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Certified Registered Nurse Anesthetist Performance and Perceptions: Use of a Handheld, Computerized, Decision Making Aid During Critical Events in a High-fidelity Human Simulation Environment

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

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ABSTRACT

CERTIFIED REGISTERED NURSE ANESTHETIST PERFORMANCE AND PERCEPTIONS: USE OF A HANDHELD, COMPUTERIZED DECISION MAKING AID DURING CRITICAL EVENTS IN A HIGH-FIDELITY HUMAN SIMULATION ENVIRONMENT

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With the increasing focus on patient safety and human error, understanding how practitioners make decisions during critical incidents is important. Despite the move towards evidence-based practice, research shows that much decision making is based on intuition and heuristics ("rules of thumb"). The purpose of this study was to examine and evaluate the methodologic feasibility of a strategy for comparing traditional cognition versus the use of algorithms programmed on a personal digital assistant (PDA) in the management of unanticipated critical events by certified registered nurse anesthetists (CRNAs).

A combined qualitative-quantitative methodology was utilized. The quantitative element consists of a pilot study using a cross-over trial design. Two

case scenarios were carried out in a full-scale, high fidelity, simulated anesthesia care delivery environment. Four subjects participated in both scenarios, one without and one with a PDA containing a catalog of approximately 30 events with diagnostic and treatment related information in second scenario. Audio-videotaping of the scenarios allowed for definitive descriptive analysis of items of interest, including time to correct diagnosis and definitive intervention. The qualitative approach consisted of a phenomenological investigation of problem solving and perceptions of PDA use and the simulation experience by the participants using "think aloud" and retrospective verbal reports, semi-structured group interviews, and written evaluations.

Qualitative results revealed that participants found the PDA algorithms useful despite some minor technical difficulties and the simulated environment and case scenarios realistic, but also described feelings of expectation, anxiety, and pressure. Problem solving occurred in a hypothetico-deductive manner. More hypotheses were considered when using the PDA. Time to correct diagnosis and treatment varied by scenario, taking less time with the PDA for one but taking longer with the PDA for the other, likely due to differences in pace and intensity of the two scenarios. The methodologic investigation revealed several areas for improvement including more precise control of case scenarios. All participants agreed with the value of using high fidelity simulation, particularly for problem solving of critical events, and provided useful information for more effective utilization of this tool for education and research.

CHAPTER 1 - INTRODUCTION

Introduction to the Problem

Theories on human problem solving and decision making were developed in an attempt to describe how people use cognitive skills and knowledge. The importance of sound decision making by health care professionals has lead researchers to apply and examine these theories within the field of health care. The concept of intuition and its role in clinical decision making has been investigated as well. With a better understanding of how clinicians solve problems, methods by which to assist and/or enhance diagnostic accuracy have been explored. In addition, the focus on medical error and its human component has led to concern for patient safety and a directive by the Institute of Medicine to enhance knowledge and identify tools to prevent human error and ensure patient safety.

There is a need to identify root causes of threats to patient safety and develop effective systematic approaches to increase accurate problem solving and decision making and prevent the occurrence of errors and misadventures. The advent of computer technology, particularly handheld devices, provides an opportunity for study into the area of computer assisted decision making, with the ultimate goal of improving patient outcomes. The primary purpose of this study was to explore the effect of a computer-

based aid on problem solving by certified registered nurse anesthetists, hence to be referred to as "anesthetists", during critical events in a simulated environment.

Additional areas examined include the problem solving thought processes of anesthetists during these critical events, their perceptions of the use of computer-based aid for problem solving, and their perceptions of the simulation center. Finally, an independent panel of clinician anesthetists reviewed the videotaped scenarios to evaluate the authenticity of the simulated environment.

Background and Problem Statement

Human Error

In its landmark publication, the Institute of Medicine noted the extensive contribution of human error in generating negative patient outcomes (Kohn et al., 1999). A growing concern over medical errors has led to the desire for a better understanding of mental processes and effective methods of predicting and reducing human error in health care. When examining human error, the complex environment in which health care providers function must be considered. Performance of practitioners in complex systems has been described as having blunt end and sharp end factors (Cook & Woods, 1994). The blunt end includes the resources and constraints under which the practitioner functions and the organizational context of the system. The importance of organizational context in system failures is described in detail by Reason (1990). The organizational context of a system influences the physical and cognitive resources available to the practitioner. Those who operate at the blunt end, such as hospital administrators, government regulators, unit managers, system architects, and suppliers of technology, try

to affect safety at the sharp end via resources, constraints, and organizational context. The sharp end encompasses the cognitive processes of the practitioner and his/her direct interaction with the patient. To improve safety in health care, both human performance (the sharp end) and the work environment (the blunt end) must be considered.

Dynamism, time pressure, complexity, variability, and risk are all descriptive of the domain of anesthesia. The shear number of decisions and large variety of technical and drug interventions performed by the anesthetist, often in the setting of time and production pressure, dramatically increases risk of error during the course of care. Both skill-based errors (accidents or execution failures) and knowledge/rule-based errors (mistakes or planning failures) are not uncommon. It is widely acknowledged that the majority of adverse anesthesia-related outcomes (morbidity, mortality, high cost) are inextricably wedded to human error (Cooper, Newbower, Long, & McPeek, 1978; Gaba, 1989). While humans are destined to err, thoughtfully designed and robust systems can minimize the risk of human error and reduce negative patient outcome (Kohn, Corrigan & Donaldson, 1999; Blike & Biddle, 2000). The emphasis should be upon minimizing the human error component, and where possible, extinguishing or attenuating the effects of errors that will invariably occur.

Intuition

In addition to personal knowledge and experience, interventions during anesthesia care may be based upon the practitioner's subjective, intuitive judgment regarding what should be done in the face of a particular clinical challenge. There are several definitions of intuition in the literature. For purposes of this study *intuition* is defined as "the

immediate knowing of something without the conscious use of reasoning" (Guralnick, 1987, p. 320). The intuitive approach is recognized by the academic and clinical nursing communities (Hammond, Kelly, Schneider & Vancini, 1967; Benner & Tanner, 1987; Schraeder & Fischer, 1987; King & Appleton, 1997; Benner, Hooper-Kyriakidis & Stannard, 1999). Benner and Tanner (1987) suggest intuitive judgment is what separates decision making by humans from computers. They also propose an intuitive component in expert versus beginner decision making.

By definition, decision making implies a selection among plausible or competing options. When a case or problem arises that falls outside of common occurrence or a well-defined pattern, the provider is often forced to improvise, invent, or creatively enterprise a solution that may be based as much on the unconscious reasoning of intuition as the conscious use of knowledge. Also, in what could be described as a multi-tasking effort, as the provider is analyzing the problem he/she is also reevaluating current actions taken and using this information to determine future interventions. Schon (1988) describes this act of thinking about what one is doing while doing it as "reflection-in-action". This "reflection-in-action" and intuitive performance is the essence of what may be referred to as the "art" of anesthesia. It typifies the approach of many practitioners and helps them to negotiate their complex, uncertain, dynamic environment. However, by virtue of it being as much an "art" form as anything else, it evades objective definition and analysis.

The concept of intuition is not embraced by all. Lamond & Thompson (2000) reject the nursing community's reliance on intuition, stating this approach has lead to

variations in clinical practice and the patient outcomes associated with it. In an era that demands accountability and justification for decisions, the ambiguity surrounding the definition and nature of intuition is troublesome. Lamond & Thompson recommend a systematic, analytic approach to decision making that allows for explicit examination of the process in relation to expected outcomes.

Intuition-based nursing intervention has been studied in an attempt to describe and define the process. Much of this work relies on study participant's memory retrieval of instances where intuition occurred and when it helped; unfortunately these explorations suffer from hindsight bias (Benner & Tanner, 1987, Schraeder & Fischer, 1987). As with the pilot who based on intuition feels that a takeoff can be safely achieved in an ice storm and who successfully achieves that end, what is learned in that experience might not take into consideration all physical, mechanical and environmental factors. A future intuitive takeoff under similar conditions may not be successful. Correspondingly, it has been shown that nurses rarely deviate from preconceived notions or conceptual orientations when presented with new or different information. When confronted with a clinical problem, nurses tend to be cognitively cautious in revising initial judgments or hypotheses (Hammond, Kelly, Schreider, & Vancini, 1967). Early intuitive judgments and decisions may lead the practitioner down a path he/she is slow to reconsider.

Clinical Problem Solving

To aid with problem solving and decision making during critical events, protocols and algorithms have been developed, such as the Basic Life Support (BLS), Advanced

Cardiac Life Support (ACLS), and Pediatric Advanced Life Support (PALS) algorithms, the Malignant Hyperthermia (MH) protocol, and the American Society of Anesthesiologists (ASA) Difficult Airway algorithm. An algorithm is a prescribed set of operations or formal routine for problem solving and/or task completion. One of the benefits of protocol or algorithm driven responses to critical events is they remove intuition and provider bias from the approach in favor of systematically defined intervention. The BLS, ACLS, and PALS algorithms and the MH protocol have been shown to be effective in improving patient outcomes (BLS - Cummins, Eisenberg, Hallstrom & Litwin, 1985; Weaver, Hill, Fahrenbruch, Copass, Martin, Cobb, & Hallstrom, 1988; Cummins & Graves, 1989; ACLS - Lowenstein, Sabyan, Lassen, & Kern, 1988; Birnbaum, Robinson, Kuska, Stone, Fryback, & Rose, 1994; PALS - Kyriacou, Arcinue, Peek & Kraus, 1994; Hickey, Cohen, Strausbaugh & Dietrich, 1995; Sirbaugh, Pepe, Shook, Kimball, Goldman, Ward & Mann, 1999; MH - Kolb, Horne & Martz, 1982; Streubing, 1995).

There is a beneficial effect on patient outcome when physicians utilize computer-based interventional systems that remove subjectivity and intuition-based approaches in certain kinds of medical conditions (Hunt, Haynes, Hanna & Smith, 1998). In anesthesia care, where complicated engineering interfaces directly with the user (much like aviation), computer-guided checkout is superior to routine practitioner checkout when evaluating an apparatus with prearranged, clinically relevant faults (Blike & Biddle, 2000). A multi-institutional study examining intensive care unit performance concluded that one factor important in preventing death, lowering complication rate, and saving

money included the establishment of standard protocols in treating patients with specific conditions (Pronovost et al., 1999)

No research examining the role of intuition or the use of electronic facilitated decision making by anesthesia practitioners was found in searching the literature. The complex manipulations necessitated by the anesthesia and surgical experience predispose the patient to a wide range of common and uncommon side effects. If not appropriately managed, many of these side effects may lead to a negative outcome. A mismatch between cognition and task speed or task density may decrease the likelihood of positive resolution in a critical situation. When a highly definable and recognizable critical incident occurs and time is abundant, intervention may be based highly upon cognitive processes. However, when time is of the essence or the task exceeds cognitive capacity, intuition may prevail. Where possible, anesthesia practitioners should make every attempt to increase the amount of critical analytic thought into making decisions rather than relying upon ill-defined intuition.

Problem Statement

Intuition may always play a role in some decision making, but it is appropriate to increase analytic thought and provide decision support whenever possible. Can decision support in the form of preprogrammed handheld computers be useful to anesthetists in their work environment? Will their use result in the correct diagnosis and treatment more often and in less time? How do anesthetists solve clinical problems? These were the central issues explored in this study. As discussed earlier, human error by anesthesia practitioners is a leading cause of adverse anesthesia related outcomes. No systematic

approach to facilitate timely and accurate diagnosis and treatment during critical events by anesthetists has been examined or is universally embraced by the community of interest. Nor has study into the problem solving thought processes of anesthetists been undertaken.

Purpose

The purpose of this study was to explore and evaluate a methodology for examining the effect of handheld computing technology use on the accuracy and speed of problem solving by anesthetists during critical patient care events. To accomplish this, a combined quantitative-qualitative design centered on a pilot study was utilized. With the use of high fidelity human simulation, plausible critical patient care events occurring during and immediately following anesthesia were developed and implemented. A personal digital assistant (PDA) was preprogrammed with a catalog of events, some particularly useful for the simulated patient care scenarios. Key areas of interest included anesthetist performance with and without computer assisted decision making technology, the problem solving thought processes of anesthetists, anesthetist perceptions of PDA use and the simulated environment, and authenticity of the simulated environment. The important task of testing the reliability and validity of the instruments and simulated case scenarios was also performed. These items will be discussed in more detail in the following chapters.

Research Questions

The use of computer assisted decision making by anesthetists during critical events invoked the following quantitative research questions:

1. Will the use of handheld computer-based aid result in more timely accurate diagnosis by anesthetists during critical patient care events?
2. Will the use of handheld computer-based aid result in more timely effective treatment by anesthetists during critical patient care events?
3. Will the anesthetists using handheld computer-based aid have a higher the rate of correct diagnosis and treatment than those not using handheld computer based aid?

Qualitative research questions related to the conduct of this study included:

1. What are the anesthetist's perceptions of the simulated environment and case scenarios?
2. What are the anesthetist's perceptions of the use of handheld computer based aid?
3. What are the problem solving thought processes of anesthetists?

A final question for this research project asked "Is the proposed methodology feasible for future research?" The answer to this question was based on both qualitative and quantitative results and is discussed in chapter 5.

Theoretical Framework

The information processing theory (IPT) of human problem solving put forth by Newell and Simon (1972) served as the underlying framework for this study. Information processing theory is a descriptive model of problem solving in that its purpose is to describe how humans actually solve problems (not how they ought to as a prescriptive theory would purport to do). Problem solving behavior is presented as an

interaction between the information processing system (the individual) and the outside task environment. The internal representation of the problem by the information processing system occurs in what Newell and Simon (1972) describe as a 'problem space'. A conceptual model was developed and is presented in Figure 1, showing the relationship between the task environment, information processing system, and problem space for the proposed study.

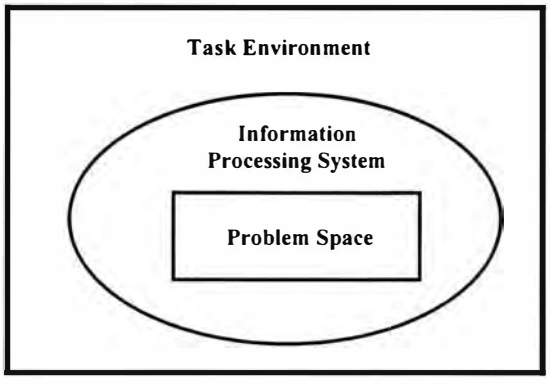

Figure 1. Conceptual Model of Information Processing Theory

Information processing analysis of a given task attempts to trace the flow of information through the mind that occurs in order to complete that task. Measurement of the performance of information processing often emphasizes frequency of success on a task and performance speed (Anderson, 1980). Sternberg (1985) agrees that information-processing researchers usually address how rapidly and accurately the processes under examination are performed.

Elstein, Shulman and Sprafka (1978) utilized IPT as the underlying framework for their research of medical problem solving. Using both quantitative and qualitative techniques they conducted and in depth study of the reasoning processes of twenty-four physicians on a variety of simulated clinical problems. While Newell and Simon studied problems where participants were tasked with reaching a known goal, the resolution of a clinical problem is not known ahead of time. Therefore, Elstein, Shulman and Sprafka sought to develop an information processing model of physician problem solving, which will be discussed in more detail in the following chapter. Generalizability of their results has since been explored in the field of nursing but not specifically within the specialty of nurse anesthesia.

This study collected information on speed and accuracy during task performance, and data to explore the anesthetist's problem solving thought processes with and without the PDA. Utilization of the PDA's preprogrammed treatment algorithms may lead to a more systematic, algorithmic approach, reducing the use of intuition and resulting in fewer errors and improved patient outcomes.

Scope and Approach

This section describes the scope of the research and methodological approach that was used to execute this study and arrive at the results.

Scope

This study explored the individual problem solving performance of a small group of anesthetists in two critical patient care scenarios using high fidelity simulation. Due to the complex and costly nature of this methodology, this initial effort served as a pilot

study. The exploratory nature of this study provided insight to the feasibility of the design and allowed for identification of methodological weaknesses. Study participants were recruited from the Richmond, VA area. Data collection took place at the Virginia Commonwealth University Nurse Anesthesia Department's Center for Research in Human Simulation.

Approach

This research utilized a combined qualitative-quantitative model using a mixed-methodology design (Creswell, 1994). The quantitative element consisted of a pilot study of an experimental cross-over trial design and an evaluation of the authenticity of the simulated environment. For the former, descriptive data of anesthetist performance was collected in a full-scale, high fidelity simulated anesthesia care delivery environment. For the latter, an independent panel reviewed the videotaped scenarios using a standardized coding instrument.

The qualitative element consisted of a phenomenological investigation of anesthetist problem solving and perceptions of PDA use and the simulation experience from their participation in the pilot study. Data collection methods for this element included think aloud and retrospective verbal reports, semi-structured group interviews, and written evaluations.

