow for a richer discussion of SA in practice. Collective familiarity with a model of SA could be encouraged by providing continuing professional development for anesthesiologists in the form of readings or lectures on the topic. In his study of tacit knowledge in the workplace, Eraut suggested that such continuing education might provide "a vocabulary for talking about aspects of …experiences which had been previously difficult to discuss," and would provide theoretical knowledge to help individuals "make sense of their experience."[52(p.120)]

Those participants who did have some familiarity with the modality of simulation appeared to be more comfortable with the terminology of SA and more easily able to discuss the concept of SA in an explicit manner. This comfort with the terminology was also more apparent in the participants who had aviation experience *(*e.g. were either pilots themselves or had participated in patient air transport activities). SA is an integral part of the vocabulary of CRM and NTS frameworks;[127] with a common explicit language and structure for thinking about SA, it is possible that a subset of anesthesiologists with simulation, aviation or similar experience, may be able to be more explicit, and less tacit or intuitive, in their thinking and discussion of the subject of SA. This finding has not been reported in the medical education literature, as there has been little focus to date on how exactly clinical anesthesiologists understand and discuss the topic of SA in the workplace.

As greater numbers of anesthesiologists gain familiarity with simulation through the residency training experiences and via continuing professional education activities,[128, 129] their familiarity with the language of CRM, including SA, will likely evolve. Simulation is now a mandatory part of Canadian anesthesiology residency training, and is being used to evaluate senior anesthesiology resident performance in a summative fashion.[130] As such, we are likely witnessing a time of transition in which SA is moving from a tacit concept to one that is more explicitly understood and discussed. Examples of other concepts in medical education that have undergone a transition from tacit to explicit include professionalism[131-133] and communication skills.[134-136] These topics are now widely acknowledged as important concepts in medical education, and a similar "growing degree of consensus"[137] related to an understanding of SA is not only possible, but likely.

5.1.2 Learning SA

Our participants described learning their own SA skills mostly informally, through their own incremental clinical exposure, from their role models, and through self-reflection on error and near misses. In some cases SA was learned formally and deliberately through simulation. Participants thought that, although some trainees possessed inherently better SA skills, SA was something that could be learned. Participants also expressed that trainees needed to have acquired fundamental anesthesiology knowledge and skills, which they felt had usually occurred by the 3rd postgraduate year, in order to focus on learning SA, but acknowledged that learning about SA likely occurred throughout medical training regardless of level.

The tacit nature of the concept of SA was reflected in our participants' descriptions of their

mostly unplanned and informal learning experiences.[52, 59, 138] Similar to our participants' experiences, Larsson described tacit learning within the specialty of anesthesiology as occurring "through training, experience, and reflection."[139] Our participants' SA learning also reflect theories of social learning, particularly in relation to role modeling.[122] Role modeling is recognized as part of the "informal curriculum" within medical education[60] and our participants described learning SA from role-models (both positive and negative) during their training. In addition to these informal types of learning, participants (especially those who had more recently completed training) also discussed their experiences in learning SA through simulation, where the topic was discussed more explicitly. Through formalized introduction of NTS early on in training, simulation offers a chance to learn about topics like SA in a more deliberate fashion.[140]

Learning experiences related to SA can be complex, and influenced by multiple factors and experiences with other individuals. For example, a mandatory pre-operative briefing is done prior to every surgery, wherein the surgeon, anesthesiologist, nurses and patient run through a checklist in order to share information about the case and discuss any anticipated concerns. Even if a staff anesthesiologist demonstrates positive role modeling through active participation and sharing of SA with other team members, a dismissive attitude from another team member (e.g. surgeon or nurse) regarding the value of the briefing may negatively impact an anesthesiology trainee's learning. Furthermore, a negative role-modeling experience within the briefing may make it less likely that a trainee will choose to speak up, or share SA, with the surgical team later in the case. Simulation may be used to purposively counteract these types of negative learning experiences, for example by providing learners with the opportunity to practice speaking up (and practice sharing SA) in a less intimidating environment.[141]

While our participants were able to discuss some of the ways they had learned SA, they also expressed opinions about the nature of individual SA skills and the extent to which SA could be learned. Some participants thought SA ability was largely intrinsic, but most agreed that training in SA could bring about improvements to a variable extent. The learning trajectory for SA was thought to be different for each individual, but participants generally agreed that midway through a 5-year residency (by at least the 3rd post-graduate year) residents would exhibit increasing skill with SA, at least in the context of routine cases. The development of SA skill was felt to represent one marker of transitioning from being from "junior" to "senior" resident (which parallels the development of expertise),[2] although some "junior" residents can exhibit excellent SA skills early in training. As the level of training progressed, participants expected the trainees' SA skills to be more advanced, especially the higher levels of SA (in particular level 3 SA); it was expected that senior trainees would anticipate problems and make preparations to deal with such problems in advance.

Our participants' beliefs that individuals could learn SA skills and improve their SA is important because if SA is thought to represent a stable, immutable trait, it follows that it would not be a worthwhile endeavour to try to develop SA in trainees. There is evidence that training does improve SA skills,[29, 125] although it has been difficult to show that improvements in SA (and CRM) skills do influence outcomes in either aviation or medicine.[125] Still, SA is a skill that can be addressed through training in attention management, the use of checklists and briefings, information seeking/filtering, self-checking and contingency planning.[29] Participants' beliefs that SA learning required a solid baseline level of knowledge is similar to what has been

described in aviation teaching, where a primary focus on SA "can only be performed once the trainee has demonstrated competence to manage aircraft systems…so that they have sufficient additional capacity to take on… a higher workload."[142(p.21)] Our participants' beliefs regarding the abilities of trainees to improve and acquire SA skills, along with their general agreement that trainees require solid fundamental skills and knowledge before they can focus on learning SA skills, are therefore not unique to anesthesiology,[142] and likely influenced their approaches to teaching SA, which will be discussed below.

5.1.3 Teaching SA

Our participants agreed that it was important to teach SA in anesthesiology, and they used different methods to do so, including talking-aloud (narrating) during patient care activities, describing and demonstrating scanning behaviours, role modeling including using checklists and participation in briefings, debriefing after critical events, and giving learners graduated independence to practice their own SA skills (with varying levels of supervision). Some participants mentioned teaching through explicit discussion of SA during simulation activities. Although many participants highlighted simulation as a teaching tool with no risk of patient harm, some expressed concerns about the inauthenticity of the simulation environment, and the importance of real clinical experience in developing SA. Barriers to teaching SA were discussed, including participants' limited understanding of how exactly to teach it, the time pressure in the operating room and the need to prioritize patient safety above trainees' learning opportunities.

Our participants' descriptions of how they taught SA appeared to be reflective of a "cognitive

apprenticeship" model, which aims to make tacit concepts more explicit through the following teaching strategies: modeling, coaching, scaffolding, articulation, reflection, and exploration.[67, 68] While participants described using one or more of these strategies to teach SA, it appeared that they did this intuitively, without referencing a model or framework underlying their teaching methods. Ong et al.[72] found that surgeons similarly used teaching methods that aligned with the cognitive apprenticeship model while providing clinical (intraoperative) teaching; however while the surgeons used modeling, coaching and scaffolding effectively, they did not tend to use the methods of articulation, reflection, or exploration to teach their trainees. The cognitive apprenticeship model is one that might help teachers in anesthesiology recognize and name the methods they are using to teach the tacit concept of SA, and thus might help them to be more explicit and intentional in their teaching of SA.

In contrast to the clinical teaching environment, simulation was mentioned as a teaching method where SA skills were explicitly introduced and practiced, without risk of patient harm. Simulation is now frequently integrated into anesthesiology residency NTS teaching curricula.[143] There is some evidence that CRM skills (which include SA) taught using simulation do transfer to clinical settings.[144, 145] While the anesthesiologists we interviewed appeared to accept and endorse simulation as a teaching tool, they also raised concerns about the modality, including the lack of authentic interpersonal interactions and non-verbal cues in simulations, that would be present in true clinical situations. They also felt that the trainees' heightened alertness in the context of knowing some critical event would likely occur influenced their SA during simulation. Participants did not feel that simulation would replace clinical experience in terms of SA teaching; exposures to patients in an actual clinical context, and authentic interaction with

colleagues and patients, were mentioned as important experiences in cultivating SA, in addition to simulation. The use of interprofessional simulation, with a focus on authentic interpersonal interaction, may mitigate some of the concerns our participants expressed regarding the use of simulation to teach SA and other NTS.[64, 146] A focus on real-world clinical experience, as emphasized within the cognitive apprenticeship model,[67] must be balanced with the new reality that time spent in the clinical environment may become more limited with CBME programs in anesthesiology. Additionally, the use of simulation mitigates some of the barriers that our participants identified regarding SA teaching, namely concerns for patient safety, and the time pressure experienced in the operating room.[147, 148] Simulation is also increasingly being used in the assessment of trainees' technical and non-technical skills,[130] although assessment of SA through simulation was not a focus of our participants' discussions of SA assessment, as outlined below.

5.1.4 Assessment of SA

With regard to assessment of SA, our participants described evaluating their trainees' skills in gathering and interpreting information, along with how well they could anticipate possible future events. Some participants used real-time questioning probes in a SAGAT-like fashion, although they were not formally aware of this assessment tool. Participants found SA challenging to assess, given the internal nature of the process. Often SA assessment was a gestalt process, and participants used their judgements of their trainee's SA ability in order to make decisions about trusting them or allowing them clinical independence. Despite the important consequences of SA assessments, participants found it difficult to give feedback on SA to trainees and worried that the feedback would be taken as personal criticism.

Researchers have been developing various tools to measure SA since the 1980s.[10, 77, 149] Assessment tools like the SAGAT and the ANTS behavioural system are most often used in the context of the simulated environment;[57, 78, 79, 127, 150] and there has been less focus on how these type of assessments of SA have been used in the clinical environment.[81] While our participants tended to discuss the use of simulation for learning and teaching of SA, they did not emphasize the role of simulation in the assessment of SA; rather, they focused on assessments of their trainees' SA ability within the clinical context. Our participants did not describe using any formal tools to evaluate residents' SA in the clinical teaching setting. Some described SAGAT-like questioning behaviours although the use of the technique was intuitive. Assessments of SA were often described as "gestalt", informal assessments. Participants repeatedly described trainees struggling with SA as those "who just didn't get it." Without being able to identify where the trainee was struggling (was it, in fact, a lack of SA that was the problem, and was it the perception, comprehension, or anticipation of an event that was problematic for the trainee?), participants could not provide specific, justifiable, and actionable feedback to trainees. Furthermore, participants indicated that they did not feel that they could trust trainees whom they judged to have poor SA, and they did not feel comfortable leaving these trainees alone with patients in the operating room. The idea of clinical trust and entrustment is important in CBME,[151] along with a focus on observation and assessment of trainees.[85] Since it appears that entrustment decisions were being made, often implicitly, at least in part based on assessments of SA, we need to know more about how SA is being assessed as a competency. Resources which have been developed to specifically identify aspects of competency in NTS and SA[152] might help to clarify such judgements.

While participants agreed that SA must be assessed, and that such assessment would be valuable for trainees, they found it difficult to provide trainees with feedback on their SA. Participants expressed concern that negative feedback on SA would be received as personal criticism, and would be dismissed by the trainee as simply a difference of opinion or practice style. These concerns are similar to those expressed by physician preceptors interviewed by Watling et al.,[153] who articulated their fears that trainees are poorly receptive to negative feedback. Preceptors also expressed concern about harming trainees with their feedback.[153] Our participants expressed these types of concerns regarding giving SA feedback, especially if that feedback was negative, as they worried that trainees might perceive a lack of either credibility or constructiveness in the feedback,[154] given that participants themselves admitted to difficulty with verbalizing the construct of SA.

5.2 Implications for education

The shift towards CBME in residency has prompted a call to make the implicit parts of medical practice more explicit.[53, 85, 155, 156] The specialty of anesthesiology is experiencing a time of transition; within the context studied in this research, anesthesiologists recognized the importance of SA to safe and expert practice, but appeared to lack a common working definition of SA which might inform teaching and assessment practices. Anesthesiologists have looked to aviation training as a model of explicit and deliberate SA teaching and assessment,[3] and even aviation experts have acknowledged the tacit nature of SA and NTS, given that "traditionally [human factors] have been associated with airmanship or just plain common sense; and knowledge was gained through experience and a process of infusion."[142(p.8)] However, now that

SA training in mandatory in aviation, that implicit or tacit understanding of SA has evolved to include a common language to explicitly discuss and train this concept. Physicians and anesthesiologists appear to be working towards becoming more deliberate in discussing, teaching and assessing SA as well. An example of more explicit acknowledgement of SA within medical education and CBME is the inclusion of SA in CanMEDS 2015 as a specific competency within the medical expert role (milestone 5.2): "Adopt strategies that promote patient safety and address human and system factors."[157] Specifically, trainees within the "transition to discipline" stage are expected to be able to "describe the principles of situational awareness and their implications for medical practice."[157] Within the "core of discipline" stage, trainees must "apply the principles of situational awareness to clinical practice."[157] The progression of SA skills is being acknowledged as part of the transition from novice to expert medical practitioner.[2, 157]

Recent changes within the assessment culture in our study context also point to a transition in recognition of the importance of SA. In early 2017 (after the completion of all the data collection for this study), the daily assessment forms for anesthesiology residents were changed to include specific evaluation of "situational awareness" in addition to other competencies like communication, team collaboration, critical thinking, organization, and technical skills. This may represent a shift in how the concept of SA is being acknowledged by medical educators in Calgary. Furthermore, anesthesiologists must now consider SA explicitly during resident evaluation (regardless of their own underlying understanding of the construct), and residents are now receiving feedback specifically on SA, on a daily basis. However, it is still unclear how exactly the feedback on SA in this context is being generated, how specific or actionable it is, and how it is being used. Despite these unknowns and challenges associated with changes in

assessment of SA, it is quite possible that if the data collection for this study were to occur at the present time, the views of participants and findings of the study would be different, as acknowledgement of the concept has changed.