Significance

A body of research and literature is developing that addresses the potential and validity of computer-based decision support technologies in the clinical setting. A variety of applications and devices, both portable and nonportable, have been explored

(East et al., 1992; Ebell & Barry, 1998; Enders, Enders, & Holstad, 2002; Evans et al., 1995; Friedman, et al., 1999; Goldblum, 2002; Grasso & Genest, 2001; Jamison et al., 2002; McDonald, Hui, & Tierney, W.M., 1992; Miller, Beattie, & Butt, 2003; Morris, 1999; Ratib, McCoy, McGill, Li, & Brown, 2003; Roth, Leon, Milner, Herting, & Hahn, 1997). The use of portable databases as tools that can render health care workers safer and more efficient has been publicized in highly visible lay sources (Austin, 2002; Cowley, 1999; Freudenheim, 2001).

A potential value of the technology assessed in this study was its point-of-care (at the bedside) application for incident management. Use of the PDA in this setting is logical, has face validity, and has the potential to foster desirable patient outcome in traditional health care decision making (Grimm, Shimoni, Harlan, & Estes, 1975; Grimshaw & Russell, 1993; McDonald, Hui, & Tierney, 1992). Implementation of a decision-support or decision-guide tools in the routine clinical setting by those actually involved in direct patient care is highly desirable. The always critical, often urgent, bedside nature of decision making that characterizes anesthetist-delivered care highlights the value of a logical, systematic approach that factors available data and information into the process.

There is a need for systematic evaluation of computer-based decision making aid in all realms of patient care. In critical care environments, such as anesthesia care, it is imperative that computer-based protocols be subjected to clinical investigation and held to the same degree of rigor as pharmacological interventions. Unfortunately, with few exceptions, clinical decision support devices and interventions have not been rigorously

studied. No study of this nature has been performed in the field anesthesia likely due to matters of complexity, cost, and patient safety. The proposed study removes the patient safety factor and thus, while still costly and complex, allows for its execution. Such a study will be groundbreaking in nature and the first step in a platform of research in this area.

Assumptions and Limitations

This study has been designed and will be analyzed based on the following assumptions:

1. Use of high fidelity human simulation within the simulated operating room environment is a valid means for evaluating anesthetist behavior.
2. The simulated case scenarios are realistic
3. The simulation center accurately represents the real-world operating room environment.

The chief limitation of this study is the use of the simulation center to carry out the case scenarios. While the value of high fidelity simulation as a learning tool has been rated highly by participants (Gaba & DeAnda, 1988; Henrichs, Rule, Grady, & Ellis, 2002; Holzman, Cooper, Gaba, Philip, Small, & Feinstein, 1995; Kurrek & Fish, 1996; Schaefer & Gonzalez, 2000) there are still drawbacks to its use. Despite best attempts to convincingly portray operating room environment and culture the result is still somewhat artificial. Some participants have reported increased anxiety before and during simulated events. However, high fidelity simulation does offer the significant advantage of a nonhazardous means for training and evaluating providers in rare clinical situations. To

design and carry out this study in the clinical area would take many years and involve unacceptable patient risk.

A second limitation is the focus on individual performance. Arguably, problem solving by groups of two or more individuals occurs often within the clinical environment. However, this was outside the scope of this study.

Summary of Remaining Chapters

The following chapters present the related empirical and theoretical literature, methodology and data analysis techniques. Chapter 2 provides a review of relevant literature and explains the theoretical framework of the study. Chapter 3 describes the study sample and data collection and analysis methods. Results will be presented in Chapter 4, and Chapter 5 will include a summary of the study findings and a discussion of policy implications, limitations, and recommendations for future research.

CHAPTER 2 – LITERATURE REVIEW

Introduction and Background

The proliferation of computer technology into many dimensions of health care is undeniable. Certainly the level of sophistication varies from one hospital to another, but with the introduction of portable handheld devices, or personal digital assistants (PDAs), a degree of computer technology can be carried by the provider for use in any location. Applications are numerous and include, but are not limited to, general and specialized drug reference programs, infectious disease profiles and antibiotic guidelines, medical, nursing, and pharmacy student education and evaluation, pain assessment, patient monitoring, charting, incident reporting, and medical image viewing. In addition, wireless communications technology allows for easy access of clinical information from almost any location and is particularly useful in remote areas.

Studies examining the use of computer technologies to improve patient care have been largely positive, but caution must be exercised when generalizing the results. A diversity of data, settings, and methodologies make comparisons of existing studies difficult and their replication in different areas challenging. Also, some have suggested that too much additional information can hinder decision making (Sisson, Schoomaker, & Ross, 1986). This can be particularly true in critical situations, when demands on the clinician's attention are high. During routine care the anesthetist must deliver the

anesthetic and attend to the patient, assess, evaluate, and manage a variety of technological devices, interact with other members of the operating room environment, and contend with a myriad of other distractions. When the patient's condition is deteriorating, the anesthetist must be able to manage all of this under the additional burdens of stress and time pressure. In this type of situation would decision making algorithms accessed on PDAs be helpful?

This literature review first presents current knowledge and research on problem solving and decision making. Basic principles are explained, leading to a more detailed discussion of these activities in the clinical area and when performed under stress. Next, the available literature and research to date on computer-assisted decision making are examined. A discussion of the use of simulation technology within the field of anesthesia follows. From this, a foundation was developed for the conceptual framework used in this study. The framework is supported by theoretical and empirical literature in the areas of information processing theory and additional applications from the literature in simulation technology.

Problem Solving and Decision Making

Traditional psychology categorizes problem solving and decision making into distinct domains. However, these daily cognitive activities of anesthetists are not so easily separated. In much of the medical and nursing literature problem solving and decision making are discussed interchangeably or in combination with one another. The following is an explanation of these terms and a discussion of how they will be used in the proposed study.

Basic Principles

According to Anderson (1995), the goal of cognitive psychology is "to understand the nature of human intelligence and how it works" (p. 1). Areas of study within cognitive psychology include perception, attention, language, memory, and thought. The category of thought can be further broken down into subcategories of problem solving, reasoning, judgment and decision making. The isolation of these processes in experimental cognitive psychology is achieved by simple, highly controlled and specific research designs and testing environments (Anderson, 1980; Newell & Simon, 1972). In complex, real-world environments this isolation is difficult, if not impossible, to achieve. Indeed, in studies of clinicians in their natural environment, the terms and concepts of problem solving, reasoning, judgment and decision making are, as mentioned earlier, often used interchangeably or in combination (Elstein et al., 1988; Elstein, Shulman, & Sprafka, 1978; Kirwan, Chaput de Saintonge, Joyce, & Currey, 1986; Offredy, 2002; Sisson, Schoomaker, & Ross, 1986).

Mayer (1992) describes a problem as having the following characteristics: givens, goals, and obstacles. He defines a *problem* as a present state that is desired to be in another state with no obvious or direct way to accomplish the change. Problem solving would encompass the behavior an individual takes to achieve the desired state. Bower (1975) defines a *decision* as "a choice between two or more alternative courses of action for each of which an individual must evaluate and compare the expected consequences" (p. 65). The proposed study involves presenting the anesthetist with a clinical problem that if not correct will lead to a negative patient outcome. The anesthetist will have to

make decisions in order to solve the problem. One focus of this study is whether or not use of the preprogrammed PDA will aid decision making and result in faster solving of the problem and/or a higher rate of achieving the solution to the problem. It is within this context that the terms problem solving and decision making will be used.

The information processing theory (IPT) of human problem solving served as the underlying framework this study. Information processing theory grew out of the work of British psychologist Donald Broadbent (Anderson, 1980). By combining the fields of human-factors work, or research on human skills, and information theory, which abstractly analyzes the processing of knowledge, the information processing approach of cognitive psychology was formed. Concurrent work in the computer science field of artificial intelligence by Allen Newell and Herbert Simon also indirectly influenced development of information processing methodology by providing a host of applicable computer-based concepts. Later, Newell and Simon (1972) undertook a more detailed exploration of the information processing approach and human problem solving, and put forth what is now generally referred to as IPT.

As described earlier, IPT postulates that human beings, in their problem solving activities, operate as *information processing systems* (Newell & Simon, 1972). Parts of an information processing system (IPS) include a processor, memory, receptors, and effectors. Problem solving involves interaction between these components. The external component of IPT is the *task environment*, an environment with a goal, problem, or task which the individual is assumed to be motivated to solve or complete. The task environment includes all aspects of the external environment related to the goal, problem,

or task. In order to explain how the IPS represents the task environment internally, Newell and Simon (1972) introduced the concept of the *problem space*. The problem space represents the current situation as well as the possibilities for change and transformation of that situation. A visual representation of these three components is shown below in Figure 2.

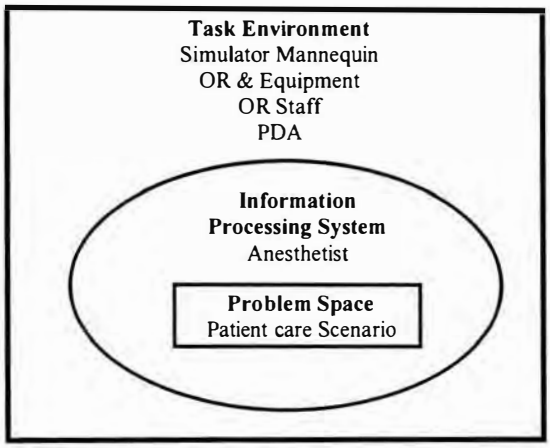

Figure 2. Applied Conceptual Model of Information Processing Theory

The IPS, task environment, and problem space are the basis for problem solving behavior and along with the following four propositions, as described by Simon (1978), shape IPT:

1. A few, and only a few, gross characteristics of the human information processing system are invariant over task and problem solver. The information processing system is an adaptive system, capable of molding its behavior, within wide limits, to the requirements of the task and capable of modifying its behavior substantially over time by

learning. Therefore, the basic psychological characteristics of the human information processing system set broad bounds on possible behavior but do not determine the behavior in detail.

2. These invariant characteristics of the information processing system are sufficient, however, to determine that it will represent the task environment as a problem space and that the problem solving will take place in a problem space.

3. The structure of the task environment determines the possible structures of the problem space.

4. The structure of the problem space determines the possible programs (strategies) that can be used for problem solving. (p.272-273)

There are several types of knowledge that are used in problem solving. Lindsay and Norman (1972) distinguish the following:

1. Facts – basic proposition that are immediately available to the individual
2. Algorithms – sets of rules that automatically generate answers
3. Heuristics – rules of thumb or general plans of actions or strategies

Mayer (1992) provides the following examples:

> Generating a solution to the question "What is 8 x 4?" involves a fact - generating a solution for "What is 262 x 127?" involves an algorithm; and a heuristic would be an estimate of the correct answer by rounding to manageable numbers. (p.178)

As discussed earlier, some also consider intuition to be a form of knowledge used in problem solving. This is not wholly accepted as intuition has not been clearly defined.

For example, Benner and Tanner (1987) refer to intuition as "understanding without rationale" (p. 23) while King and Appleton (1997) describe it as "the integration of forms of knowing in a sudden realization" (p. 195).

Like intuition, the use of heuristics in clinical problem solving and decision making is a recognized, but not always embraced, phenomenon. This is not to say the two concepts are interchangeable. While intuition can be described as an instinctual, vague sense of knowing, heuristics are strategies that are used to simplify complex processes. Heuristics can be described as rules of thumb, which "reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations" (Tversky & Kahneman, 1974, p. 1124). Lindsay and Norman (1977) describe heuristics as "procedures or outlines for searching for solution which are generally easy to use" (p. 555). Chi and Glaser (1985) point to heuristics as general methods that can shorten or simplify the path to solutions. However, heuristic methods do not guarantee a solution, and while they can be useful, they may also result in systematic errors of judgment (Tversky & Kahneman, 1974).

An important concept of IPT is bounded rationality, which refers to the limit of an individual's "ability to determine what the optimal behavior is, or to execute it if he can determine it" (Newell & Simon, 1972, p. 55). This is attributed to the inherent restrictions of human computational ability, with particular regard to short-term memory. Based on Miller's work (1956) it is generally accepted that humans have the capacity to negotiate between 7 +/- 2 alternatives for a single attribute at a given time. He goes on to report that "people are less accurate if they must judge more than one attribute

simultaneously" (p.89). These constraints may result in the use of intuition and/or heuristics to aid in problem solving.

Clinical Decision Making

There is little research on problem solving and decision making specifically by anesthetists. Kremer, Faut-Callahan, and Hicks (2002) performed a groundbreaking study of clinical decision making by anesthetists using IPT as the theoretical framework. They conducted a retrospective analysis of adverse anesthetic outcomes from medical liability claims in an attempt to identify strategies and errors in decision making. In addition to failure to use available clinical information, anchoring and availability heuristics were observed in over half of the studied cases. Anchoring refers to the tendency not to deviate from an earlier diagnosis despite new, contradictory evidence. Availability involves overly relying on one's own clinical experience at the risk of failing to consider other prevalent causes of a problem. This research shows how heuristics can lead to errors in decision making. The authors point out that identification of the types of errors clinicians make may aid in developing means to prevent them. They also suggest using full body simulators to improve decision making by healthcare providers, particularly in crisis situations. Limitations of this study include its retrospective nature. Data was collected from patient records with no means to directly ascertain the thought processes of the anesthetists. This study incorporated the recommendation of using high fidelity human simulation and collected detailed information directly from the participant anesthetist in an attempt to more fully describe and understand their thought processes.

As there is little research on clinical problem solving and decision making specifically by nurse anesthetists, it is helpful to explore relevant studies in the fields of nursing and medicine. Information processing theory has been used by both fields as a theoretical foundation upon which to base their explorations Research into problem solving and decision making by both nurses and physicians began the 1970's and gained significant momentum after the publishing of Elstein, Shulman and Sprafka's seminal work on problem solving and diagnostic reasoning by physicians in 1978. According to Greenwood (1998) many studies of clinical reasoning by nurses sprang from this work.

Elstein, Shulman and Sprafka (1978) report the findings of a five-year program of research on medical problem solving that began in early 1969 and concluded in early 1973. Using IPT as the underlying framework, they examined the thought processes of physicians in order to describe how, within the limits of bounded rationality, they solve complex problems. Their program of research was comprised of several studies, the first set of which examined problem solving by a panel of experienced physicians using three different methods. One was in a simulated physician's office setting. Three case scenarios were developed, intended to be "problems that a general internist practicing in a community hospital of moderate size could be reasonably expected to see" (p. 47). Actors were trained to play the roles of patients and the entire interaction between doctor and patient was videotaped. In order to gain further insight, the physician was encouraged to "think aloud" during the interaction and also participated in a video-stimulated recall session.

The second study comprised four "paper and pencil" simulations of modified patient-management problems (PMPs). Each 30 – 45 minute PMP was designed to simulate certain aspects of the physician-patient encounter that would normally occur over weeks or months. The final study presented four fixed-order "paper and pencil" problems in which the quantity and sequence of clinical data were out of the participant's control. The physicians were categorized into two groups – those who were recommended by their peers as good diagnosticians, the "criterial" group, and those who were not so recommended, the "noncriterial" group. Results showed no difference in performance between the two groups. The authors suggest that this may be due to inconsistencies in task performance. Gordon (1978), in his study of reasoning by medical students, reported substantial variability in performance by the same participant on different problems. These findings suggest that competence may be case related.

With further analysis, Elstein, Shulman and Sprafka developed a general model of medical inquiry with four-stages:

1. cue acquisition
2. hypothesis generation
3. cue interpretation
4. hypothesis evaluation

Findings of interest included observations that hypotheses are generated early and the hypotheses considered are limited in number. Early hypothesis generation presumably serves to guide further inquiry and to control the size of the potential problem space. In this manner, the physician manages his or her information processing resources based on

the demands of the task environment. Simultaneous consideration of no more than five to seven hypotheses appears to be due to the limits of cognitive capacity. However, the strategy of early hypothesis generation may lead to the following problems:

1. retained hypotheses my be excessively general as a way of incorporating inconsistencies
2. new or certain findings may be disregarded to avoid having to generate new hypotheses
3. some findings may be given inflated importance to fit with existing hypothesis

In order to minimize these tendencies the authors recommend strategies to aid the decision maker. Computer assisted diagnosis is mentioned but is essentially discounted due to, at the time, the perceived necessity of a terminal "in every consulting room" (p. 295). Handheld computing technology removes this barrier and provides an opportunity for study of this subject.