One of the tensions in teaching SA, as articulated by our participants, was the dilemma of how to provide the trainee with the opportunity and time to exercise clinical SA (especially Endsley's levels 2 and 3) versus the requirement to maintain patient safety. This problem has previously been articulated within the context of CBME: "Although no one would dispute that patient safety is of paramount importance, members of the profession also have a responsibility to the professional formation of learners."[85] For example, if an anesthesiologist supervising a trainee noticed that the patient's oxygen saturation had decreased, but the trainee did not perceive this, how long could the supervisor wait to intervene? Would it be safe and reasonable to allow the trainee to notice the drop in oxygen saturation (level 1 SA), come up with a differential diagnosis (level 2 SA) and intervene to correct the problem? The conservative answer would be that patient safety supersedes the trainee's opportunity to develop their SA in the clinical environment. The liberal view would be that trainees must be allowed, at some point, to "struggle" and be forced to work through a problem. Our study respondents articulated this concern in teaching SA, and then often discussed using simulation as a possible SA teaching modality that eliminates the issue of maintaining patient safety. It appears that both simulation experiences and authentic clinical exposures to patients will be necessary to optimize SA teaching going forward.

As previously discussed, other formerly tacit topics in medical education have received more explicit acknowledgement in the medical education curriculum, and lessons from faculty

development to improve teaching and assessment of such topics may provide insights for SA education.[158] Zeidner et al.[158] have suggested basing any teaching intervention "on a solid theoretical framework, permitting a clear definition" of the concept; specifying program goals and behavioural outcomes; identifying the appropriate educational and developmental context for teaching (i.e. considering the resident's level of training); integrating teaching throughout the curriculum (i.e. not limiting teaching to simulation, but including the clinical environment explicitly); generalization of skills to other contexts (i.e. encouraging practice of SA skills in a non-clinical context); providing professional development for teachers; and creating robust assessment programs. All of these strategies would also be useful for programmatic and faculty development related to SA. Strategies for faculty development for CBME, discussed specifically within the context of anesthesiology,[156] include focusing on further education for faculty regarding the topics they are expected to teach trainees (e.g. explaining SA using Endsley's model), but also developing their teaching skills related to those topics (e.g. introducing faculty to the cognitive apprenticeship model) and assessment activities (e.g. providing training on the ANTS behavioural marker system). These interventions could help change the nature of current gestalt, non-specific assessments described by our study participants, to more actionable, specific feedback on SA for trainees.

5.3 Future research directions

While the results of our analysis have increased our appreciation of how our study participants pragmatically understand SA, and how they learn, teach and assess SA, there are many questions that remain. Which educational activities and experiences would accelerate the learning of SA in trainees? What are the most effective ways to teach SA, using simulation and real clinical

experiences? How do we define competency in SA, and is there an agreed-upon level of competency in SA skills for anesthesiologists? How can we improve the quality of SA assessment in our educational environment?

The findings from the current study may help shape future research into the topic of SA in anesthesiology. Possible future research includes exploring whether SA is indeed a tacit concept in other Canadian anesthesiology training programs, along with how the concept has evolved in these educational settings. Other approaches to teaching and assessment of SA in different programs could be contrasted with the methods reported in this study. Since there are advantages and disadvantages to using simulation in the teaching of SA, it would be useful to explore the integration of simulation and clinical experiences for SA learning and teaching, particularly in the context of CBME.

While it was not possible to interview trainees in this current study, the logical next step in expanding our understanding of SA in anesthesiology would be to examine the perceptions and experiences of trainees. Furthermore, residents might be able to share their insights into how their SA has evolved during training, compared with their baseline abilities. Since trainees are continually progressing through various stages of learning and competence, it is possible that they might have reflected more deliberately on their changing skills in SA, and might be able to articulate these thoughts more clearly than anesthesiologists who completed their training long ago. A collaborative approach between preceptors and trainees in researching SA would likely yield richer, more useful data related to SA learning, teaching and assessment.

Since our study has identified the lack of a shared operational definition for SA amongst faculty members, along with concerns regarding assessment and feedback related to SA, interventions focusing on faculty development will likely be undertaken, and these should be evaluated over time. Examples of future projects might include the development of workshops or educational rounds for teachers and assessors of SA, and training in the use of assessment tools like ANTS or SAGAT. Established curriculum development frameworks, like Kern's 6 step model,[159] could guide faculty development projects, and provide direction for dissemination of such work.

5.4 Strengths and limitations

While this study has offered some insights into SA in anesthesiology, there are a number of limitations. We looked at only one practice setting at a single point in time. It might be difficult to generalize the findings to a different context, as each anesthesiology training program has its own unique educational culture. However, since the focus of this study was to pragmatically study SA with the aim of improving SA education within our program, this was a practical and rational approach. Additionally, much of the discussion in this study focused on individual SA, not on team or distributed SA. While team and distributed SA are undoubtedly important, the reality is that we teach and assess our trainees on an individual basis, and therefore a focus on individual SA was quite appropriate as a means of exploring the concept in this context.

With regard to data analysis, I did much of the coding for this project, with the risk of bringing my own biases into the coding, including my views on SA, my knowledge of the existing literature, and my own clinical and simulation experiences related to SA in anesthesiology training and practice. This was mitigated by the fact that all members of the study team

reviewed all the transcripts, actively coded several of these transcripts each, and that regularly meetings were held to discuss and debate emerging ideas and themes. Furthermore, I recoded transcripts after a thorough team discussion of the codebook, in order to increase the rigor in the study. My own experiences in anesthesiology, and my understanding of language and jargon that is often used professionally, likely aided in communication with the research participants, providing insider access to discussion that likely yielded even richer, more detailed data than an non-anesthesiologist would have been able to obtain during the interview process.

As I was intimately involved at the time of the study with coordinating the formal educational program for our residents, as well sitting on the residency training committee, it was not appropriate for me to perform one-on-one interviews with residents, and I was not able to elicit their thoughts and points of view on SA in anesthesiology. It would be very important to explore the trainee perspective of SA, and the current study will provide a useful basis for future research into this topic.

5.5 Conclusions

The participating anesthesiologists in this study did appear to understand SA, although a commonly used operational definition was lacking, as were formal or regular discussions of SA within the workplace. Although SA was clearly relevant and important to the specialty, it remained a somewhat tacit and nebulous concept in this anesthesiology setting. Existing theoretical models could be used more deliberately to provide anesthesiologists with a deeper understanding of the concept of SA, and a common language with which to approach discussion with trainees; in particular, Endsley's three-level model appeared to best reflect how our

respondents understood SA. The teaching of SA described by our participants reflected aspects of a cognitive apprenticeship model, and faculty development to share this model might help make teachers more aware of the methods being used to teach SA, which in turn might make their teaching of SA more deliberate. While simulation was discussed as an important educational modality that could be used to explicitly introduce the concept of SA, and to allow development of SA skills without the risk of patient harm, authentic clinical experience was felt to be vital for SA learning and teaching. The optimal incorporation of both simulated and true clinical experiences related to SA will require careful reflection as the CBME paradigm is realized in anesthesiology training. Assessment of SA must become more explicit and deliberate (particularly in the context of CBME) since judgments about SA appeared to form part of entrustment decisions made by anesthesiologists in this setting. Faculty development is needed so that SA may be discussed, taught, and assessed more explicitly in anesthesiology training.

References

1. Endsley MR. Theoretical underpinnings of situation awareness: a critical review. In: Endsley MR, Garland DJ, editors. *Situation awareness analysis and measurement*. Mahway: Lawrence Erlbaum Associates; 2000. p. 3-32.
2. Endsley MR. Expertise and situation awareness. In: Ericsson KA, Charness N, Feltovich PJ, Hoffman RR, editors. *The Cambridge handbook of expertise and expert performance*. Cambridge: Cambridge University Press; 2006. p. 633-511.
3. Gaba DM, Howard SK, Small SD. Situation awareness in anesthesiology. *Human Factors*. 1995;37(1):20-31.
4. Fletcher GC, McGeorge P, Flin RH, Glavin RJ, Maran NJ. The role of non-technical skills in anaesthesia: a review of current literature. *British Journal of Anaesthesia*. 2002;88(3):418-29.
5. Stanton NA, Chambers PR, Piggott J. Situational awareness and safety. *Safety Science*. 2001;39(3):189-204.
6. Gilson R. Special Issue Preface. *Human Factors*. 1995;37(1):3-4.
7. Sarter NB, Woods DD. Situation awareness: a critical but ill-defined phenomenon. *The International Journal of Aviation Psychology*. 1991;1(1):45-57.
8. Endsley MR. Design and evaluation for situation awareness enhancement. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. 1988;32(2):97-101.
9. Endsley MR. Toward a theory of situation awareness in dynamic systems. *Human Factors*. 1995;37(1):32-64.
10. Salas E, Prince C, Baker DP, Shrestha L. Situation awareness in team performance: implications for measurement and training. *Human Factors*. 1995;37(1):123-36.

11. Adams MJ, Tenney YJ, Pew RW. Situation awareness and the cognitive mangement of complex systems. *Human Factors*. 1995;37(1):85-104.

12. Parush A, Campell C, Hunter A, Ma C, Calder L, Worthington J, et al. *Situational Awareness and Patient Safety*. Ottawa: The Royal College of Physicians and Surgeons of Canada; 2011 [cited 2017 February 21]. Available from: http://www.ottawahospital.on.ca/wps/portal/Base/TheHospital/QualityAndSafety/PatientSafety/SituationalAwarenessPatientSafety.

13. Green B, Parry D, Oeppen RS, Plint S, Dale T, Brennan PA. Situational awareness - what it means for clinicians, its recognition and importance in patient safety. *Oral Diseases* [Internet]. 2016 Jul 22:1-5. doi:10.1111/odi.12547

14. Flach JM. Situation Awareness: Proceed with Caution. *Human Factors*. 1995;37(1):149-57.

15. Hoffman R. Origins of situation awareness: cautionary tales from the history of concepts of attention. *Journal of Cognitive Engineering and Decision Making*. 2015;9(1):73-83.

16. Patrick J, Morgan PL. Approaches to understanding, analysing and developing situation awareness. *Theoretical Issues in Ergonomics Science*. 2010;11(1-2):41-57.

17. Anonymous. Summary of the various definitions of situation awareness [Internet]. London: Royal Aeronautical Society Human Factors Group. Date Unknown [cited 2017 February 26]. Available from: http://www.raes-hfg.com/crm/reports/sa-defns.pdf.

18. Smith K, Hancock PA. Situation awareness is adaptive, externally directed consciousness. *Human Factors*. 1995;37(1):137-48.

19. Bedny G, Meister D. Theory of activity and situation awareness. *International Journal of Cognitive Ergonomics*. 1999;3(1):63-72.

20. Klein G. Analysis of situation awareness from critical incident reports. In: Endsley MR, Garland DJ, editors. *Situation awareness analysis and measurement*. Mahway: Lawrence Erlbaum Associates; 2000. p. 51-73.

21. Salmon PM, Stanton NA, Walker GH, Baber C, Jenkins DP, McMaster R, et al. What really is going on? Review of situation awareness models for individuals and teams. *Theoretical Issues in Ergonomics Science*. 2008;9(4):297-323.

22. Flin R, Patey R, Glavin R, Maran N. Anaesthetists' non-technical skills. *British Journal of Anaesthesia*. 2010;105(1):38-44.

23. Schulz CM, Endsley MR, Kochs EF, Gelb AW, Wagner KJ. Situation awareness in anesthesia concept and research. *Anesthesiology*. 2013;118(3):729-42.

24. Vannucci A, Kras JF. Decision making, situation awareness, and communication skills in the operating room. *International Anesthesiology Clinics*. 2013;51(1):105-27.

25. Endsley MR, Bolstad CA. Individual differences in pilot situation awareness. *The International Journal of Aviation Psychology*. 1994;4(3):241-64.

26. Parush A, Kramer C, Foster-Hunt T, Momtahan K, Hunter A, Sohmer B. Communication and team situation awareness in the OR: implications for augmentative information display. *Journal of Biomedical Informatics*. 2011;44(3):477-85.

27. Fioratou E, Flin R, Glavin R, Patey R. Beyond monitoring: distributed situation awareness in anaesthesia. *British Journal of Anaesthesia*. 2010;105(1):83-90.

28. Salmon PM, Stanton NA, Walker GH, Jenkins DP. *Distributed situation awareness: advances in theory, measurement and application to teamwork*. Aldershot: Ashgate Publishing, Ltd; 2009.

29. Endsley MR, Robertson MM. Training for situation awareness in individuals and teams. In: Endsley M, Garland DJ, editors. *Situation awareness analysis and measurement*. Mahway: Lawrence Erlbaum Associates; 2000. p. 349-66.

30. Bleakley A, Allard J, Hobbs A. 'Achieving ensemble': communication in orthopaedic surgical teams and the development of situation awareness-an observational study using live videotaped examples. *Advances in Health Sciences Education*. 2013;18(1):33-56.

31. World Health Organization. WHO surgical safety checklist [Internet]. Geneva: World Health Organization. 2009 [cited 2017 March 16]. Available from: http://www.who.int/patientsafety/safesurgery/checklist/en/.

32. Haynes AB, Weiser TG, Berry WR, Lipsitz SR, Breizat AH, Dellinger EP, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. *New England Journal of Medicine*. 2009;360(5):491-9.

33. Gordon M, Darbyshire D, Baker P. Non-technical skills training to enhance patient safety: a systematic review. *Medical Education*. 2012;46(11):1042-54.

34. Fletcher G, Flin R, McGeorge P, Glavin R, Maran N, Patey R. Anaesthetists' Non-Technical Skills (ANTS): evaluation of a behavioural marker system. *British Journal of Anaesthesia*. 2003;90(5):580-8.

35. Flin R, Glavin R, Maran N, Patey R. *Anaesthetists' Non-Technical Skills (ANTS) System Handbook v1.0* [e-book]. Aberdeen: University of Aberdeen; 2012 [cited 2017 February 2]. Available from: https://www.abdn.ac.uk/iprc/documents/ANTS Handbook 2012.pdf

36. Blum RH, Boulet JR, Cooper JB, Muret-Wagstaff SL. Simulation-based assessment to identify critical gaps in safe anesthesia resident performance. *Anesthesiology*. 2014;120(1):129-41.

37. Morgan PJ, Kurrek MM, Bertram S, LeBlanc V, Przybyszewski T. Nontechnical skills assessment after simulation-based continuing medical education. *Simulation in Healthcare: Journal of the Society for Simulation in Healthcare*. 2011;6(5):255-9.

38. Arora S, Miskovic D, Hull L, Moorthy K, Aggarwal R, Johannsson H, et al. Self vs expert assessment of technical and non-technical skills in high fidelity simulation. *American Journal of Surgery*. 2011;202(4):500-6.