Several studies in the nursing community examining clinical decision making have identified IPT as the theoretical framework. One group of researchers, (Putzier, Padrick, Westfall, & Tanner, 1985; Tanner, Padrick, Westfall, & Putzier, 1987; Westfall, Tanner, Putzier, & Padrick, 1986) sought to apply Elstein, Shulman and Sprafka's (1978) model of diagnostic reasoning to three groups - practicing nurses, junior nursing students, and senior nursing students. They performed a series of studies to examine certain components of this model. Participants were given hypothetical case scenarios and instructed to "think aloud" as they worked through the problem. A researcher was present during the process to answer questions related to the cases, and also to obtain

clarification of the subjects thought processes. Results showed that all study participants engaged in early hypothesis formulation, with no statistical difference in the average number generated between the three groups. The average number of diagnostic hypotheses (7 – 8) is consistent with accepted limits of human cognitive capacity. Hypothesis-driven cue-based data acquisition was the most frequently used strategy for problem solving. These findings are compatible with Elstein, Schulman, and Sprafka's diagnostic reasoning model.

Offredy (2002) also used IPT along with Elstein, Schulman, and Sprafka's model of diagnostic reasoning as the underlying framework for her investigation into clinical decision making by nurse practitioners (NPs). She compared responses to six patient scenarios by 11 NPs and 11 physician general practitioners (GPs) practicing in southeastern England. The scenarios were developed by two NPs and one GP and were based on actual cases of an NP not involved in the study. The process of cue acquisition, early hypothesis generation, cue interpretation, and hypothesis evaluation was characteristic of both groups. Cue acquisition appeared to be more efficient by the GP group. The author suggests this may be due to the greater knowledge base and experience and ability to consolidate larger pieces of information by the GPs. Overall, the NPs and GPs used similar reasoning strategies consistent with Elstein, Schulman, and Sprafka's diagnostic reasoning model. Whether the problem solving thought processes of anesthetists fit into this model will be explored.

Decision Making Under Stress and Uncertainty

Anesthetists practice in an environment of dynamism, time pressure, complexity, variability, and risk. They are required to make numerous decisions and perform a variety of technical and drug interventions during each anesthetic, often in the setting of time and production pressure. Add to this any additional stress related to the environment or the patient's condition and the risk of error increases. Of interest is how to ease cognitive strain in stressful situations, allowing the anesthetist to think clearly and avoid error. Cognitive aids such as manuals, checklists and protocols are available but their use in anesthesia is minimal compared with that in the field of aviation (Gaba, Fish, & Howard, 1994). In fact, research on human factors in aviation has informed and guided similar work in the field of anesthesia. Wickens, Stokes, Barnett and Hyman (1993) examined the effects of stress on pilot judgment in the simulated setting. They proposed that resulting stress from anxiety-provoking situations, such as bad weather, system failure, and time pressure, may exert an important degrading influence on the quality of decision making.

The authors examined decision making by 20 pilots during a high fidelity flight simulation. The subjects were separated into stress and nonstress groups, with the stress group being subjected to a variety of concurrent tasks and stress manipulations. Results showed a significant reduction in performance of the stress group in terms of decision optimality and level of confidence in the decisions that were made.

Many factors can lead to stress for the anesthetist – time and production pressure, equipment failure, high patient acuity, noise, fatigue, interpersonal issues, and task

density to name a few. An important aspect of problem solving and decision making that can increase stress and cognitive strain is uncertainty. Humans are routinely faced with making decisions under uncertainty, based on subjective assessments of the probability of what may occur. When faced with assessing the probability of an uncertain event or the value of an uncertain quantity, many people rely on heuristic principles to simplify complex tasks into more manageable operations. As discussed earlier, these heuristics can be useful but sometimes result in error.

Unfortunately, much of the decision making in health care involves some degree of uncertainty, whether it be regarding the patient's condition, the effectiveness of a treatment or medication, or how a patient will react to an intervention. Eddy (1982) reports that "physicians do not manage uncertainty very well, that many physicians make major errors in probabilistic reasoning, and that these errors threaten the quality of medical care" (p. 249). He studied the case of using mammography to sort lesions into two groups, benign and malignant. Results showed most physicians misinterpret statements about the accuracy of mammography and estimate the probability of malignancy to be much higher than it actually is.

The use of cognitive aids to assist the anesthetist in problem solving and decision making, particularly during critical events, is recommended by Gaba, Fish, and Howard (1994). Such aids relieve the anesthetist of having to memorize every piece of information needed for all possible cases. The most useful cognitive aids are immediately available and would include the patient's medical and anesthesia records. A variety of checklists, protocols, information cards and reference handbooks may be

carried by the anesthetist or stored in the anesthesia cart in each operating room. More detailed textbooks and reference manuals are usually available in a central location. The authors encourage anesthetists to design and produce their own aids to optimize their ability to handle critical events. This is in part the reasoning behind development of the PDA algorithm catalog for this study.

Previous Reports on Computer Assisted Decision Making

There are a variety of computer applications in health care. Numerous reviews and studies describe the way in which computers have been utilized and integrated into clinical practice. Initially this involved desktop versions, but with improved technology there has been some transition to portable handheld devices, or PDAs. Hunt, Haynes, Hanna, and Smith (1998) categorized research studies on computer-based clinical decision support systems four groups: drug dosing, reminders for preventive care, diagnosis, and other aspects of medical care (disease management, test ordering, cost containment). The following is a discussion of select studies representing each of these categories.

Morris (1999) describes a desktop program of bedside computerized protocols that standardize clinical decisions for patients diagnosed with acute respiratory distress syndrome (ARDS). As indicated, in this case the diagnosis has already been made and the protocol provides specific instructions and dynamic standing orders driven by patient data or status. East et al. (1992) conducted a study during the development of these protocols. Specifically, they evaluated the effect of using a computerized protocol with end-expiratory alveolar pressure as a primary control variable for management of

pressure control inverse ratio ventilation (PCIRV) on hemodynamic, ventilatory and respiratory parameters. A convenience sample consisted of seven patients with ARDS. Individuals with ARDS are at increased risk for lung injury with traditional positive pressure ventilation due to high peak airway pressures. Baseline data was compared to measurements obtained during the 24 hour protocol use period using analysis of variance. Identical protocol logic with the same oxygenation endpoint was used both prior to and during the study period.

Results showed a significant decrease in peak airway pressure, positive end-expiratory pressure, and cardiac output and an increase in mean airway pressure and pulmonary artery pressure during the study period as compared with baseline readings. There was no difference in blood pressure or oxygenation. No conclusive evidence regarding incidence or resolution of barotrauma was obtained. Based on these results, the authors recommend the use of end-expiratory alveolar pressure as a primary control variable for oxygenation. Unfortunately neither a crossover design nor randomization was used, therefore the possibility of period effect due to passage of time and evolution of the disease must be considered when interpreting the results.

Also in 1992, McDonald, Hui, and Tierney studied the effects of desk-top computer-generated reminders for influenza vaccination of patients at high risk for pulmonary disease. Residents and faculty members of a general medicine clinic were randomly assigned to either receive or not receive a computer generated vaccine reminder for eligible patients who had a scheduled appointment. Over a three year period 4,555 patient records were analyzed. Results showed physicians who received the reminders

vaccinated eligible patients twice as often (P=.0001). There was an accompanying decrease in the number of emergency room visits (P<.05), hospitalizations (P<.01), and blood gas determinations (P<.001) for patients seen by physicians in the reminder group. The authors attribute this to a greater use of influenza vaccine. Additional findings supporting their conclusions include the correlation of observed benefits with the incidence of influenza and the absence of benefits when influenza infections rates were very low (non-winter months, few cases of influenza during first year of study).

Evans et al. (1995) evaluated a decision support tool improve the use and control the cost of antibiotic therapy. When accessed, this desktop system alerts the physician of pertinent patient information, provides direct access to other medical information, and suggests an antibiotic regimen. All antibiotics ordered for patients admitted to the Shock/Trauma/Respiratory Intensive Care unit were completed using the decision support tool. During the 7-month study period data were collected and then analyzed and compared with data from the previous 12 months. Antibiotics were ordered 588 times during the study period and physicians used the suggested antibiotics 218 times (37%). The most common reason given for selecting a non-recommended antibiotic was the patient having an infection not identified by the computer (134, 36%). The ordering physician did not agree with the suggested dosage 44 times (12%). In comparing the control and study period data, there was a statistical decrease in the average patient antibiotic cost ($382.68 to $295.65). There was also an accompanying decrease in average length of stay, time to discharge and number of antibiotic adverse events, although these changes were not statistically significant. The authors point out they did

not expect physicians to use the suggested antibiotics every time, but this is an example of how decision support tools can facilitate (not replace) clinical judgment. Further development and enhancement of the tool was recommended based on the promising results of the study.

Friedman et al., 1999 conducted a study comparing two different computer-based consultation systems (ILIAD and Quick Medical Reference) over 3 user levels (medical student, resident, and faculty physicians). Each participant performed diagnostic evaluations on 9 out of 36 case scenarios developed by physician coinvestigators. This was a partially randomized controlled trial in that the participants were recruited volunteers. Otherwise, assignment to the decision support system and case scenarios was random. Data was collected from 1995 to 1998 at three sites from a total of 216 participants. Correct diagnoses were compared prior to and after use of the consultation system. Overall, correct diagnoses appeared in participant hypothesis lists 39.5% of the time before and 45.5% after consultation system use. The authors also developed and validated a diagnostic quality score which they used for statistical analysis. These scores increased after consultation ($p<.001$). The size of increase was inversely proportional to participant level suggesting a useful role for these systems in education. While the results show modest improvement in diagnostic reasoning, there are several limitations of the study. Some participants had more experience with the consultation systems than others, which could have affected the results. The participants were all based in the academic setting, hindering generalizability. Also, written case summaries were used

which limited access to information that would normally be available during a patient work-up.

The above represent examples of how computer-based problem solving aids have been introduced and studied. The following are examples specific to handheld devices. In 1997 Roth, Leon, Milner, Herting and Hahn published one of the first articles describing a clinical application specifically for a PDA (the PalmPilot™). The authors developed a program for fluid resuscitation calculation in both pediatric and adult burn victims. The user interface is comprised of four parts: two screens to determine the percent of total body surface area burned and two screens for weight entry and fluid calculation (one for adults and one for children). Unfortunately, while the authors indicated plans to clinically evaluate the system, no corresponding studies have yet been published.

Ebell and Barry (1998) describe the development of InfoRetriever®, a PDA program that provides rapid access to evidence-based information. This program is designed for use by primary care physicians. Resources used include the Cochrane Database of Systematic Reviews, Journal of Family Practice POEMs™ (patient-oriented evidence that matters), evidence-based clinical practice guidelines, diagnostic calculators for history and physicals and laboratory and imaging studies, and drug information. The user interface is designed for simple, rapid use via a series of three menus. The first menu lists 17 broad, primarily organ system category links. Selection of a category triggers a search of all databases and generates a list of all relevant symptoms and diagnosis. Any of these items can be accessed for more detailed information about the

topic of interest. Evaluation of the program has not been published yet, although the authors state their intent to study its effects on learning by medical students. All potential information undergoes a rigorous review before being added to the database, which is updated every quarter. More detailed information regarding InfoRetriever® can be obtained at the InfoPoems website (2004).

In 2001Grasso and Genest reported on the use of PDAs in reducing medication error rates. After identifying several problem areas contributing to medication errors, the handwritten discharge medication list was chosen for intervention. A program was developed to provide immediate electronic access to patient and drug information with the ability to easily execute, document, and generate a patient's discharge medication list. Initial evaluations of the PDA program, while limited, showed positive user-satisfaction results and a decrease of physician requests for drug information from pharmacists by 45% during the first six months of use.

A year later, Grasso, Genest, Yung, and Arnold (2002) followed up with a retrospective study comparing discharge medication errors prior to and after introduction of the above PDA program. In the four months prior 20/110 (22%) errors were detected in the hand-written discharge medication lists. During the four-month period after the PDA program was introduced 7/90 (8%) errors were detected ($P<.05$). Types of errors included erroneous exclusion of a currently used drug, erroneous addition of a new drug, incorrect or incomplete dosage, quantity, or frequency, illegibility, and inclusion of usages that are prone to misinterpretation (i.e., trailing zero, 1.0 can be misread as 10). Degree of harm the detected errors may have caused the patient was not evaluated. All

PDA-period errors involved medications excluded from the discharge list. The authors stated that in all instances this was due to medications being added after the discharge list had been printed from the PDA. While it is possible the reduction in error rates was due to some other factor, the authors state there were no changes in admission or discharge criteria or in medical, nursing or pharmacy staff during the study period. The results show a promising reduction in medication error rates after introduction of the PDA program, but a corresponding decrease in patient injury can only be suggested.

As evidenced in this review, computer applications have evolved along with concurrent increases in technology. The majority of applications appear to be geared toward primary care and administrative activities. Investigations involving human subjects must be carefully designed to protect the participants, particularly if they are patients. In some cases, ethical or methodologic issues render conduct of a study idea unfeasible. In theses instances, simulation of patient-based scenarios has been introduced as a means to complete theses studies. Unfortunately, generalizability of these results to behavior in clinical practice is questionable. For this reason, attempts to mirror the actual clinical environment as closely as possible have been made. The following is a review and discussion of the evolution of simulation in the field of anesthesia.

Simulation in Anesthesia

Advances in technology have allowed simulation as an education tool and area of research in anesthesia to evolve. There are several studies evaluating anesthesia practitioner performance using simulated, hypothetical events. One of the earliest attempts at a physical simulator system for anesthesia was the Sim One project which

partially recreated the anesthetist's work environment but with considerable limitations (Abrahamson, Denson, & Wolf, 1969). Sim One was a partial human mannequin (waist up) with an anatomically correct airway presented on an operating table. Both arms were extended, the left for intravenous injection and the right fitted with a blood pressure cuff. A stethoscope was taped over the left chest through which heart and breath sounds could be heard. Other features included eyes that could open and close, and temporal and carotid pulses. This accomplishment was followed by the development of a variety of simulation programs and equipment for training and education in the late 1980's.

Some applications were accomplished via computer programs requiring the participant to interact with a desk-top monitor and keyboard. Schwid (1987) describes the development of a screen-based anesthesia simulator by integrating a set of physiologic computer models with a graphic display. Subsequently in 1992, Schwid and O'Donnell published a study describing the use of screen-based computer simulation to evaluate diagnostic and treatment patterns by anesthesia residents, faculty anesthesiologists and private practice anesthesiologists. Patient scenarios for the study included esophageal intubation, anaphylaxis, and cardiac arrest. According to the results, fixation errors were made by 65% of participants and time elapsed from most recent ACLS training was predictive of successful simulation navigation. This is suggestive of the benefit of algorithmic driven management.

Alternatively, Gaba and DeAnda (1988) chose to recreate the task environment of the anesthetist to allow for both manual and cognitive activities. The Comprehensive Anesthesia Simulation Environment (CASE) integrated an intubation/thorax mannequin,

standard monitors and equipment, and commercial and custom computer programming in a mock operating room environment with individuals performing in key roles (surgeon, circulating room nurse). The authors developed several patient care scenarios, both benign and life-threatening. Participants rated the overall experience as realistic, with the least realistic feature being the mannequin. Most commented on the educational value of the experience, indicating the system's merit as a teaching tool.

In 1990 DeAnda and Gaba conducted another study using the CASE. They observed nineteen first and second year residents during "routine" care of a head/neck surgical procedure with six different event challenges (ranging from kinked intravenous tubing to cardiac arrest). The authors identified 132 unplanned incidents ranging from mild to severe, with most being due to human error.

Chopra et al. (1994) designed a similar system with a partial mannequin, the Leiden Anesthesia Simulator (LAS), which they used to assess subsequent anesthetist performance after simulator training. During the first phase of the study, all individuals participated in a simulated control scenario of anaphylactic shock. In the second phase, subjects were randomly assigned to receive simulation training in the management of anaphylactic shock (group A) or malignant hyperthermia (group B). Four months later all participants took part in a malignant hyperthermia scenario. Group B performed better, with results showing a statistical difference in response time (P=.01), treatment score (P=.04) deviation score (P=.01) and total performance score (P=.01). There was no statistical difference for all measures between the groups for the anaphylactic shock

scenario. The authors concluded that training on an anesthesia simulator improved anesthetist performance.

Gaba and DeAnda (1988) envisioned simulation as a means for many activities in addition to individual education and training, including assessment of clinical competence, group instruction on management of critical events, and research into problem solving and error prevention to name a few. Advances in simulation technology have resulted in the development of more life like full-body mannequins with a wide variety of features and abilities. This has led to additional efforts to increase realism of the simulated environment by redesigning and/or converting and equipping facility space to reproduce the clinical operating room as closely as possible. Many institutions of higher learning now house high-fidelity simulation centers geared toward research and education. There is also a course of study designed around high fidelity simulation specifically for the field of anesthesia – Anesthesia Crisis Resource Management (ACRM, Howard, Gaba, Fish, Yang, & Sarnquist, 1992).