39. Bahl R, Murphy DJ, Strachan B. Non-technical skills for obstetricians conducting forceps and vacuum deliveries: qualitative analysis by interviews and video recordings. *European Journal of Obstetrics & Gynecology and Reproductive Biology*. 2010;150(2):147-51.

40. Schulz CM, Krautheim V, Hackemann A, Kreuzer M, Kochs EF, Wagner KJ. Situation awareness errors in anesthesia and critical care in 200 cases of a critical incident reporting system. *BMC Anesthesiology* [Internet]. 2016; 16(1):1-10. doi:10.1186/s12871-016-0172-7

41. Smith AF, Glavin R, Greaves JD. Defining excellence in anaesthesia: the role of personal qualities and practice environment. *British Journal of Anaesthesia*. 2011;106(1):38-43.

42. Flin RH, O'Connor P, Crichton M. Situation Awareness. In: Flin RH, O'Connor P, Crichton M, editors. *Safety at the sharp end: a guide to non-technical skills*. Aldershot: Ashgate Publishing Ltd.; 2008. p. 17-41.

43. Singh H, Petersen LA, Thomas EJ. Understanding diagnostic errors in medicine: a lesson from aviation. *Quality & Safety in Health Care*. 2006;15(3):159-64.

44. Parker WH, Johns A, Hellige J. Avoiding complications of laparoscopic surgery: lessons from cognitive science and crew resource management. *Journal of Minimally Invasive Gynecology*. 2007;14(3):379-88.

45. Panesar SS, Carson-Stevens A, Mann BS, Bhandari M, Madhok R. Mortality as an indicator of patient safety in orthopaedics: lessons from qualitative analysis of a database of medical errors. *BMC Musculoskeletal Disorders* [Internet]. 2012 Jun 08; 13:93-101. doi:10.1186/1471-2474-13-93

46. Uramatsu M, Fujisawa Y, Mizuno S, Souma T, Komatsubara A, Miki T. Do failures in non-technical skills contribute to fatal medical accidents in Japan? A review of the 2010-2013 national accident reports. *BMJ Open* [Internet]. 2017 Feb 16; 7(2):e013678. doi:10.1136/bmjopen-2016-013678

47. Sculli GL, Fore AM, Neily J, Mills PD, Sine DM. The case for training Veterans Administration frontline nurses in crew resource management. *The Journal of Nursing Administration*. 2011;41(12):524-30.

48. Hinton J. Artificial experience: situation awareness training in nursing [Dissertation]. Minneapolis: Capella University; 2011.

49. Hogan MP, Pace DE, Hapgood J, Boone DC. Use of human patient simulation and the situation awareness global assessment technique in practical trauma skills assessment. *Journal of Trauma-Injury Infection & Critical Care*. 2006;61(5):1047-52.

50. Sitterding MC, Broome ME, Everett LQ, Ebright P. Understanding situation awareness in nursing work: a hybrid concept analysis. *Advances in Nursing Science*. 2012;35(1):77-92.

51. Tower M, Chaboyer W. Situation awareness and documentation of changes that affect patient outcomes in progress notes. *Journal of Clinical Nursing*. 2014;23(9-10):1403-10.

52. Eraut M. Non-formal learning and tacit knowledge in professional work. *The British Journal of Educational Psychology*. 2000;70(1):113-36.

53. Larsson J. Monitoring the anaesthetist in the operating theatre - professional competence and patient safety. *Anaesthesia*. 2017;72(Suppl. 1):76-83.

54. Bryson EO. Teaching by Example: Best Practices for Education in the Operating Room and the Lecture Hall. In: Frost E, editor. *Comprehensive Guide to Education in Anesthesia*. New York: Springer; 2014. p. 15-27.

55. Gugerty LJ, Tirre WC. Individual differences in situation awareness. In: Endsley MR, Garland DJ, editors. *Situation awareness analysis and measurement*. Mahway: Lawrence Erlbaum Associates; 2000. p. 249-76.

56. Wright SM, Fallacaro MD. Predictors of situation awareness in student registered nurse anesthetists. *AANA Journal*. 2011;79(6):484-90.

57. Hansel M, Winkelmann AM, Hardt F, Gijselaers W, Hacker W, Stiehl M, et al. Impact of simulator training and crew resource management training on final-year medical students' performance in sepsis resuscitation: a randomized trial. *Minerva Anestesiologica*. 2012;78(8):901-9.

58. Wright MC, Taekman JM, Endsley MR. Objective measures of situation awareness in a simulated medical environment. *Quality & Safety in Health Care*. 2004;13(Suppl. 1):i65-71.

59. Eraut M. Informal learning in the workplace. *Studies in Continuing Education*. 2004;26(2):247-73.

60. Cruess SR, Cruess RL, Steinert Y. Role modelling--making the most of a powerful teaching strategy. *British Medical Journal*. 2008;336(7646):718-21.

61. Graafland M, Schraagen JM, Boermeester MA, Bemelman WA, Schijven MP. Training situational awareness to reduce surgical errors in the operating room. *British Journal of Surgery*. 2015;102(1):16-23.

62. Gregory A, Hogg G, Ker J. Innovative teaching in situational awareness. *The Clinical Teacher*. 2015;12(5):331-5.

63. Lee Chang A, Dym A, Venegas-Borsellino C, Bangar M, Kazzi M, Lisenenkov D, et al. A comparison of simulation training versus classroom-based education in teaching situation awareness: Randomized control study. *Chest*. 2015;148(4):461A.

64. Gordon M, Box H, Halliwell JA, Farrell M, Parker L, Stewart A. Enhancing health care non-technical skills: the TINSELS programme. *The Clinical Teacher*. 2015;12(6):413-7.

65. Blackwood J, Duff JP, Nettel-Aguirre A, Djogovic D, Joynt C. Does teaching crisis resource management skills improve resuscitation performance in pediatric residents? *Pediatric Critical Care Medicine* [Internet]. 2014 May; 15(4):E168-E74. doi:10.1097/PCC.0000000000000100

66. Dedy NJ, Bonrath EM, Zevin B, Grantcharov TP. Teaching nontechnical skills in surgical residency: a systematic review of current approaches and outcomes. *Surgery*. 2013;154(5):1000-8.

67. Collins A, Brown JS, Holum A. Cognitive apprenticeship: making thinking visible. *American Educator*. 1991;15(3):6-11.

68. Lyons K, McLaughlin JE, Khanova J, Roth MT. Cognitive apprenticeship in health sciences education: a qualitative review. *Advances in Health Sciences Education: Theory and Practice* [Internet]. 2016 Aug 20:1-17. doi:10.1007/s10459-016-9707-4

69. Bass EJ, Ernst-Fortin ST, Duncan PC, editors. An intelligent debriefing system for situation awareness training. *FLAIRS Conference*; 1998; Sanibel Island, Florida.

70. Gavriel J. Cognitive apprenticeship. *Education for Primary Care*. 2015;26(6):422-3.

71. Stalmeijer RE, Dolmans DH, Snellen-Balendong HA, van Santen-Hoeufft M, Wolfhagen IH, Scherpbier AJ. Clinical teaching based on principles of cognitive apprenticeship: views of experienced clinical teachers. *Academic Medicine*. 2013;88(6):861-5.