The goal of ACRM is to teach individuals how to better manage critical events through effective resource management. As critical events are rare in anesthesia the high-fidelity human simulation environment provides an ideal venue for ACRM instruction. ACRM has been the subject of several studies. Holzman Cooper, Gaba, Philip, Small, & Feinstein (1995) surveyed 72 ACRM course participants regarding their immediate impressions of the curriculum and the simulated environment. It was the authors' intent to evaluate the feasibility of conducting the ACRM course at a different facility from where it was developed, although no specific methodological design was

described. Overall the course was rated highly by the participants and portability of the program between institutions was confirmed by the authors.

Kurreck and Fish (1996) sought to more clearly identify anesthesiologists' perceptions and concerns regarding anesthesia simulation and ACRM training. They conducted a descriptive study using two survey questionnaires. The first survey was distributed to practitioners with a low likelihood of previous simulator experience. The response rate was fair at 39.3%. In general, respondents were strongly supportive of both the purchase and use of a simulator for education, but did not support compulsory use for recertification. The second survey was an exit evaluation completed by 35 out of 36 anesthesiologists who had participated in an ACRM course. Responses were positive as to the content of the course and benefit to the participants, but the idea of mandatory use for recertification was not addressed.

In addition to ACRM, the full-scale human simulator has also been incorporated into a comprehensive difficult airway training module. Gonzalez and Schaefer first describe their program of instruction on the ASA Difficult Airway Algorithm using the CAE Electronics Human Simulator Training System in 1996. Initial exit survey results showed high participant satisfaction and perceived value of the experience. In 1998, Schaefer, Dongilli and Gonzalez conducted a quasi-experimental study of anesthesiology resident performance using a one-group pretest–post-test design. The treatment involved didactic lecturing and handouts of the ASA Difficult Airway Algorithm and "hands on" individualized instruction and scenario drills using a full-scale human simulator. All 18 participants were pre and post-tested in a simulated, real-time difficult airway scenario.

Prior to the treatment, 50% of all residents failed to successfully manage an emergent, unanticipated difficult airway within five minutes. After the three-hour treatment 93% successfully managed the scenario in less than five minutes (P=.01). It is important to note that the post-test was not administered until 4-6 weeks after the pre-test and treatment. There are several threats to the validity of the one-group pretest–post-test design, including history, statistical regression and particularly maturation due to the considerable delay from pretest to post-test. Post-test scores can also be affected simply by administration of the pretest or any changes in instrumentation.

Two years later Shaefer and Gonzalez (2000) conducted a third study similar to the latter mentioned above. Using the same design, the authors evaluated 120 paramedics on their ability to appropriately follow an airway protocol and use a Combitube. The program involved a simulation-based pretest, a 2.5 – 3 hour review course with hands-on training, and a simulation-based post-test. According to the results, the percentage of paramedics that followed the airway protocol and established ventilation using the Combitube increased from 27 to 93%. There was no delay from pretest, treatment, and post-test, attenuating the threat of maturation to validity. Statistical regression would also appear to be a minor threat due to extremes in both pretest and post-test scores. Results would suggest that simulator-base training is an effective education tool. The authors state their intent to follow up with a field evaluation but no such study has yet been published.

An important issue in assessing clinician performance is the reliability and validity of the tools and/or instruments used. The reliability of a tool reflects the

consistency with which it measures what it is designed to measure. Tools must also be valid in that they measure what they are intended to measure. Byrne and Greaves (2001) reviewed several studies involving anesthetic simulation to evaluate the assessment instruments used. Overall, they recommended further efforts to increase the efficacy of methodologies for simulator performance assessment, particularly if the goal is use for certification or recertification. The following is a discussion of some of the studies they reviewed.

Devitt et al. (1997) sought to evaluate the inter-rater reliability of a 3-item rating scale to assess clinician performance. Two scenarios with five anesthetic problem events each were developed and role-played. Each scenario was videotaped three times for a total of 30 anesthetic events to be evaluated. Two clinicians uninvolved in the study reviewed the videotapes using the rating scale (no response to the situation, score = 0; compensating intervention defined as physiological correction: score = 1; corrective treatment, defined as definitive therapy, score = 2). Results were compared using the kappa statistic for a value of 0.96 ($P<.001$) indicating excellent inter-rater reliability.

The following year Devitt et al. (1998) published a study to evaluate reliability and construct validity of the two case scenarios (5 problem events each, 10 total items) used in the previous study. Eight residents and 17 faculty anesthesiologists participated in each scenario. The same scoring system was utilized and results were analyzed using Cronbach's coefficient alpha with subsequent item analysis. Four of the items showed poor internal consistency. When deleted the value for the remaining items was 0.66 indicating good internal consistency. Using the known-groups technique, the authors

tested for construct validity by comparing the overall scores of the residents with the faculty anesthesiologists. On the six remaining reliable items faculty anesthesiologists scored higher than residents ($P<.001$) as would be expected, demonstrating positive construct validity.

That same year Gaba et al. (1998) assessed group performance during simulated crises using technical and behavioral ratings. Twenty-eight videotape recordings from an ACRM course conducted in 1992, during which 14 groups participated in two scenarios (MH – malignant hyperthermia and CA – cardiac arrest). Ratings of crisis management behaviors were completed using an instrument (adapted from the field of aviation) by five anesthesiologists. A five-point ordinal scale was used. For technical assessment, the investigators developed a list of appropriate actions and assigned point values. Three anesthesiologists evaluated the tapes for technical behavior, the final score being represented as a fraction of the maximum possible score. Technical scores for all teams were high. The corrected Within-group Inter-rater Reliability Coefficient (r_{wg}) was 0.65 for the CA scenario and 0.62 for the MH scenario ($P<.0002$ for both) showing good agreement. Inter-rater reliability for behavioral scoring ranged from poor to good depending on the statistical test used. The authors did recommend refinement of the behavioral rating tool as many of the behaviors correlated with each other. They also suggested reducing the 5-point ordinal scale some scores were infrequently used (i.e. 5 = outstanding) to improve interrater reliability.

Morgan, Cleave-Hogg, Guest, and Herold (2001) examined the validity and reliability of an anesthesia simulator performance assessment tool. The 25-point criterion

based checklist was developed to evaluate medical students during their anesthesia rotation. Each subject (n=140) participated in one of six case scenarios on the seventh day of their 10-day rotation. Ten faculty anesthesiologists having little or no interaction with the students were recruited and trained to use the tool. The raters were randomly assigned into five pairs, each of which viewed and scored between 25 – 34 taped performances. Inter-rater reliability was good as evidenced by mean reliability estimates of 0.77 and 0.86 for single and average paired assessments respectively. The authors compared checklist scores with clinical evaluation marks and written test scores. Results showed poor correlation between all three methods, calling validity of the tool into question. This raises the concern of generalizability results from the simulated environment to the clinical area. However, the two established evaluation methods (clinical evaluation and written test scores) did not correlate either so it is difficult to know which of the methods is invalid.

In 2003 Weller et al. published a study evaluating reliability of an anesthesiologist performance assessment tool for use in the high-fidelity simulated environment. Using videotapes made during an ACRM course held in 1999 and 2000, eight anesthesiologists (three primary raters that had been involved in developing the tool and five additional raters that had not) used a 5-point scoring tool to rate aspects of knowledge and behavior and overall performance. The Interclass Correlation Coefficient (ICC) provided and estimate of the reliability of the ratings that would be obtained one, two, or three out of the eight original raters, providing estimate of the actual number of raters need for a

reliable assessment. ICCs ranged from 0.70 to 0.85 in all three scoring areas for good inter-rater reliability with at least two raters.

Theoretical Framework

In their exploration into the theory of information processing, Newell and Simon (1972) attempt to describe the process of human problems solving, the variant and invariant characteristics of the problem solver, and the nature of the environment in which the problem solving takes place. Their proposition that the task environment has significant influence over the behavior of the problem solver will be evaluated in this study. Without any other changes in the task environment, the effect of introducing of a handheld computerized decision making aid (the PDA) on information processing performance was investigated. Measurement of the performance of information processing often emphasizes task success and performance speed (Anderson, 1980; Sternberg, 1985). The PDA will serve as the independent (treatment) variable and task success and speed will serve as the dependent (response) variables for the quantitative element of the study.

Information processing analysis of a given task attempts to trace the flow of information through the mind that occurs in order to complete that task. The qualitative element of the study examined the processing strategies used by the anesthetist within the problem space. As discussed earlier, Elstein, Shulman and Sprafka (1978) developed a model of diagnostic reasoning of physicians based on information processing theory. The authors were attempting to describe the thought processes occurring within the

problem space. A visual representation incorporating their four-stage model into the conceptual model of IPT presented earlier is shown below in Figure 3.

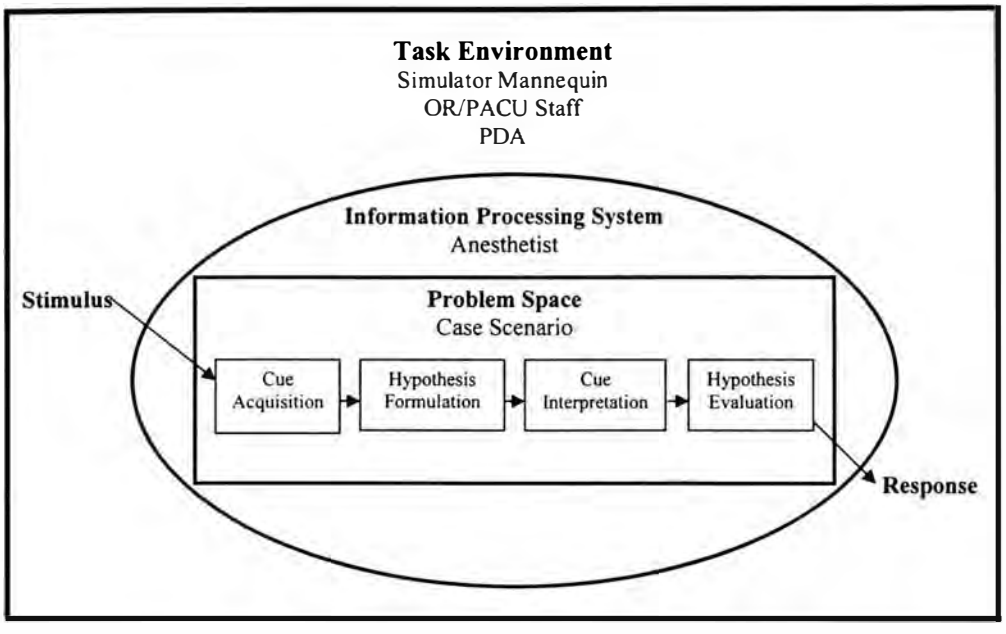

Figure 3. Combined Applied Conceptual Model of Information Processing Theory and Diagnostic Reasoning

This combined model serves as the underlying foundation for this study. It was proposed that the reasoning strategy of anesthetists could be described using Elstein, Shulman and Sprafka's physician model. Studies in the field of nursing described earlier support this proposition (Offredy, 2002; Putzier, Padrick, Westfall, & Tanner, 1985; Tanner, Padrick, Westfall, & Putzier, 1987; Westfall, Tanner, Putzier, & Padrick, 1986).

Summary

Greenwood wrote "it is at least arguable that a combination of approaches to the exploration of clinical reasoning, in differing care settings and, possibly, involving different subject populations would both expedite the generation of insights and deepen our mutual understandings of the complexity of human reasoning" (p. 845). The high fidelity simulated environment provides a safe medium to study clinician response to critical events by replacing the human patient with a full body simulator. The literature has focused on practicing anesthesiologist, resident anesthesiologist and medical student performance. There is little or no literature on anesthetist performance in the simulated setting. No prospective studies of problem solving by anesthetists have been undertaken, nor has the PDA been evaluated in the manner planned for in this study. It is argued that this study will contribute new insights and enhance understanding of clinician problem solving and the use of newer technology in patient care.

CHAPTER 3 – METHODOLOGY

Introduction

This section presents plans for research design, sample selection, event catalog and case scenario development, programming of the PDA, preparation of the study participants, execution of the case scenarios within the simulation center, data collection, and data analysis. This study made use of both quantitative and qualitative research methodologies. The idea of combining quantitative and qualitative methodologies within the same study is discussed by Newman and Benz (1998). Quantitative research is typically thought of as deductive and qualitative as inductive, and they are generally viewed as separate and distinct. However, Newman and Benz argue that quantitative and qualitative constructs are both present in all behavioral research. The authors suggest that both paradigms coexist and together form what they refer to as a *qualitative-quantitative research continuum*.

The motivation behind utilizing a combined qualitative-quantitative methodology is to add breadth and depth to the study, and to better understand the area under investigation. In this case, a mixed-methodology design as described by Creswell (1994) will be used. This design is characterized by qualitative and quantitative activities that are highly integrated at one or more steps of the research process. Based on their review of 57 mixed-method research studies Greene, Caracelli, and Graham (1989) describe five

general purposes for using this type of methodology, including triangulation, complementarity, development, initiation, and expansion. For this study, the reason for using a mixed-methodology design is complementarity, where both qualitative and quantitative methods are used to evaluate a single aspect or similar facets of a phenomenon to for a deeper understanding of the area of interest and triangulation, where multiple data collection strategies are used to enhance validity. Briefly, the quantitative element consists of a descriptive analysis of pilot study results and subsequent methodologic investigation. The qualitative element will employ phenomenological inquiry. Between these two elements there will be five components of data collection:

1. First component – quantitative data collection via direct observation of the simulation runs using a standardized tool and then confirmation by viewing videotaped recordings.
2. Second component – qualitative data collection via direct observation of the simulation runs using a standardized tool and review of the videotape recordings
3. Third component – qualitative data collection via a video-assisted recall session where the participant will view the video-recording with an interviewer who will facilitate detailed recall of their thought processes during the event.
4. Fourth component - qualitative data collection via a semi-structured group interview to elicit participant perceptions of PDA use and the simulator experience

5. Fifth component – quantitative and qualitative data collection involving independent review of the videotaped simulations using a standardized evaluation tool to further establish validity and authenticity of the simulated setting. Participants will also be asked to complete a similar evaluation tool for comparison.

This research study was approved by the Virginia Commonwealth University Institutional Review Board. Informed consent was obtained from all participants prior to participation.

Design and Sample

The same sample group will be used for all segments of data collection. In this section, the quantitative research component will be discussed first, followed by an explanation of the qualitative design component. A discussion of the sampling methodology will complete this section.

Quantitative Element

This study has two quantitative research components. One is to explore the effect of a computer-based aid on problem solving by anesthetists. The second is an evaluation of the authenticity of the simulated environment and case scenarios. The pilot study design will be examined and discussed in the concluding chapter. A cross-over trial design with matched-pair sampling will be utilized for the pilot study. While inferential statistics will not be used to analyze the data, it will be discussed in this chapter as it relates to the research and sampling design.

Cross-over trials have been used extensively in medicine, primarily to assess differences between treatments or medications in a group of patients. According to Senn (1993) a cross-over trial is one in which "subjects are given sequences of treatments with the object of studying differences between individual treatments" (p. 3). The proposed study will employ the simplest and most common form of cross-over design where the subjects will receive two treatments, one being an active treatment and the other being no treatment or placebo. Senn refers to this as the AB/BA design, with the treatments being labeled A (PDA) and B (no PDA). Half of the study participants will receive A first and then cross over to receive B. The remaining subjects will receive B first and then cross over to receive A. Data collection for this study took place over the course of two days. Half of the participants were studied on the first day, and the other half on the second day as shown in the example below in Figure 4.

	Day 1		Day 2	
	PDA	No PDA	PDA	No PDA
Scenario 1	Female 1		Male 2	
		Male 1		Female 2
Scenario 2	Male 1		Female 2	
		Female 1		Male 2

Figure 4. Diagram of Cross-over Trial

As Louis, Lavori, Bailor and Polansky (1984) point out, it is important in cross-over designs that both treatments are realistic alternatives and each can be administered after the other. In this study the participant either cared for the patient while having access to a PDA or cared for the patient without having access to a PDA. As discussed previously, the use of handheld computer technology has become more commonplace and has

numerous applications for healthcare providers to take advantage of. Alternatively, current standards of care do not require anesthetists to utilize handheld computer technology. Therefore, it was assumed that both alternatives were realistic for the purposes of this study.

The sequence and timing of administration of treatments or medications in a cross-over design requires consideration. One disadvantage of cross-over trials is the threat of carry-over effects (Jones & Kenward, 1989; Senn, 1993). Senn defines carry-over as "the persistence (whether physically or in terms of effect) of a treatment applied in one period in a subsequent period of treatment" (p. 8). This study examined anesthetists in a simulated patient care environment with the presence or absence of a decision making aid, not real patients in the clinical environment undergoing administration of a sequence of treatments or medications. Removal of the PDA will not result in any residual physiological effects on the participant.

Carry-over effects can also take the form of learning or fatigue effects. There is a remote possibility that the anesthetist using the PDA during their first scenario could view a treatment algorithm that would apply to the second scenario. For this reason, approximately thirty algorithms were programmed into the PDA and the two scenarios have been designed to avoid overlap in treatment modalities. Also, a tracking system allowed precise review of files used by the participants and identification of potential carry-over effects. It is also possible that after participating in the first scenario, the anesthetist could become more relaxed and less anxious in the simulated environment allowing him or her to perform at a higher level during the second scenario. For this

reason, anesthetists with previous exposure to the simulated environment were recruited. Fatigue is unlikely to play a due to the short duration of data collection. In summary, while the potential for carry-over effects cannot be completely discounted for this study, it does not face the more stringent requirements and concerns of timing and sequence.

In addition to carry-over effects, there are other factors that could cause cross-over differences not to be distributed at random and include the following:

1. period effect – a simple trend effect
2. period by treatment interaction – the general effect of a treatment varies according to the period in which it was given
3. participant by treatment interaction – the effect of the treatment is not general but varies from subject to subject
4. participant by period interaction – trend effects that vary by subject

According to Senn (1993) carry-over and period effects and period by treatment interactions can be adjusted for during data analysis and will be discussed in more detail in that section. Senn goes on to state that participant by treatment interaction and patient by period interaction do not significantly affect the validity of analysis but may increase variability of results and hence lead to difficulties with interpretation.

As mentioned earlier, data collection took place over the course of two days. The purpose of this was to aid in attenuation of two other disadvantages of clinical cross-over trials – drop-outs and inconvenience to the participants. Clinical cross-over trials typically span over weeks to months. One could argue that the likelihood of participants dropping out of a one day versus a one month study is lower. Participation in this study

was still an inconvenience to the subjects as data collection occured on a weekday, presumably a work day. Again, this is still arguably less of a convenience than a study requiring several visits over the course of weeks or months. In addition, subjects participated on a volunteer basis and were compensated monetarily for the loss of their work day.

Senn (1993) states there are significant advantages of the cross-over design. Fewer patients need to be recruited to obtain the same number of observations as a parallel group trial. This is desirable due to the high cost of running the simulation center and reimbursing the study participants. Also, to obtain the same precision in estimation fewer observations have to be made. Louis, Lavori, Bailor and Polansky (1984) concur that a cross-over design with a small sample size can yield the same statistical accuracy as a larger parallel study.

The second quantitative element involves a methodologic evaluation of the simulated environment, case scenarios, and PDA use. Polit and Hungler (1999) describe methodologic research as "controlled investigations of the ways of obtaining, organizing, and analyzing data . . . . [that] address the development, validation, and evaluation of research tools or techniques" (p. 208). They also point out that methodologic inquiry is particularly important for studies involving highly complex, intangible phenomenon. For this study, this was accomplished by using a standardized data collection tool adapted from Hotchkiss, Biddle, and Fallacaro's (2002) "videotape coding instrument" (permission obtained). Videotape recordings of the simulation runs were examined by three independent reviewers using the videotape coding instrument. Validity of the

simulated environment and reliability of the data collection tool were assessed. Data from a similar tool adapted for use by the participants, a "participant evaluation form", where also collected, analyzed, and discussed. A more detailed discussion of this information can be found later in this chapter.

The importance of carrying out a study with a powerful, precise, robust design is the motivation behind the pilot nature and methodologic inquiry of this research project. The crossover trial and sampling design, simulated environment, case scenarios and PDA will all be questioned and evaluated.

Qualitative Element

There are two components to the qualitative element of this study. One is to examine the problem solving thought processes of the anesthetists. The second is to describe participant thoughts and perceptions regarding the use of the PDA and the simulation experience. Elstein, Shulman and Sprafka state they used a broad range of methods for their studies of diagnostic reasoning including naturalistic, experimental and descriptive designs. In developing their model of diagnostic reasoning, they used a naturalistic, or qualitative, approach, although no specific qualitative methodology was identified. Process-tracing techniques were utilized to analyze the resulting verbal data from their simulated experiments.

This study will utilize the phenomenologic method for both quantitative subcomponents for two reasons. One is uniformity, but more importantly are the tenets of the phenomenologic approach. According to Karlsson (1989) the fundamental aim of phenomenology is "to describe the phenomenon as faithfully as possible" (p. 57). In

using this approach the researcher attempts maintain objectivity and avoid any pre-fixed hypothetical assumptions. Moustakas (1994) states that conducting phenomenological research "involves a return to experience in order to obtain comprehensive descriptions that provide the basis for a structural analysis that portrays the essences of the experience" (p. 13).

There are varying methodologic interpretations of phenomenology with different authors describing different strategies for conduct of such research. However, the following concepts are generally consistent across most phenomenologic studies and include the following (Polit & Hungler, 1999):

1. Bracketing – the process of identifying and setting aside any prejudgments, biases, and preconceived ideas about the phenomenon under investigation (also referred to as epoche)
2. Intuiting – the mindset of remaining open to the meanings attributed to the phenomenon by those who have experienced it and immersion in the phenomenon under investigation
3. Analyzing – coding and categorizing of the data
4. Describing – occurs when the researcher has come to understand and define the phenomenon

The step of data analysis has also been approached in a number of ways. For exploration into the decision making processes of the participants a process-tracing technique will be used. The use of process-tracing methods for phenomenological research has been demonstrated in the literature (Karlsson, 1987). This technique was

also used by Elstein, Shulman, & Sprafka (1978), supporting the rationale for its use in this area of the study.

For exploration into participant perceptions of PDA use and the simulation experience, data analysis methods described by Creswell (1994) and Moustakas (1994) were employed. Observations by the primary investigator during the simulation runs, written comments by the participants from evaluation forms, and semi-structured group interview results will be combined and analyzed. The technique of using more than one data collection strategy, referred to as method triangulation, serves to strengthen internal validity. Data collection and both data analysis methods will be described in more detail later in this chapter.

Sample

The issue of sample size deserves special attention. When faced with limited resources, the advantage of smaller sample sizes offered by cross-over designs is desirable. This must be balanced with the importance of being able to identify statistically accurate differences in the treatments. Inferences were not drawn from the quantitative results of the pilot study, but a discussion of the reasoning behind utilizing the crossover design as it relates to sample size and selection was warranted. It also served as an area for subsequent evaluation and critique.

Louis, Lavori, Bailor and Polansky (1984) examined 13 cross-over studies published in *The New England Journal of Medicine* during 1978 and 1979. Nine of the 13 studies had sample sizes less than 20, five having 10 or less. The smallest study, by Raskin and Unger (1978), involved four diabetic patients undergoing two different

insulin infusion regimens. The authors monitored urea nitrogen excretion after each regimen for a total of eight measurements. Analysis using a matched pairs t-test yielded a t-statistic of 7.5 with 3 degrees of freedom, showing strong evidence of a statistical difference between the two regimens. According to Louis, Lavori, Bailor and Polansky in order to achieve the same degree of statistical difference using a parallel comparison, if the variation in response was the same, a sample size of 56 (28 in each treatment group) would be required.

This demonstrates a basic characteristic of cross-over designs that is also described by Senn (1993). To use his example, a cross-over design involving ten participants with a baseline reading and three different treatments on each would yield 40 observations. A parallel group trial would require 40 participants to obtain the same number of observations, but, as Senn points out, this data would not be as useful due to between-patient variation. By having each individual serve as their own control, between-patient variation is eliminated. However, due to the nature of the study, it is not possible to have each participant serve as their own control. This would require having the anesthetist participate in the same scenario for both treatments. The learning carry-over effect from the first simulation run to the second would be too great.

For this reason a *matching* procedure was utilized. According to Polit & Hungler (1999) matching "involves using knowledge of subject characteristics to form comparison groups" (p. 224). Matching offers the advantage of increased power, allowing for use of smaller sample sizes (Kraemer & Thiemann, 1987). It was proposed that matched pairs would serve as controls for each other and be recruited based on the

following characteristics: sex, years of experience as an anesthetist, and familiarity with the simulation center.

Taking all of this into consideration along with the resource constraints of time, money, and availability of study participants this pilot study engaged a sample size of four for a total of eight observations. A convenience sample of four study volunteers (two males and two females), all practicing anesthetists, were recruited from the Richmond, VA area. In each instance, once the first male and female were recruited, a search for an individual that fit the matched pair profile was initiated. Participation is this study was on a voluntary basis.

Randomization was achieved via coin tossing. On the first day of the study, a coin flip determined which anesthetist participated in the first simulation run and a second coin flip dictated whether or not a PDA was provided for that first simulation run. This initial coin toss determined subsequent order and PDA-use for the rest of the simulation runs so that each anesthetist participated in one scenario with a PDA and one without. For simulation runs without the PDA participants were instructed to manage the event using their own knowledge, beliefs, customary approaches, and experiences. For simulation runs with the PDA, participants were instructed to exercise use of a PDA during management of the event in addition to using their own knowledge, beliefs, customary approaches, and experiences.

Practicing anesthetists are busy, highly in-demand professionals. Therefore, in partial compensation for the lost workday, a small participation incentive of $500.00 was provided. Participants signed a nondisclosure agreement and were counseled on the need

not to discuss the study scenarios or methodology. Two subjects were studied each research day and sequestered from one another to further avoid information exchange.

Case Scenarios

Two patient care scenarios were developed for the purposes of this study. Experts in the domain of high fidelity human simulation participated in this development to establish high face validity. Within each scenario the patient's problem or condition, if left undiagnosed or uncorrected, could lead to a simulated critical incident. Scenario one incorporated increasing peak airway pressure during a general anesthetic with mechanical ventilation for a 72 year old, chronically hypertensive male taking nadolol (Corgard™) undergoing an inguinal herniorrhaphy (see Appendix A). A gradually increasing peak airway pressure, secondary to developing pulmonary edema from iatrogenic overhydration and anesthetic agent induced myocardial depression, was introduced. Following randomization, one male and one female anesthetist were instructed to routinely provide care to the "patient" and in the event of any unexpected manifestations, use an electronically summoned and directed protocol from the PDA. The remaining two anesthetists were instructed to routinely provide care to the "patient" and in the event of any unexpected manifestations employ their own knowledge, beliefs, customary approaches, and experiences in managing the incident.

A cross-over design was then implemented for the second scenario (see Appendix B). The two subjects who employed the PDA-driven protocol in the first scenario were instructed to manage a healthy 28 year old female in the post anesthesia care unit recovering from a general anesthetic for laparoscopic cholecystectomy without the PDA.

Alternatively, the two subjects who did not use the PDA for the first scenario were provided with one for the second scenario. Scenario two was complicated by delayed awakening secondary to profound hypoglycemia as a result of incidental, unrealized manipulation of an undiagnosed insulinoma (insulin-producing tumor of the pancreas).

The use of hypothetical case scenarios to evaluate clinical performance is not a new concept. It does raise the question of whether or not the clinician would respond similarly with a real patient under the same circumstances. The realism of decision making under risky, hypothetical circumstances has been studied by Wiseman and Levin (1996). In a series of three experiments involving either investment of time and effort, monetary gambling, or both, they examined risky decisions made by participants under real versus hypothetical conditions. In each of the three experiments the participants did not differ in their decisions between real and hypothetical conditions. This, along with earlier studies that have shown the predictive value of laboratory studies for real-world behavior (Irwin, McClelland, & Shulze, 1992; Norris & Devine, 1992; Spector, Cohen, & Penner, 1976), supports the proposed methodology. Use of case scenarios in the simulated environment also offers the added safety of removing real patients from experiments on clinical problem solving. Validity of the case scenarios is also an important issue and will be discussed in more detail in a later section.

Personal Digital Assistant

The independent (treatment) variable to be manipulated in this study was use of a PDA. As described earlier, four volunteer anesthetists participated in two scenarios each, one with a PDA and one without.

Two Dell™ Axim X5 model PDAs were purchased for use in this study. The PDA was programmed with a catalog of common and uncommon events that can arise during the course of anesthesia (See Appendix C). Some of these events were in the form of potential patient manifestations which may be caused by a variety of underlying factors (i.e. hypotension). Others were specific phenomenon, such as hyperthyroidism. This catalog was derived from both recognized literature (Bready, Mullins, Noorily, & Smith, 2000; Gaba, Fish, & Howard, 1994) and underwent rigorous review by a group of seven anesthesia-domain experts including both anesthetists and anesthesiologists.

It is acknowledged that a willingness to abandon personal styles of management in favor of a computerized approach may be difficult. Furthermore, any electronic protocol would need to be easy to use in addition to being readily available at the point-of-care. For this reason Adobe® Acrobat 5.0 was chosen as the software platform. Initially, the catalog of events was edited and formatted using Microsoft® Word 2002. Each topic on the menu list was programmed to hyperlink to the selected event content. At the end of the content for each event a hyperlink labeled 'back to top' was inserted to return the user back to the menu list. Once complete, the file was converted to portable document format (PDF) using Adobe® Acrobat 5.0. The file was evaluated, tested, and corrected to satisfaction of the researchers.

To simplify access to the catalog, the file was opened to the menu list for the participants. The catalog of events was presented in a scroll down menu form with the list of events in alphabetical order. After the participant selected a particular event by touching the PDA screen with the stylus, the event content appeared in the form of a

scroll-down window with diagnostic and interventional information categorized into clear, standardized, easy to use taxonomy. At the end of the content for each event touching the 'back to top' link with the stylus returned the display back to the menu list.

Preparation of Participants

All participants underwent a standardized familiarization briefing with the department's simulation director and received explicit instructions in the operation and use of the PDA. While participants with previous exposure to the simulator center were recruited, a standardized tour of the simulation center was provided along with an explanation of features and limitations of the mannequin (see Appendix D). A general description of activities for the day was also provided (see Appendix E). Participants were also be instructed to "think aloud", or verbalize their thoughts, during the simulation runs (Appendix F). A more detailed discussion of think aloud methodology is discussed later in this chapter. An informed consent form was reviewed with and signed by all participants.

High Fidelity Human Simulation

Background

Virginia Commonwealth University's Center for Research in Human Simulation is housed within the Department of Nurse Anesthesia. This full-scale, high fidelity simulation facility is state-of-the-art. Occupying 1300 square feet, it includes an operating room with adjacent area that can be used as a post anesthesia, emergency, or intensive care unit. Next to the operating room is the simulator control room, which houses the computer and audiovisual hardware, and provides a complete view of all

activities through a one-way mirror. Across the hall is a classroom/conference room with a closed circuit television and projection screen which allows live viewing of the simulation lab and also serves as a post-simulation experience debriefing area.

The Center for Research in Human Simulation has two full body patient simulators: the MedSim Patient Simulator and the Laerdal SimMan™ Universal Patient Simulator, both of which will be utilized in this study. MedSim Patient Simulator features include palpable pulses, audible heart and breath sounds, a realistic airway and lungs which exhale carbon dioxide, eyes that blink and respond to light, pain, hypoxia, and medications, and a delivery system for intravenous fluids and drugs. Insertion of central lines and chest tubes can be performed, as well as CPR. The left arm can be programmed to move and the right thumb will twitch in response to a nerve stimulator. Computer controlled management of vital signs including heart rate and rhythm, oxygen saturation, blood pressure, exhaled carbon dioxide can be manipulated based on the scenario and respond appropriately to over 80 different drugs. With special Drug Editor software, new drugs or agents can be added to the program. The Laerdal SimMan™ Universal Patient Simulator has most of the same features except that the eyes do not blink or respond, nor does it have left arm movement or right thumb twitch capability. Neither produces secretions of any kind or change skin color or temperature. A more detailed description of both simulators is provided in Appendix D.

Ancillary equipment in the Center includes a fully operational operating room table, a North American Drager Narkomed 2B anesthesia machine, Baxter and Imed multi-chamber infusion pumps, Hewlett Packard patient monitors, and a fully stocked

anesthesia cart. Separate emergency carts are maintained as well, including a difficult airway cart with multiple alternative airway management devices, a Malignant Hyperthermia Cart, and a Code Cart with defibrillator. A variety of other typical surgical and anesthesia equipment and supplies complete the simulated environment. For alternatives to operating room scenarios the center has an intensive care unit (ICU) bed, emergency room (ER) stretcher, neonatal isolette and pre-hospital care equipment.

Audiovisual recording is accomplished via four ceiling mounted video cameras and captures a variety of angles. Ceiling and wireless lapel microphones allow for clear and accurate recording of both room noises and conversations and individual verbalizations. Voice activated headsets are utilized by simulation faculty for communication while scenarios are in session. Facility space, equipment, and personnel are costly but essential for the Center's operation.