72. Ong CC, Dodds A, Nestel D. Beliefs and values about intra-operative teaching and learning: a case study of surgical teachers and trainees. *Advances in Health Sciences Education: Theory and Practice*. 2016;21(3):587-607.

73. Flin R, Yule S, Paterson-Brown S, Maran N, Rowley D, Youngson G. Teaching surgeons about non-technical skills. *The Surgeon: Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland*. 2007;5(2):86-9.

74. St-Martin L, Patel P, Gallinger J, Moulton CA. Teaching the slowing-down moments of operative judgment. *The Surgical Clinics of North America*. 2012;92(1):125-35.

75. Yule S, Parker SH, Wilkinson J, McKinley A, MacDonald J, Neill A, et al. Coaching Non-technical Skills Improves Surgical Residents' Performance in a Simulated Operating Room. *Journal of Surgical Education*. 2015;72(6):1124-30.

76. Pew RW. The state of situation awareness measurement: heading towards the next century. In: Endsley M, Garland DJ, editors. *Situation awareness analysis and measurement*. Mahway: Lawrence Erlbaum Associates; 2000. p. 33-51.

77. Endsley MR, Selcon SJ, Hardiman TD, Croft DG. A comparative analysis of SAGAT and SART for evaluations of situation awareness. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. 1998;42(1):82-6.

78. Morgan P, Tregunno D, Brydges R, Pittini R, Tarshis J, Kurrek M, et al. Using a situational awareness global assessment technique for interprofessional obstetrical team training with high fidelity simulation. *Journal of Interprofessional Care*. 2015;29(1):13-9.

79. Crozier MS, Ting HY, Boone DC, O'Regan NB, Bandrauk N, Furey A, et al. Use of human patient simulation and validation of the Team Situation Awareness Global Assessment Technique (TSAGAT): a multidisciplinary team assessment tool in trauma education. *Journal of Surgical Education*. 2015;72(1):156-63.

80. Jones DG. Subjective measures of situation awareness. *Situation awareness analysis and measurement*. Mahway: Lawrence Erlbaum Associates; 2000. p. 113-28.

81. Byrne A, Turner M, Lewis E, Murphy A, Chawathe MP, Thomas P. Training for non-technical skills measurement. *Anaesthesia*. 2015;70(3):368-9.

82. Graham J, Hocking G, Giles E. Anaesthesia non-technical skills: Can anaesthetists be trained to reliably use this behavioural marker system in 1 day? *British Journal of Anaesthesia*. 2010;104(4):440-5.

83. Zhang Y, Drews F, Westenskow DR, Foresti S, Agutter J, Bermudez JC, et al. Effects of integrated graphical displays on situation awareness in anaesthesiology. *Cognition, Technology & Work*. 2002;4(2):82-90.

84. Wauben LS, Dekker-van Doorn CM, van Wijngaarden JD, Goossens RH, Huijsman R, Klein J, et al. Discrepant perceptions of communication, teamwork and situation awareness among surgical team members. *International Journal for Quality in Health Care*. 2011;23(2):159-66.

85. Carraccio C, Englander R, Van Melle E, Ten Cate O, Lockyer J, Chan MK, et al. Advancing competency-based medical education: a charter for clinician-educators. *Academic Medicine*. 2016;91(5):645-9.

86. Kennedy TJ, Lingard LA. Making sense of grounded theory in medical education. *Medical Education*. 2006;40(2):101-8.

87. Bowen GA. Grounded theory and sensitizing concepts. *International Journal of Qualitative Methods*. 2006;5(3):12-23.

88. Corbin JM, Strauss AL. *Basics of qualitative research : techniques and procedures for developing grounded theory*. 3rd ed. Los Angeles: Sage Publications; 2008.

89. Creswell JW, Creswell JW. *Qualitative inquiry & research design : choosing among five approaches*. 3rd ed. Thousand Oaks: Sage Publications; 2013.

90. Charmaz K. *Constructing grounded theory: a practical guide through qualitative analysis*. London: Sage Publications; 2006.

91. Breckenridge J, Jones D, Elliott I, Nicol M. Choosing a methodological path. *Grounded Theory Review: An International Journal* [Internet]. 2012 [cited 2017 April 15]; 11(1). Available from: http://groundedtheoryreview.com/2012/06/01/choosing-a-methodological-path-reflections-on-the-constructivist-turn/

92. Watling CJ, Lingard L. Grounded theory in medical education research: AMEE Guide No. 70. *Medical Teacher*. 2012;34(10):850-61.

93. Watling C, Driessen E, van der Vleuten CP, Lingard L. Learning culture and feedback: an international study of medical athletes and musicians. *Medical Education*. 2014;48(7):713-23.

94. Watling CJ, Kenyon CF, Zibrowski EM, Schulz V, Goldszmidt MA, Singh I, et al. Rules of engagement: residents' perceptions of the in-training evaluation process. *Academic Medicine*. 2008;83(Suppl. 10):S97-100.

95. Watling C, Driessen E, van der Vleuten CP, Lingard L. Learning from clinical work: the roles of learning cues and credibility judgements. *Medical Education*. 2012;46(2):192-200.

96. Braun V, Clarke V. *Successful qualitative research: A practical guide for beginners*. London: Sage Publications; 2013.

97. Braun V, Clarke V. Using thematic analysis in psychology. *Qualitative Research in Psychology*. 2006;3(2):77-101.

98. Braun V, Clarke V. What can "thematic analysis" offer health and wellbeing researchers? *International Journal of Qualitative Studies on Health and Well-being* [Internet]. 2014 [cited 2017 April 2]; 9:26152. doi:10.3402/qhw.v9.26152

99. Braun V, Clarke V, Terry G. Thematic analysis. In: Rohleder P, Lyons AC, editors. *Qualitative research in clinical and health psychology*. Basingstoke: Palgrave Macmillan; 2014. p. 95-113.

100. Green J, Thorogood N. Qualitative methodology and health research. In: Green J, Thorogood N, editors. *Qualitative Methods for Health Research*. 3rd ed. London: Sage Publications; 2014. p. 3-34.

101. Dicicco-Bloom B, Crabtree BF. The qualitative research interview. *Medical Education*. 2006;40(4):314-21.

102. Statistics Canada. Population of census metropolitan areas: Statistics Canada. 2016 [cited 2017 March 9]. Available from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo05a-eng.htm.

103. Eng R. Residency Training Program Manual Calgary: Department of Anesthesiology. 2015 [cited 2016 December 1]. Available from: http://cumming.ucalgary.ca/pgme/files/pgme/program-manual-2015-16-jun-18-2015.pdf.

104. Pearce C. Department of Anesthesia Annual Report. Calgary: University of Calgary; 2015.

105. ACUDA. National curriculum for Canadian anesthesiology residency [Internet]. Ottawa: The Royal College of Physicians and Surgeons of Canada; 2014 [cited 2017 September 11]. Available from: https://www.mcgill.ca/anesthesia/files/anesthesia/national_curriculum_2014_8.pdf.

106. The Royal College of Physicians and Surgeons of Canada. Specific standards of accreditation for residency programs in anesthesiology [Internet]. Ottawa: The Royal College of Physicians and Surgeons of Canada; 2012 [cited 2017 April 20]. Available from: http://www.royalcollege.ca/cs/idcplg?IdcService=GET_FILE&dID=227.