Authenticity and Validity

The realism of the hypothetical case scenarios and simulated environment are very important. Establishing validity of an instrument is extremely difficult (Polit & Hungler, 1999) and the simulated environment is no exception to this rule. The simulator center to be used has face validity in that it appears to portray what it sets out to portray. It was designed by practicing anesthetists to represent the natural environment as closely as possible. Responses from simulation-participant questionnaires, commenting positively on the 'realness' of the experience, support the assumption of face validity of high fidelity simulated environments (Gaba & DeAnda, 1988; Holzman, Cooper, Gaba,

Philip, Small, & Feinstein, 1995; Kurreck, Devitt, & McLellan, 2000; Kurrek & Fish, 1996).

Content validity refers to an instruments representativeness of all possible tasks or questions for a particular phenomenon or construct. The simulator centers design is based on accepted principles of patient management and technical and non-technical skills related to patient care. Incorporation of all aspects of the anesthesia environment, from the patient mannequin to the equipment and supplies to operating room staff allows for testing across a broad range of phenomenon. This supports the content validity of the simulated setting.

Criterion-related validity is concerned with the degree to which an instrument correlates with some other criterion. However, there must be a concrete, easily measured criterion to compare to the target instrument. Ideal evidence of criterion-related validity for the simulated environment would be improved performance in the clinical setting. Unfortunately, similar data collection in the clinical area would be difficult and time-consuming due to the rarity of adverse events and numerous variations in the task environment. While not impossible, this task is outside the scope of the proposed study.

Criterion-related validity can also be evaluated by testing groups that are expected to differ based on a known characteristic. Several studies comparing the performance of more and less experienced subjects in the simulated environment showed better performance by the more experienced group (Byrne & Jones, 1997; Devitt, et al., 1998; Forrest, Taylor, Postlethwaite, & Aspinall, 2002). While this study did not examine

anesthetists with varying degrees of clinical experience, this evidence does support the idea that high fidelity human simulation possesses construct validity.

Hotchkiss, Biddle, and Fallacaro (2002) examined the authenticity of the simulation environment. A group of three independent reviewers evaluated a total of 42 videotapes of student nurse anesthetists learning crisis management techniques in the simulated environment. A data collection tool was developed, face validated, and utilized for the study. A high degree of interrater reliability for the tool was established. Results showed the simulation environment to be reasonably realistic but with areas for improvement. Key concerns include the failure to convincingly portray the operating room "culture" and the high degree of anticipation displayed by the student anesthetist being videotaped. Reviewers rated the case scenarios as being very realistic, albeit brief (average tape length 22 minutes). The authors make the important point that until the authenticity of the simulator-based experience is fully established, the possibility of the simulated environment itself contributing to provider error cannot be ruled out. In order to further establish the authenticity of the simulation environment, a similar evaluation was performed for this study.

Conduct of the Study

Most studies have addressed the issue of speed to diagnosis in the form of yes/no questions (i.e. was diagnosis reached in a timely fashion?). This study evaluated speed to diagnosis as the actual time taken to reach the correct diagnosis. For this reason, consistency of the case simulations was crucial. Case scenarios were closely managed using simulator software and a predetermined timetable so the timing and sequence of

events during the each case scenario was as consistent as possible. Faculty and graduate assistant volunteers from the Department of Nurse Anesthesia filled the roles of operating room or post anesthesia recovery staff. Each volunteer was given a profile of the case and their specific role during the simulation (see Appendix A and B). A single individual performed the same role for every simulation in an effort to maintain consistency across simulations.

As discussed earlier, one of the disadvantages of the mannequin is its inability to simulate all possible patient manifestations. This was of particular concern for CS2 with regard to lung sounds. It was important to ensure that each participant received the same information across scenarios. For this reason an individual, hereon to be referred to as the 'simulator consultant', was incorporated into the simulated environment. The simulator consultant, an experienced anesthetist with a background in high-fidelity human simulation, was stationed in an unobtrusive location near the mannequin in CS1 to provide this clinical information. For CS2, the function of the simulator consultant was integrated into the role of the recovery room nurse. A panel of experienced anesthetists developed a list of possible questions related to the clinical presentation of the "patient" that might be asked by the participants. Content addressing these potential questions was added to the case scenario profiles (see Appendix A and B). If the participant asked a question not addressed on the list, the simulator consultant, also an experienced anesthetist, answered the question using his best judgment and added it to the profile for consistency across the rest of the scenarios. While this is not ideal, it was necessary to have a mechanism in place to address this issue. Participants were informed as to the

presence of the simulator consultant and encouraged to ask for clarification of any patient signs, symptoms or behavior (e.g. What am I hearing for lung sounds?).

Data Collection

Observation of Simulations

Relevant information during the actual simulation was recorded using a "Simulation Observation Data Collection Tool" (see Appendix G). This tool was developed by the primary investigator based on knowledge and expertise in the area under study. It was then reviewed by a panel of experts in the fields of high fidelity simulation training and evaluation to achieve consensus and establish high face validity. Audio-videotaping permitted subsequent, detailed review of the simulation runs and confirmation of observed data. The dependent (outcome) variables measured in this study and captured via the tool were as follows:

1. Time to identification of abnormal event – the time in minutes and seconds from the start of the simulation to the first indication (verbal or nonverbal) of recognition of an abnormal event
2. Time to correct diagnosis – the time in minutes and seconds from the start of the simulation to the participants first indication (verbal or nonverbal) of the correct diagnosis as stated in Appendix A
3. Time to definitive intervention – the time in minutes and seconds from the start of the simulation to the indication (verbal or nonverbal) of definitive intervention as stated in Appendix A

Data was also collected on the number of times the participant referred to the PDA, the total amount of time spent using the PDA, any occurrences of skill or knowledge-based error, and perceived anesthetist reactions to PDA use and the simulation environment. For the purposes of this study, skill and knowledge-based errors were defined as follows:

1. skill-based error (also referred to as a *slip* or *execution failure*)– takes place during the performance of an action that does not occur as planned (i.e. turning the wrong dial or grabbing the wrong syringe)
2. knowledge-based error (also referred to as a *mistake* or *planning failure*) – takes place when an action occurs as planned but is inappropriate (i.e. treating increased airway pressure with a bronchodilator when the actual cause is endobronchial intubation)

During the simulation the primary investigator completed the tool and then confirmed the findings by viewing the videotaped recordings.

Qualitative data was also collected by the primary investigator using an observation tool (see Appendix H) developed by Henrichs (1999). According to Polit and Hungler (1999) observation is a common, useful, versatile approach to data collection. The researcher can record the information through direct observation as the event actually occurs or via video recording. Observation also offers the advantage of collecting nonverbal (in addition to verbal) data (Creswell, 1994). Limitations of observation include observer bias, considered a significant problem by Polit and Hungler. A specific technique, called "bracketing", was performed to minimize this threat and is

discussed in the data analysis section of this chapter. Other potential limitations included unskilled researchers and distorted behavior due to participant awareness of being observed. Despite the disadvantages, it is a powerful and complementary tool for qualitative research.

Think Aloud Protocol

As described earlier, participants were instructed to think aloud, or verbalize their thoughts, during the simulation runs. The use of think aloud protocols are established within the literature but are not without criticism. One argument against this technique is higher level mental processes may not be accessible by the subject and therefore absent from verbal reports (Nisbett & Wilson, 1977). Proponents argue that verbal reports provide at least indirect evidence of the thought processes that produce them (Backlund, Skanuer, Montgomery, Bring, & Strender, 2003; Ericsson & Simon, 1980; Ericson & Simon, 1993; Hayes, 1982; Newell & Simon, 1972).

There is also the question of whether thinking aloud changes the individual's thought processes. In their experiments involving problems of logic, Newell and Simon (1972) addressed this issue and found that subjects performing under think aloud conditions performed similarly to those who didn't. Upon reviewing a large number of studies using think aloud methodologies, Ericsson and Simon (1980) concluded that think aloud data accurately reflect conscious verbal thought processes, and that verbalizing information only affects cognitive processes if instructions require verbalization of information that would otherwise not be attended to. They also presented a model within

the framework of IPT of how individuals verbalize information when instructed to think aloud which will be utilized for the proposed study.

Ericsson and Simon (1980) developed this model to aid in interpretation of verbal data. This model is based on the following assumptions:

1. human cognition is information processing
2. information is stored in several memories having different capacities and accessing characteristics (several sensory stores of short duration, a short-term memory (STM) with limited capacity and intermediate duration, and a long-term memory (LTM) with large capacity and relatively permanent storage)
3. information recently acquired or attended to by the central processor is kept in the STM and is directly accessible for further processing (e.g., for producing verbal reports), whereas information from LTM must first be retrieved and transferred to STM before it can be reported.
4. due to limited capacity of STM, only the most recently heeded information is accessible directly, but a portion of the contents may be fixated in the LTM before being lost and can sometimes be retrieved at a later point in time

Therefore, when the verbal data was obtained is related to the type of memory from which was drawn. In the case of think aloud instructions, the individual is verbalizing the information while it is being attended to in STM. In the case of retrospective reporting immediately after task performance, the model predicts that some information will still be in STM allowing for direct reporting and also some retrieval of episodic associations stored in LTM.

Another issue is the effect of thinking aloud on task performance. Ericsson and Simon (1984) propose that this depends on the type of information the participant verbalizes. Various processes, such as recoding or filtering, may occur between the attended information in the central processor and its corresponding verbal report. The authors categorize these into the following three levels of verbalization:

1. Level one verbalization – direct articulation of information stored in verbal form
2. Level two verbalization – articulation of information that must be encoded into verbal form
3. Level three verbalization – articulation of only a selected type of information (requiring scanning or filtering) or information that would not normally be attended to (requiring inference or generative processes)

According to the authors, the model predicts that level one verbalizations will not affect the cognitive processes nor slow the individual's task performance. Level three verbalizations would have substantial effects on cognitive processes and task performance, while for level two verbalizations they remain unaffected with little or no effect on task performance.

The think aloud protocol for this study required level one and possibly level two verbalizations. While much of the information attended to by the anesthetist naturally occured in the form of language, some visual and auditory information may have require conversion to names or labels. Ericsson and Simon (1984) point out that even for complex tasks verbalization can remain at level one, particularly if the individual is

familiar with the task environment. Instances of level two verbalizations could potentially slow task performance although this is not well described in the literature. The think aloud protocol served as more than just a means for verbal data collection, but also to direct simulator responses based on verbal reports of actions or interventions by the participant. It was also applied consistently across all simulations and subjects.

All participants were given typed instructions (see Appendix F), which were read aloud by the primary researcher and then followed by an opportunity for participants to request clarification or ask questions. The instructions involved a simple request for the participant to think aloud in an effort to elicit level one type verbalizations (Ericsson & Simon, 1993). All verbalizations were transcribed for subsequent analysis using process-tracing techniques.

Video-stimulated Recall

The idea of using videotape playback of and event to stimulate recall by an individual for use in therapy was first introduced in the literature by Kagan, Krathwohl, and Miller (1963). Later, Kagan (1973) further described this process as part of an educational program for students of counseling and psychotherapy. The goal of this technique is for the participant to recall as honestly and accurately their thoughts, feelings and reactions during the event. An important component of the technique involves the presence of a "facilitator", an individual who probes and encourages the participant to express this information. The facilitator must be nonjudgmental and non-critical, but at the same time assertive and confrontational in a non-hostile manner.

In their research of diagnostic reasoning by physicians, Esltein, Shulman, and Sprafka (1978) used video-stimulated recall in an attempt to further elucidate the thoughts, feelings, associations and strategies occurring in the physician's mind at any given moment during the playback. As discussed earlier, this, along with other forms of data collection led to development of a model of diagnostic reasoning. Video-stimulated recall will be used in a similar manner in this study to examine the extent to which this model describes the diagnostic reasoning processes of anesthetists. The primary investigator served as recall facilitator. The session was tape-recorded and transcribed for subsequent analysis using process tracing techniques.

Group Interviews

In order to explore participant perceptions of PDA use and the simulator experience, a semi-structured focus group interview served as one mode of qualitative data collection for this study. Phenomenologic studies often involve interviewing as a data collection strategy with anywhere from one to a few hundred participants, although 3 to 10 is typically recommended (Creswell, 1998). Creswell describes focus group interviews as advantageous when interviewees are similar and cooperative with each other. Under these circumstances, their interaction may yield enhanced information in a shorter period of time. Creswell recommends the following for these types of interviews:

1. Adequate recording procedures
2. Use of an interview protocol or topic guide
3. A quiet location free of distractions

4. During the interview, follow the protocol, complete within the time specified, be respectful, courteous, and a good listener, and refrain from offering advice or comments

Two semi-structured focus group interviews (two participants each) were conducted at the end of each research day. Key areas of interest included:

1. The ease or difficulty of using the PDA.
2. The ease or difficulty associated with incorporating the PDA into the diagnostic and interventional care of the patient.
3. The realism of the simulated operating room setting.
4. The realism of the simulator mannequin.
5. The realism of the case scenarios.

A standardized topic guide with a list of areas and questions to be covered was utilized (see Appendix I). The sessions were tape-recorded and transcribed for subsequent analysis.

Videotape Coding Instrument

With their permission, Hotchkiss, Biddle, and Fallacaro's (2002) videotape coding instrument, with some modification based on needs of this study and their recommendations, was used (see Appendix J). The tool has both quantitative and qualitative type questions. Three practicing anesthetists with no experience in full-body simulation training were recruited to review each of the 8 videotapes. A training session to educate and familiarize the reviewers with the simulation center and the coding

instrument was conducted prior to video review. The results were analyzed and the modified tool assessed for interrater reliability.

Participant Evaluation Form

The study participants were also asked to complete a similar, appropriately modified videotape coding instrument (see Appendix K). The tool has both quantitative and qualitative type questions. Each participant completed one evaluation for each of the two scenarios. Where appropriate, responses between the reviewers and participants were compared. As described earlier, qualitative data from this tool was combined and analyzed with observations by the primary investigator during the simulator runs and structured group interview results to explore participant perceptions of PDA use and the simulation experience.

Data Analysis

Quantitative Data

Data analyses from all questions are reported using descriptive techniques in the next chapter. A summary of case scenario occurrences with corresponding times are presented in table format. Simulation Observation Tool results were analyzed and presented in the following manner. Data from questions one through five of this tool are ratio level data in the form of time in minutes and seconds which were converted to the nearest hundredth of a minute (i.e. 11 min 45 sec → 11.75 min). Results from questions six through eight also provide ratio level data, and along with questions one through five are summarized using measures of central tendency and variability. The nominal measurements from questions nine through twelve are reported as frequencies and

percentages. Descriptive analysis is useful in providing information about the characteristics of a topic of interest, but it does not allow for assumptions regarding causality.

For the benefit of the primary researcher, inferential statistical analysis was also performed on the ratio level data from questions one through five in order to demonstrate how it would be performed in a larger sample. As an added exercise, analysis was performed both by hand and via a statistical software package (SPSS® Graduate Pack 10.0 for Windows®). No attempts to make inferences from the sample population are made, but results are presented and interpreted in a hypothetical manner. For this purpose, an alpha of $p<0.05$ represented the threshold for group differences. The following are presented as null hypotheses that would be tested in this exercise:

H_1: There will be no observable difference in time to reach the correct diagnosis by anesthetists using PDAs compared to anesthetists not using PDAs in the simulated case scenarios.

H_2: There will be no observable difference in time to institute definitive treatment based on the correct diagnosis by anesthetists using PDAs compared to anesthetists not using PDAs in the simulated case scenarios.

The data was first analyzed using a matched pairs *t*-test as described by Senn (1993). In analyzing the data in this way, the following assumptions are made:

1. cross-over differences are distributed at random about the true treatment effect
2. the data are approximately normally distributed

As described earlier, each participant's matched partner served as their control as shown in Figure 5.

	PDA	No PDA	Cross-over difference
Case scenario 1	Female 1 (F1)	Female 2 (F2)	F1 – F2
	Male 1 (M1)	Male 2 (M2)	M1 – M2
Case scenario 2	Female 2 (F2)	Female 1 (F1)	F2 – F1
	Male 2 (M2)	Male 1 (M1)	M2 – M1

Figure 5. Diagram of Matched Pairs *t*-test

The fact that matched pairs served as controls for each other (instead of each individual serving as their own control) and that two different scenarios were used introduces the potential that cross-over differences may not be distributed at random. Each anesthetist participated in case scenario one (CS1) first. This could not be avoided due to the small sample size and the importance of varying the treatment sequence (PDA vs. No PDA). This introduces the possibility of a period, or trend, effect. In order to assess for the possibility of period effects a two-sample *t* approach was used and is laid out in Figure 6. By comparing the means of the cross-over differences for the two sequences we can examine the treatment effect while adjusting for period effects. If the results are similar to the matched pairs *t*-test it would be suggestive of an absence of period effects.

Testing for carry-over effects in cross-over designs is controversial. Senn (1993) argues that tests for carry-over are "virtually impossible to interpret reasonably independently of the treatment effect" (p. 13). He sites numerous references to support his claim. Instead, he urges that carry-over should be dealt with in the design of the

Sequence			
CS1		CS2	
PDA/No PDA		No PDA/PDA	
Matched pair	Cross-over difference	Matched pair	Cross-over difference
F1/F2	F1-F2	F2/F1	F2-F1
M1/M2	M1-M2	M2/M1	M2-M1

Figure 6. Diagram of Two-sample *t* Approach Adjusting for Period Effect

study. The issue of carry-over as it relates to this study has been discussed earlier in this chapter. Strategies to attenuate carry-over were incorporated into the design and limitations were acknowledged.

The nominal, dichotomous data from questions nine through twelve were analyzed using McNemar's test (Burns & Grove, 1993, Jones & Kenward, 1989). The McNemar test is appropriate for before and after or cross-over type trials where the groups to be compared are dependent. It would be desirable to know if there was a difference in the behavioral reaction to the simulation environment between the two scenarios. With the "yes" and "no" responses indicated as "+" and "-" respectively, a contingency table is constructed in Figure 7. Subjects whose scores changed from positive to negative from CS2 to CS1 are tallied in cell A and vice versa for cell D. Values in cells B and C represent scores that remained unchanged and are not included in the analysis. The binomial distribution as described by Jones and Kenward would be used to evaluate a null hypothesis that there is no difference in perceived behavior of participants between CS1 and CS2. It must be emphasized again that this inferential analysis was performed as an exercise and example, not to draw conclusions.

		CS 1	
		-	+
CS 2	+	A	B
	-	C	D

Figure 7. Diagram of 2 x 2 Contingency Table for the McNemar Test

Quantitative data from the videotape coding instrument was analyzed in a manner similar to Hotchkiss, Biddle, and Fallacaro's (2002) original study. Frequency and percentage distributions were calculated for all questions. Interrater reliability of the reviewers was assessed using the kappa coefficient (κ). The κ statistic is described by Carletta (1996) as a uniform measure of reliability with the advantage of correcting for expected chance agreement. It serves to assess agreement among a set of coders based on categorical data using the following equation:

$$\kappa = (P(A) - P(E))/(1 - P(E))$$

where P(A) is the proportion of times that the coders agree and P(E) is the proportion of times the coders would be expected to agree by chance. A κ of zero indicates no agreement other than that which would be expected by chance, while a κ of one signifies total agreement. It is generally agreed that $\kappa > .8$ demonstrates good reliability, with $.67 < \kappa < .8$ suggesting fair reliability (Carletta, 1996).

Qualitative Data

Qualitative data from observations by the primary investigator during the simulator runs, written comments by the participants from evaluation forms, and the semi-structured group interviews were evaluated in the following manner. As opposed to quantitative analysis, data collection, analysis, and interpretation often occur

simultaneously with the qualitative approach (Cresswell, 1994). Collection of information, categorization and formatting of the information, and writing of the qualitative text can take place at the same time. First, however, bracketing, or epoche, was performed to minimize researcher bias. Epoche is a term from Greek philosophy and refers to suspension of judgment. Moustakas (1994) describes it as a process whereby any preconceived perceptions, preferences, judgments and feelings are set aside. It requires a period of attention and concentration during which the investigator can review his or her thoughts and set aside biases and prejudgments. Moustakas recommends that this procedure be repeated as necessary to ensure and open and receptive outlook.

The process of intuiting was performed next. This involved immersion into the phenomenon under investigation and being open to the meanings attributed to the phenomenon by those who experienced it. All data was transcribed and read by the primary investigator. From this major ideas and themes were noted and a general description of the experiences was written. The observation notes, evaluative comments, and transcribed interview sessions were then reviewed a second time. Any additional ideas or thoughts about the underlying meanings were added.

The primary investigator then transitioned to the analyzing phase. As explained earlier, the data analysis methods described by Creswell (1994) and Moustakas (1994) were used to explore participant perceptions of PDA use and the simulation experience. *Horizonalization* was performed first, where the original protocols were divided into statements. Each statement was treated as having equal value. From this, a list of nonoverlapping, nonrepetitive statements was developed. As described by Moustakas, a

process of *reduction and elimination* was performed on all statements. Each statement was evaluated for two requirements:

1. Does it contain a moment of the experience that is a necessary and sufficient constituent for understanding it?
2. Is it possible to abstract and label it? (p.121)

Expressions not meeting the above criteria were deleted, along with overlapping, repetitive, and vague statements. Those remaining were considered horizons, or invariant constituents, of the experience.

The invariant constituents were categorized into *clusters of meaning* (Creswell, 1998). Within each cluster, the statements were separated into columns based on similarity and interrelatedness. A review of the original data was performed to see if any new statements or clusters needed to be added. The clustered constituents were then considered and given a thematic label. Validation of these core themes was performed by confirming them against the original data. Themes that were not explicitly expressed or compatible with the original data were eliminated.

Once this was completed a *textural description* of what was experienced, including verbatim examples, was written next to each cluster. This was followed by reflection and then a *structural description* of possible meanings and perspectives of how the phenomenon was experienced. Moustakas (1994) defines this as "a vivid account of the underlying dynamics of the experience" (p. 135). Finally, the primary researcher constructed an overall report, or *exhaustive description*, of the meaning and essence of the experience.

The process-tracing data analysis methods described by Svenson (1989) were used to evaluate the diagnostic reasoning processes of the participants. Data for this analysis included think aloud verbalizations from simulation runs and retrospective verbal reports from video-assisted recall sessions. First, a representation system, or cognitive model, that reflected the research problems addressed by the study and the prior knowledge in the area under investigation was. The model of diagnostic reasoning developed by Elstein, Shulman and Sprafka (1978) discussed in the previous chapter served as the representative system for this analysis. It consists of four major activities and is shown in Figure 8.

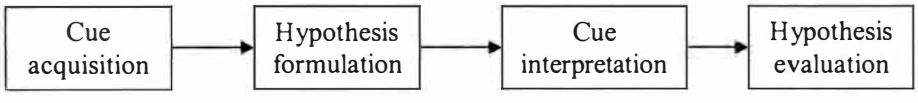

Figure 8. Model of Diagnostic Reasoning

As explained by Svenson, the smallest units of a representative system are called *primitives*. These primitives are related to their corresponding elements in the verbal protocol. Elstein, Shulman and Sprafka identified three fundamental units, or primitives, in describing diagnostic reasoning of physicians:

1. Information search units – data gathering behavior, any statement or act that seeks information
2. Cues – data or findings
3. Hypothesis – formulations of possible solutions to a problem

A coding scheme was also identified. According to Svenson (1989) "coding scheme units are chosen on practical grounds related to the quality of the protocols and the problem being investigated" (p. 72). This would suggest that choice of the coding scheme occurs after initially viewing the transcribed records. As described by Svenson (1989) the following guidelines for transcription of the audiotaped verbalizations were used:

1. a period when a sentence is considered finished
2. a series of three periods (...) for pauses longer than five seconds
3. a new paragraph when the subject moves from one alternative to another

Sentences and/or turns in dialogue served as the smallest unit. A schematic representation of the relationship between the representative system, coding scheme, verbal protocols and coded protocols developed by Svenson (p. 74) is presented in Figure 9.

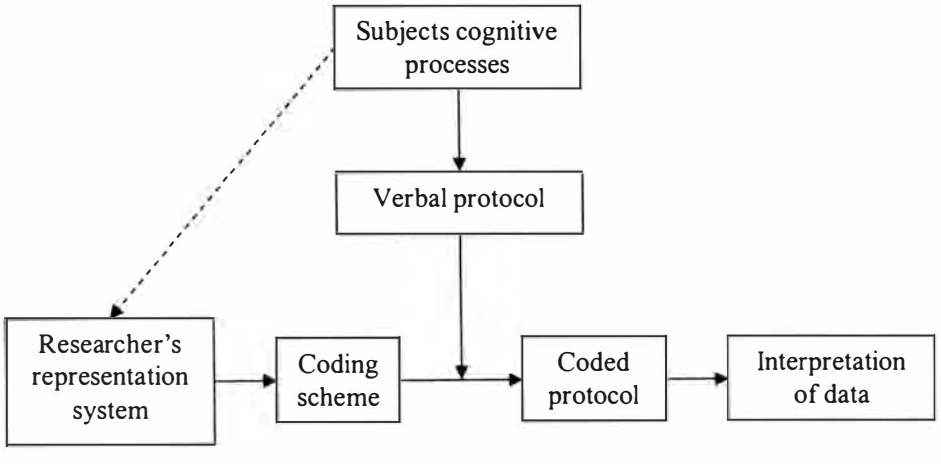

Figure 9. Diagram of Process Tracing Method

Once the verbal protocol was been broken down into the smallest coding scheme units, each unit was classified using the primitives described earlier. Occasionally, a single unit contained one or more primitives from the representative system. When this occurred, categorizations were weighted in the following manner: hypothesis > cue > information search unit. This type of priority ordering is recommended by Svenson as a means to enhance reliability. Whether or not these verbal reports could be classified according to the representative system was the primary question of this section of data analysis.

Post Hoc Analyses

The performance of post hoc analyses were performed when insights obtained from the planned analysis raised further questions that could be investigated using the collected data. These analyses may be peripherally related to the original purpose of this study, but still useful in providing additional information and in developing suggestions and ideas for future research.

Summary

The approach to a clinical conundrum or patient care issue guided by the PDA is not meant to be a perfect model. A "perfect" approach assumes many things, some of which may be unknowable. What is provided by the PDA is an expert consensus panel strategy that facilitates a systematic approach to the issue at hand, triggering appropriate intervention in the face of common or uncommon root causes. While not replacing clinician decision making, it offers point-of-care referencing, consultation and direction so that no path that has merit remains unexplored. The simulated environment is also not

a perfect substitute for the actual clinical setting but due to the rarity of critical events and concern for patient safety it allows for research that otherwise might not be accomplished. It was hoped that this study will further establish and provided additional insight into the simulated environment as a research tool in the field of anesthesia.

CHAPTER 4 – RESULTS

Introduction

This chapter contains results of the quantitative and qualitative analyses conducted in this research. Descriptive statistics from the case scenarios, participant evaluation form, and videotape coding instrument as well as results from inquiries into participant perceptions of PDA use and the simulated environment and diagnostic reasoning are presented.

Quantitative Results

Case Scenarios

All verbal data and relevant nonverbal actions from each of the eight videotaped case scenarios were transcribed. A digital clock was superimposed onto the monitor screen and recorded on the videotape. A consistent start time was identified for each case scenario and clock readings were converted to correspond with a zero start time. Times were documented at each instance where a relevant verbalization or action occurred. The action or verbalization is listed next to the corresponding time. This information is displayed for each participant (A, B, C, & D) in Tables 1 through 4 for case scenario one (CS1, in the simulated operating room environment) and Tables 5 through 8 for case scenario two (CS2, in the simulated post-anesthesia care unit environment).

Table 1

Relevant CS1 Times for Participant A (no PDA)

Time (min:sec)	Action
00:00	Start of Scenario
00:09	Report started
02:42	Report finished
02:50	Auscultates lungs
04:39	RN asks for start times
06:12	Notes drop in oxygen saturation, auscultates lungs
05:54	Auscultates lungs
07:09	Auscultates lungs
07:44	Auscultates lungs
08:31	Administers albuterol
09:17	Notes increased airway pressures
09:59	Auscultates lungs
10:23	Crackles introduced
12:31	PAP 40-50
12:50	Auscultates lungs
12:54	Diffuse crackles
13:19	Suctions endotracheal tube
13:56	Small amount clear secretions
16:04	Auscultates lungs
16:09	Increasing crackles
16:15	States intention to give furosemide, "sounds wet"
16:59	Administers furosemide
17:05	End of scenario

Key: RN – registered nurse; PAP – peak airway pressure (cm H_2O)

Table 2

Relevant CS1 Times for Participant B (PDA)

Time (min:sec)	Action
00:00	Start of scenario
00:11	Report started
01:50	Report finished
02:03	Auscultates lungs
02:22	Distant wheeze
05:45	RN asks for times
07:05	Notes decrease in oxygen saturation
07:22	Auscultates lungs
07:34	Distant wheeze
10:17	Notes decrease in oxygen saturation
10:36	Notes increased PAP
10:58	Auscultates lungs
11:09	Distant wheeze
11:57	Administers albuterol
12:12	Notes very high PAP
14:15	Notes decreased sat
14:34	Refers to PDA
14:49	Notes high PAP
17:25	Suctions
17:28	Small amt. clear secretions
18:11	Notes decrease in compliance & oxygen saturation
18:39	Auscultates lungs
18:48	Diffuse crackles
20:30	Refers to PDA
22:13	Considers pulmonary edema
23:30	Auscultates lungs
23:42	Crackles and rales
25:45	Administers positive end-expiratory pressure
27:40	Suctions endotracheal tube
27:53	Large amt. pink-tinged secretions
29:38	States desire to diurese
29:43	Administers furosemide
29:48	End of Scenario

Key: RN – registered nurse; PAP – peak airway pressure (cm H_2O)

Table 3

Relevant CS1 Times for Participant C (PDA)

Time (min:sec)	Action
00:00	Start of Scenario
00:11	Report started
02:35	Report finished
03:17	RN asks for times
03:34	Auscultates lungs
03:46	Distant expiratory wheezing
03:53	PAP 22
06:46	Auscultates lungs
07:13	PAP 38
07:16	Notes increased PAP
07:28	Distant wheezing
07:31	Refers to PDA
08:19	PAP 39
09:51	Suctions patient
10:10	Trace clear secretions
10:30	Auscultates lungs
10:48	Distant wheezing
10:54	Notes very high PAP
11:21	PAP 51
13:22	PAP 37 (hand ventilating)
13:51	PAP 51
16:51	PAP 37 (hand ventilating)
16:07	PAP 40
16:51	Auscultates lungs
17:03	Crackles
17:59	Administers albuterol
18:51	PAP 32 (hand ventilating)
19:20	Auscultates lungs
19:42	Diffuse and worsening crackles
20:26	States desire to give furosemide
22:41	Auscultates lungs
22:58	Decreased compliance, worsening crackles
23:31	Administers furosemide
23:36	End of Scenario

Key: RN – registered nurse; PAP – peak airway pressure (cm H_2O)

Table 4

Relevant CS1 Times for Participant D (no PDA)

Time (min:sec)	Action
00:00	Start of scenario
00:21	Report started
02:28	Report finished
02:39	Auscultates lungs
03:00	Slight expiratory wheeze
03:17	RN asks for start times
06:28	Auscultates lungs
06:44	Slight expiratory wheeze
06:51	Notes decreased oxygen saturation
07:26	Administers albuterol
09:58	Auscultates lungs
10:18	Slight crackles, distant wheezing
10:45	Notes urine output, fluid intake
11:22	Notes increased PAP
11:26	Auscultates lungs
11:41	Expiratory wheezing, no crackles
11:54	Notes decreased sat
11:33	Notes increased PAP
14:46	Administers 2ccs pentothal
15:57	Auscultates lungs
16:13	Diffuse crackles and wheezing
17:03	States intention to draw up furosemide
17:13	Administers 10mcgs epinephrine
17:20	Draws up furosemide
18:47	Notes increased PAP
19:05	Sends blood gas to lab
19:31	Auscultates lungs
19:55	Diffuse moist rales and wheezing
20:15	Administers furosemide
20:22	End of scenario

Key: RN – registered nurse; PAP – peak airway pressure (cm H_2O)

Table 5

Relevant CS2 Times for Participant A (PDA)

Time (min:sec)	Action
00:00	Start of Scenario
00:03	Report started
00:37	Report finished
01:08	Auscultates lungs
02:04	Mentions narcotics
02:20	Refers to PDA - delayed awakening
02:32	Asks about preoperative status
03:09	Assesses patient responsiveness
03:38	Asks if RN gave any medications
03:40	RN gets blanket for patient
04:07	Mentions intraoperative events
04:53	Asks if anesthetist who did case is available
05:10	Mentions preoperative status
05:25	Mentions surgical risk for neural injury
06:04	Mentions prolonged sedation
06:10	Mentions history of drug problems
06:18	Mentions neuromuscular blockade, asks for nerve stimulator
07:27	RN checks TOF, sustained tetanus (at participant A's request)
08:01	RN performs sternal rub
08:10	Mentions sensitivity to medications
08:34	Mentions electrolyte imbalance, hypothermia, hypoxia
09:12	RN mentions elderly patient with hypokalemia
09:41	Mentions sending labs
09:50	Asks for electrolytes
09:58	Asks for blood gas
10:30	Asks for a glucose
11:18	Labs sent
13:40	Lab results
13:55	Asks for dextrose
14:03	States glucose is 52 mg/dl
14:19	Mentions hypoglycemia
14:31	Administers 50% dextrose
14:36	End of scenario

Key: RN – registered nurse; TOF – train-of-four

Table 6

Relevant CS2 Times for Participant B (no PDA)

Time (min:sec)	Action
00:00	Start of scenario
00:09	Report started
01:01	Report finished
01:34	Asks if RN has given her any medications
01:42	Check vital signs, oxygen saturation
02:49	Asks for chart
02:53	RN asks for blanket
03:11	Mentions patient history of asthma
03:25	Assesses responsiveness
03:51	Asks about intraoperative events
04:05	Auscultates lungs
04:56	Mentions narcotics
05:11	Asks about respiratory status
05:34	Asks about preoperative status
05:55	Mentions neuromuscular blockade, asks for nerve stimulator
06:10	Mentions inhalation agent
06:42	Asks RN to call surgeon
06:44	Checks TOF
07:33	Asks about alcohol history, mentions possibility of intoxication
08:55	Asks about basic neurological status
09:47	RN mentions elderly patient with hypokalemia
10:18	Mentions sending labs
11:21	Mentions neurology consult
12:13	Asks for electrolytes
12:20	Asks for hemoglobin
12:54	Labs sent
14:07	Mentions allergic reaction
14:34	Mentions flumazenil
14:42	Mentions narcan
14:46	Lab results
17:07	Asks for flumazenil
19:12	Administers 1mg flumazenil
20:10	Administers 1mg flumazenil
22:24	Asks for narcan

Table 6 (continued)

23:46	Reviews patient history
23:56	Administers 0.04mg narcan
25:14	Reviews anesthesia record, mentions myasthenia gravis
25:47	Mentions possible neuromuscular disease
26:38	Administers 0.04mg narcan
27:24	RN mentions young patient with atropine overdose
27:30	Mentions central anticholinergic syndrome
27:46	Mentions physostigmine
28:47	Administers 0.04mg narcan
29:23	End of scenario

Key: RN – registered nurse; TOF – train-of-four

Table 7

Relevant CS2 Times for Participant C (no PDA)

Time (min:sec)	Action
00:00	Start of Scenario
00:03	Report started
01:00	Report finished
01:08	Assesses patient responsiveness
01:13	RN performs sternal rub
01:49	Checks vital signs, oxygen saturation
02:10	Mentions narcotics, neuromuscular blockade, reversal, ondansetron
02:38	Asks about patient history
02:45	Mentions birth control pills
02:48	N asks for blanket
02:55	Mentions albuterol
03:21	Mentions reversal, good respiratory rate
04:54	Ask about preoperative meds by patient
05:01	Mentions narcan
06:03	Auscultates lungs
07:31	Administers 0.02mg narcan
08:22	Mentions possible causes (inhalation agent, narcotics, blood pressure)
09:02	Asks about intraoperative vital signs
10:08	Administers 0.02mg narcan
12:01	Asks if RN gave any medications
12:23	Asks RN to call surgeon
12:59	Asks for Physicians Desk Reference
13:24	RN mentions elderly patient with hypokalemia
13:30	RN mentions young patient with atropine overdose
14:01	Mentions possible drug interactions
15:25	Mentions risk for deep vein thrombosis with birth control pills
17:23	Mention checking labs
18:19	Mentions flumazenil
19:17	Mentions air embolus
19:36	Administers 0.5mg flumazenil
20:43	Asks about compression stockings
21:40	Asks about neurology consult

Table 7 (continued)

23:00	Administers 0.5mg flumazenil
24:00	Mentions drawing labs
25:33	Asks for electrolytes and glucose
25:49	Labs sent
27:26	Lab results
27:34	States glucose is 41 mg/dl
27:51	Asks for lab to repeat test
28:01	Asks for dextrose
28:56	Mentions possible accidental insulin administration
29:16	Administers 50% dextrose
29:19	End of scenario

Key: RN – registered nurse; TOF – train-of-four

Table 8

Relevant CS2 Times for Participant D (PDA)

Time (min:sec)	Action
00:00	Start of scenario
00:08	Report started
00:56	Report finished
00:58	Asks about narcotics
01:37	Asks about patient history
02:47	Assesses responsiveness
03:43	Refers to PDA - delayed awakening
03:55	Mentions intraoperative events
04:18	Checks current vital signs
04:25	Mentions inhalation agent
04:46	Mentions prolonged drug effect, recreational drug use, hypercarbia
05:08	Mentions blood gas
05:29	Mentions hypoglycemia
05:43	Mentions albuterol, versed
05:58	Asks for glucose
06:24	Asks for electrolytes, hemoglobin
07:07	Labs sent
07:49	RN mentions elderly patient with hypokalemia
08:03	RN mentions young patient with atropine overdose
08:27	Lab results
08:33	States glucose is 52 mg/dl
08:52	Asks for 50% dextrose
10:32	Administers 50% dextrose
10:36	End of scenario

Key: RN – registered nurse

Tables 9 and 10 summarize definitive moments in each scenario for all four study participants. Case scenarios were limited to a maximum duration of 30 minutes. If the participant did not perform a listed action before the scenario was ended it is indicated in

the table as 'NP' for 'not performed'. First verbalization of an abnormal event included decrease in oxygen saturation or increase in peak airway pressures.

Table 9

Definitive Moments for CS1

Time (min:sec)				
A, no PDA	B, PDA	C, PDA	D, no PDA	Action
NA	14:34	07:31	NA	First refers to PDA
06:12	07:05	07:16	06:51	First verbalization of abnormal event
08:31	11:57	17:59	07:26	Administers albuterol
10:23	18:48	17:03	10:18	Crackles introduced
16:15	22:13	20:26	10:42	Mentions pulmonary edema*
16:15	29:38	20:26	17:03	Mentions furosemide
16:59	29:43	23:31	20:15	Administers furosemide

Key: NA – not applicable; * or symptoms of pulmonary edema

Table 10

Definitive Moments for CS2

Time (min:sec)				
A, PDA	B, no PDA	C, no PDA	D, PDA	Action
02:20	NA	NA	03:43	First refers to PDA
10:30	NP	25:33	05:58	Asks for glucose
14:19	NP	22:57	05:29	Mentions hypoglycemia
14:03	NP	27:34	08:33	States results of glucose
13:55	NP	28:01	08:52	Asks for 50% dextrose
14:31	NP	29:16	10:32	Administers 50% dextrose

Key: NA – not applicable; NP – not performed

Simulation Observation Data Collection Tool

Values for some items were recorded during the actual simulation run. Others were obtained from viewing the videotaped recordings. The complete tool can be viewed in Appendix G. Tables 11 and 12 present results from the first three questions. Values in

Table 11

Simulation Observation Data Collection Tool – CS1, Questions 1-3

First recognizes abnormal event			
	Mean (min)	Range (min)	SD (min)
Overall	6.85	1.07	0.47
With PDA	7.18	0.19	0.13
Without PDA	6.53	0.65	0.46
First indicates correct diagnosis			
Overall	17.40	11.25	5.12
With PDA	21.33	1.79	1.27
Without PDA	13.48	9.45	3.92
Provides definitive treatment			
Overall	22.62	12.74	5.44
With PDA	26.62	6.20	4.38
Without PDA	18.62	3.27	2.31

Table 12

Simulation Observation Data Collection Tool – CS2, Questions 2 & 3

First indicates correct diagnosis			
	Mean (min)	Range (min)	SD (min)
Overall	18.19	24.52	10.62
With PDA	9.9	8.84	6.25
Without PDA	26.48	7.05	4.99
Provides definitive treatment			
Overall	21.18	19.47	10.13
With PDA	12.53	3.99	2.82
Without PDA	29.84	0.33	0.23

minutes and seconds were converted to the nearest hundredth of a second for statistical calculation. For each case scenario mean time, range and standard deviation values are given for all participants (overall) and then broken down into groups of those who used the PDA during the scenario (with PDA) and those who did not (without PDA). Values

for question 1 were not calculated for CS2 due to the anesthetist being informed by the RN that something is abnormal with the patient during report at the start of the scenario. For CS2, calculations were made using an assigned time of 30 minutes (the maximum scenario time) if the action was not performed as indicated in Table 10.

Data on instances of PDA use were collected in questions four, five and six. Results are presented in Tables 13 through 18. Results to question four, the start and end times of each PDA use and the actual time spent during each use, are presented in Tables 13 through 16 for each participant. Values are calculated based on a zero start time (i.e. in Table 13 participant B picked up the PDA for the first time 14 minutes and 34 seconds into the scenario, used it for 12 seconds, and set it back down 14 minutes and 46 seconds into the scenario). Questions five and six, the total number of uses (each time the participant started using the PDA and then stopped using it constituted one use) and total time spent using the PDA, are presented in Table 17. Results are first given by case scenario and each participant separately. The overall mean and standard deviation across case scenarios was also calculated.

Table 13

Simulation Observation Data Collection Tool – Question 4, CS1, Participant B

PDA use	Start (min-sec)	Finish (min-sec)	Actual time (min-sec)
First	14:34	14:46	0:12
Second	14:59	15:29	0:30
Third	20:30	21:13	0:43
Forth	21:32	22:30	0:58
Fifth	22:58	23:06	0:08
Sixth	24:29	24:35	0:06
Seventh	24:58	25:23	0:25

Table 14

Simulation Observation Data Collection Tool – Question 4, CS1, Participant C

PDA use	Start (min-sec)	Finish (min-sec)	Actual time (min-sec)
First	08:15	09:14	0:59
Second	11:11	11:42	0:31
Third	12:05	12:58	0:53
Forth	13:28	14:23	0:55
Fifth	14:46	15:49	1:03
Sixth	17:27	17:46	0:19
Seventh	18:24	19:08	0:44
Eighth	19:25	19:36	0:11

Table 15

Simulation Observation Data Collection Tool – Question 4, CS2, Participant A

PDA use	Start (min-sec)	Finish (min-sec)	Actual time (min-sec)
First	02:26	02:38	0:12
Second	04:07	04:12	0:05
Third	05:09	05:35	0:26
Forth	05:43	06:11	0:28
Fifth	06:26	06:34	0:08
Sixth	06:54	07:10	0:16
Seventh	08:36	09:33	0:57
Eighth	10:19	10:23	0:04
Ninth	10:41	11:11	0:30
Tenth	11:30	11:40	0:10

Table 16

Simulation Observation Data Collection Tool – Question 4, CS2, Participant D

PDA use	Start (min-sec)	Finish (min-sec)	Actual time (min-sec)
First	03:43	03:59	0:16
Second	04:24	04:52	0:28
Third	05:03	05:10	0:07
Forth	05:17	05:36	0:19
Fifth	05:51	05:58	0:07
Sixth	06:06	06:23	0:17
Seventh	07:16	07:30	0:14
Eighth	09:00	09:13	0:13
Ninth	09:41	09:47	0:06
Tenth	10:00	10:08	0:08

Table 17

Simulation Observation Data Collection Tool – Questions 5 & 6

	CS1		CS2		CS1 & CS2	
	B	C	A	D	Mean	SD
Total PDA uses	7	8	10	10	8.75	1.5
Total time spent using PDA (min-sec)	3:02	5:35	3:16	2:15	3:32	1:26

Key: SD – standard deviation

Questions seven and eight document the number of skill-based and knowledge-based errors made respectively. Skill-based errors occur when the performance of an action is not executed as planned (i.e. flipping the wrong switch). Knowledge-based errors take place when an action occurs as planned but is inappropriate (i.e. providing the correct treatment for a diagnosis that is incorrect) and generally occur due to failure of higher-order cognitive processes. No skill-based errors by the participants were observed in any of the scenarios. Instances of knowledge-based errors are presented in Table 18:

Table 18

Knowledge-based errors

	CS1		CS2	
	PDA	no PDA	PDA	no PDA
# of knowledge-based errors	4	6	0	4

Using the stated definition and with the correct diagnosis of pulmonary edema for CS1 and hypoglycemia for CS2, the following acts were classified as knowledge-based errors:

For CS1
1. Administration of albuterol
2. Increasing inhaled anesthetic agent
3. Administration of thiopental
4. Administration of epinephrine

For CS2
1. Administration of narcan
2. Administration of romazicon

It is important to point out that in a clinical setting it is unlikely these acts would have resulted in permanent patient injury. It has been suggested if no harm occurs as the result of an act, then no error occurred (Cook & Woods, 1994). A more detailed discussion of these issues are presented in chapter five.

Questions nine and ten relate to PDA use and ask whether the participant appeared to easily incorporate the PDA into their care of the patient and whether they had any difficulty using the PDA. For both scenarios all participants appeared to easily incorporate and have no difficulty using the PDA. Questions 11 and 12 ask if the participant appeared to 'suspend disbelief' during the simulated case scenarios or appeared distracted by the simulated environment. From the primary researcher's

perspective, for both scenarios all participants appeared to 'suspend disbelief' and did not seem distracted by the simulated environment.

The following statistical analyses were an exercise for the benefit of the primary researcher. No inferences or conclusions based on sample population were or should be drawn, but result values were interpreted to demonstrate understanding of the analyses. The small sample size limits representativeness of the study population and does not allow for sufficient power to detect differences between groups. Cross-over differences for time to correct diagnosis and definitive treatment were calculated in the following manner using the matched-pair strategy and are presented in Tables 19 and 20. For each matched pair the PDA time (time to correct diagnosis and time to definitive treatment when using a PDA) was subtracted from the corresponding No PDA time (time to correct diagnosis and time to definitive treatment when not using a PDA). A time of 30 minutes (the maximum simulation run time) was assigned in instances where the goal was not achieved for the purpose of this exercise.

Table 19

Cross-over Differences for Time to Correct Diagnosis

	No PDA (min)	PDA (min)	Cross-over difference (min)
Case scenario 1	16.25 (A)	20.43 (C)	-4.18
	10.70 (D)	22.22 (B)	-11.52
Case scenario 2	22.95 (C)	14.32 (A)	8.63
	30.00 (B)	5.48 (D)	24.52

Table 20

Cross-over Differences for Time to Definitive Treatment

	No PDA (min)	PDA (min)	Cross-over difference (min)
Case scenario 1	16.98 (A)	23.52 (C)	-6.54
	20.25 (D)	29.72 (B)	-9.47
Case scenario 2	29.67 (C)	14.52 (A)	15.15
	30.00 (B)	10.53 (D)	19.47

A negative crossover difference value indicates that, for a given matched pair, it took longer for the participant with the PDA to accomplish the task than the participant without the PDA. A positive crossover difference value indicates it took longer for the participant without the PDA to accomplish the PDA than the participant with the PDA. This is discussed in more detail in chapter five.

Cross-over difference values were calculated and are presented in Table 21.

Table 21

Cross-over Difference Calculations for Mean & Standard Deviation

		D (min)	SD (min)
Time to Correct Diagnosis	CS1	-7.85	5.19
	CS2	16.58	11.24
	Combined	4.36	15.81
Time to Definitive Treatment	CS1	-8.01	2.07
	CS2	17.31	3.05
	Combined	4.65	14.77

Mean values were calculated as the sum of observations divided by the number of observations. Standard deviation (SD) values were calculated using the following equation:

$$SD = \sqrt{\frac{SST}{n-1}}$$

where:

SST (total sum of squares) $= \sum_{i=1}^{n}(X_i - \overline{X})^2$

n = number of observations.

A matched pairs t-test was performed first using the equation below for the t statistic:

$$t = \frac{\overline{D}_{x-y}}{SD/\sqrt{n}}$$

where:

$\overline{D}_{x-y}$ = mean difference of the paired scores
n = number of observations

Using this formula, a matched pair t-statistic for time to correct diagnosis and time to definitive treatment are calculated below respectively:

$$t = \frac{\overline{D}_{x-y}}{SD/\sqrt{n}} = \frac{4.36}{15.81/\sqrt{4}} = \frac{4.36}{15.81/2} = \frac{4.36}{7.905} = 0.552$$

$$t = \frac{\overline{D}_{x-y}}{SD/\sqrt{n}} = \frac{4.65}{14.77/\sqrt{4}} = \frac{4.65}{14.77/2} = \frac{4.65}{7.385} = 0.63$$

For this type of *t*-test the degrees of freedom (*df*) equals the number of matched pair observations minus one ($df = n - 1$). Using Polit and Hungler's (1999) table of *t*-values, the above results fail to exceed 3.182 ($df = 3$, $p = 0.05$), the value needed to reject the null hypothesis of no difference between the PDA and No PDA groups.

To assess for the possibility of period effects a two-sample *t* approach was used. The equation on the left is a pooled-variance two-sample *t*-test, while the one on the right is a separate-variance two-sample *t*-test.

$$t = \frac{\overline{D}_{CS1} - \overline{D}_{CS2}}{\sqrt{s_p^2\left(\frac{1}{n_{CS1}} + \frac{1}{n_{CS2}}\right)}} \qquad t = \frac{\overline{D}_{CS1} - \overline{D}_{CS2}}{\sqrt{\frac{s_{CS1}^2}{n_{CS1}} + \frac{s_{CS2}^2}{n_{CS2}}}}$$

where:

$\overline{D}_i$