107. Guest G, Bunce A, Johnson L. How Many Interviews Are Enough?: An Experiment with Data Saturation and Variability. *Field Methods*. 2006;18(1):59-82.

108. Hennink MM, Kaiser BN, Marconi VC. Code saturation versus meaning saturation: how many interviews are enough? *Qualitative Health Research*. 2016;27(4):591-608.

109. Lincoln YS, Guba EG. *Naturalistic inquiry*. Beverly Hills: Sage Publications; 1985.

110. Morse JM. Critical analysis of strategies for determining rigor in qualitative inquiry. *Qualitative Health Research*. 2015;25(9):1212-22.

111. Krefting L. Rigor in qualitative research: the assessment of trustworthiness. *American Journal of Occupational Therapy*. 1991;45(3):214-22.

112. Glavin R, Flin R. Review article: the influence of psychology and human factors on education in anesthesiology. *Canadian Journal of Anesthesia*. 2012;59(2):151-8.

113. Dobson G, Chong M, Chow L, Flexman A, Kurrek M, Laflamme C, et al. Guidelines to the practice of anesthesia - revised edition 2017. *Canadian Journal of Anesthesia*. 2016;64(1):65-91.

114. Frank JR, Snell L, Sherbino J. *CanMEDS 2015 Physician Competency Framework* [Internet]. Ottawa: The Royal College of Physicians and Surgeons of Canada; 2015 [cited 2017 January 20]. Available from: http://canmeds.royalcollege.ca/uploads/en/framework/CanMEDS 2015 Framework_EN_Reduced.pdf.

115. Flin R, Maran N. Basic concepts for crew resource management and non-technical skills. *Best Practice & Research Clinical Anaesthesiology*. 2015;29(1):27-39.

116. Rutherford JS, Flin R, Irwin A, McFadyen AK. Evaluation of the prototype Anaesthetic Non-technical Skills for Anaesthetic Practitioners (ANTS-AP) system: a behavioural rating system to assess the non-technical skills used by staff assisting the anaesthetist. *Anaesthesia*. 2015;70(8):907-14.

117. Yule S, Paterson-Brown S. Surgeons' non-technical skills. *Surgical Clinics of North America*. 2012;92(1):37-50.

118. Flin R, Mitchell L, McLeod B. Non-technical skills of the scrub practitioner: the SPLINTS system. *ORNAC Journal*. 2014;32(3):33-8.

119. Schulz CM. Situation awareness. In: Ruskin KJ, Stiegler MP, Rosenbaum SH, editors. *Quality and safety in anesthesia and perioperative care.* Oxford: Oxford University Press; 2016.

120. Shelton CL, Kinston R, Molyneux AJ, Ambrose LJ. Real-time situation awareness assessment in critical illness management: adapting the situation present assessment method to clinical simulation. *BMJ Quality & Safety*. 2013;22(2):163-7.

121. Cherry MG, Fletcher I, O'Sullivan H, Dornan T. Emotional intelligence in medical education: a critical review. *Medical Education*. 2014;48(5):468-78.

122. Wong A. Review article: teaching, learning, and the pursuit of excellence in anesthesia education. *Canadian Journal of Anesthesia*. 2012;59(2):171-81.

123. Murray DJ. Current trends in simulation training in anesthesia: a review. *Minerva Anestesiologica*. 2011;77(5):528-33.

124. Riem N, Boet S, Bould MD, Tavares W, Naik VN. Do technical skills correlate with non-technical skills in crisis resource management: a simulation study. *British Journal of Anaesthesia*. 2012;109(5):723-8.

125. McCulloch P, Mishra A, Handa A, Dale T, Hirst G, Catchpole K. The effects of aviation-style non-technical skills training on technical performance and outcome in the operating theatre. *Quality & Safety in Health Care*. 2009;18(2):109-15.

126. Mishra A, Catchpole K, McCulloch P. The Oxford NOTECHS System: reliability and validity of a tool for measuring teamwork behaviour in the operating theatre. *Quality & Safety in Health Care*. 2009;18(2):104-8.

127. Flin R, Patey R. Non-technical skills for anaesthetists: developing and applying ANTS. *Best Practice & Research Clinical Anaesthesiology*. 2011;25(2):215-27.

128. Lorello GR, Cook DA, Johnson RL, Brydges R. Simulation-based training in anaesthesiology: a systematic review and meta-analysis. *British Journal of Anaesthesia*. 2014;112(2):231-45.

129. Fung L, Boet S, Bould MD, Qosa H, Perrier L, Tricco A, et al. Impact of crisis resource management simulation-based training for interprofessional and interdisciplinary teams: A systematic review. *Journal of Interprofessional Care*. 2015;29(5):433-44.

130. Chiu M, Tarshis J, Antoniou A, Bosma TL, Burjorjee JE, Cowie N, et al. Simulation-based assessment of anesthesiology residents' competence: development and implementation of the Canadian National Anesthesiology Simulation Curriculum (CanNASC). *Canadian Journal of Anesthesia*. 2016;63(12):1357-63.

131. Cruess SR, Cruess RL. Professionalism must be taught. *British Medical Journal*. 1997;315(7123):1674-7.

132. Edelstein SB, Stevenson JM, Broad K. Teaching professionalism during anesthesiology training. *Journal of Clinical Anesthesia*. 2005;17(5):392-8.

133. Kearney RA. Defining professionalism in anaesthesiology. *Medical Education*. 2005;39(8):769-76.

134. Aspegren K. BEME guide no. 2: teaching and learning communication skills in medicine-a review with quality grading of articles. *Medical Teacher*. 1999;21(6):563-70.

135. Knox JD, Bouchier IA. Communication skills teaching, learning and assessment. *Medical Education*. 1985;19(4):285-9.

136. Rees C, Sheard C, McPherson A. Medical students' views and experiences of methods of teaching and learning communication skills. *Patient Education and Counseling*. 2004;54(1):119-21.

137. Wearn A, Wilson H, Hawken SJ, Child S, Mitchell CJ. In search of professionalism: implications for medical education. *New Zealand Medical Journal*. 2010;123(1314):123-32.

138. Polanyi M, Sen A. *The tacit dimension*. University of Chicago Press ed. Chicago: The University of Chicago Press; 2009.

139. Larsson J. Studying tacit knowledge in anesthesiology: a role for qualitative research. *Anesthesiology*. 2009;110(3):443-4.

140. Matveevskii AS, Gravenstein N. Role of simulators, educational programs, and nontechnical skills in anesthesia resident selection, education and competency assessment. *Journal of Critical Care*. 2008;23(2):167-72.

141. Pian-Smith MC, Simon R, Minehart RD, Podraza M, Rudolph J, Walzer T, et al. Teaching residents the two-challenge rule: a simulation-based approach to improve education and patient safety. *Simulation in Healthcare: Journal of the Society for Simulation in Healthcare*. 2009;4(2):84-91.

142. Civil Aviation Safety Authority (AU). Teaching and assessing single-pilot human factors and threat and error management: Civil Aviation Safety Authority. 2008 [cited 2017 March 15]. Available from: https://www.casa.gov.au/files/5591pdf.

143. Krage R, Erwteman M. State-of-the-art usage of simulation in anesthesia: skills and teamwork. *Current Opinion in Anaesthesiology*. 2015;28(6):727-34.

144. Boet S, Bould MD, Fung L, Qosa H, Perrier L, Tavares W, et al. Transfer of learning and patient outcome in simulated crisis resource management: a systematic review. *Canadian Journal of Anesthesia*. 2014;61(6):571-82.

145. Bruppacher HR, Alam SK, LeBlanc VR, Latter D, Naik VN, Savoldelli GL, et al. Simulation-based training improves physicians' performance in patient care in high-stakes clinical setting of cardiac surgery. *Anesthesiology*. 2010;112(4):985-92.

146. Gordon M, Box H, Farrell M, Stewart A. Non-technical skills learning in healthcare through simulation education: integrating the SECTORS learning model and complexity theory. *BMJ Simulation and Technology Enhanced Learning* [Internet]. 2015; 1:67-70. doi:10.1136/bmjstel-2015-000047

147. Price JW, Price JR, Pratt DD, Collins JB, McDonald J. High-fidelity simulation in anesthesiology training: a survey of Canadian anesthesiology residents' simulator experience. *Canadian Journal of Anesthesia*. 2010;57(2):134-42.

148. Leblanc VR. Review article: simulation in anesthesia: state of the science and looking forward. *Canadian Journal of Anesthesia*. 2012;59(2):193-202.

149. Vidulich MA, Stratton M, Crabtree M, Wilson G. Performance-based and physiological measures of situational awareness. *Aviation, Space, and Environmental Medicine*. 1994;65(5 Suppl):A7-12.

150. Dym A, Chang AL, Bangar M, Lisenenkov D, Keene A, Qadir N, et al. Comparison of objective and subjective measurements of situation awareness in simulated emergencies. *Critical Care Medicine*. 2015;43(12):62-3.

151. Ten Cate O, Hart D, Ankel F, Busari J, Englander R, Glasgow N, et al. Entrustment Decision Making in Clinical Training. *Academic Medicine*. 2016;91(2):191-8.

152. Gordon M, Baker P, Catchpole K, Darbyshire D, Schocken D. Devising a consensus definition and framework for non-technical skills in healthcare to support educational design: A modified Delphi study. *Medical Teacher*. 2015;37(6):572-7.

153. Watling CJ, Kenyon CF, Schulz V, Goldszmidt MA, Zibrowski E, Lingard L. An exploration of faculty perspectives on the in-training evaluation of residents. *Academic Medicine*. 2010;85(7):1157-62.

154. Watling C, Driessen E, van der Vleuten CP, Vanstone M, Lingard L. Beyond individualism: professional culture and its influence on feedback. *Medical Education*. 2013;47(6):585-94.

155. Smith A. In search of excellence in anesthesiology. *Anesthesiology*. 2009;110(1):4-5.

156. Fraser AB, Stodel EJ, Jee R, Dubois DA, Chaput AJ. Preparing anesthesiology faculty for competency-based medical education. *Canadian Journal of Anesthesia*. 2016;63(12):1364-73.

157. CanMEDS guide: Medical Expert: Royal College of Physicians and Surgeons of Canada. 2017 [cited 2017 March 25]. Available from: http://canmeds.royalcollege.ca/guide.

158. Zeidner M, Roberts RD, Matthews G. Can emotional intelligence be schooled? A critical review. *Educational Psychologist*. 2002;37(4):215-31.

159. Thomas PA, Kern DE, Hughes MT, Chen BY. *Curriculum development for medical education : a six-step approach*. Third edition. Baltimore: Johns Hopkins University Press; 2016.

APPENDIX A: INTERVIEW GUIDE

Interview questions:

Your experiences with the concept of situation awareness (SA)

1. What is your understanding of the concept of situation awareness?

   Probes:

   - What does the term situation awareness mean to you?
   - If you haven't heard much about situation awareness, what do you believe it refers to in anesthesia practice?

2. How have you encountered the concept of situation awareness?

   Probes:

   - When do you remember first encountering the concept of SA?
   - In what context(s) have you encountered the concept of SA?
   - Are there examples of where you have encountered the concept of SA outside of anesthesiology or the field of medicine?

3. How is the idea of SA relevant to your practice?

   Probes:

   - Can you think of an example in your practice where situation awareness was important, or affected a patient outcome?
   - How has the term come up during discussions with colleagues?
   - Are there are any examples where you may have read about the term "situation awareness"?

4. Is SA a concept that is recognized or acknowledged within your workplace culture?

   Probes:

   - Are there contexts in which your group might discuss SA, for example M+M rounds? Resident teaching sessions? Discussions about residents in difficulty?
   - Can you think of an example where situation awareness was highlighted within your group, either in practice or in discussion?
   - (If interviewee answers "not valued"): Why do you think SA is not valued in your practice group/workplace?

5. What are some of the barriers or challenges to maintaining SA in the clinical environment?

   Probes:

   - The use of technology might compromise SA. How have you encountered this?

6. How do you know if someone has good SA?

   Probes:

   - What are the ways in which you personally assess someone's SA?
   - How should SA be evaluated?

Your understanding of learning SA

7. How do you think situation awareness is learned?

   Probes:

   - What experiences help with the learning of situation awareness?
   - At what point(s) in training does situation awareness learning occur?
   - How do you think context factors into learning SA? Clinical vs. classroom vs. simulation scenario? Explicit or implicit instruction?

8. How have you personally learned about situation awareness?

   Probes:

   - Tell me about a time when situation awareness was important during your training.
   - What role did your residency training play in your learning about situation awareness?

9. What are your thoughts about whether SA is something that everyone can learn?

   Probes:

   - Discuss whether SA is an innate skill or a skill that can be developed.
   - Why might someone argue that you cannot learn situation awareness?

Your thoughts on the teaching of SA

10. How do you personally approach the teaching of situation awareness to learners?

Probes:

- How do you discuss situation awareness with learners?
- Can you tell me about any resources you have used in the teaching of situation awareness to learners?
- Where does the teaching of situation awareness take place during medical training?
- What techniques do you use to teach situation awareness?

11. What do you find to be challenging about teaching situation awareness to learners?

Probes:

- Which learners are more challenging to teach situation awareness (eg: IMGs)?
- What are the challenges or barriers to teaching situation awareness?
- When is it most challenging to teach situation awareness?
- How do you approach the learner who is struggling with situation awareness?
- Why might you choose NOT to teach about situation awareness, if you have a learner?

12. How do you know if learners are able incorporate your teaching of situation awareness into their practice?

Probes:

- Can you think of an example of when you have observed a learner incorporate your teaching into clinical practice?

Your ideas about the teaching environment and its relationship to SA teaching

13. How might we improve the teaching of situation awareness to our learners?

Probes:

- What would you have done differently in your teaching of situation awareness, now that you have had time to reflect upon this issue?
- At what stages of training is teaching of situation awareness most beneficial? Practical?

14. What faculty development would be of benefit to staff anesthesiologists regarding teaching situation awareness?

    Probes:

    - Do you have any thoughts on how to improve the teaching skills of staff anesthesiologists regarding situation awareness?
    - How can faculty improve on providing feedback to learners regarding their situation awareness?

15. Do you have any other thoughts about teaching situation awareness to learners?
16. Is there anything else you would like to discuss?

Demographic data

- Time since completion of anesthesiology training:
- University/Location of participant's anesthesiology residency:
- Participant's main practice site in Calgary:
- Participant's involvement in departmental leadership/residency training committee/programmed resident teaching activities: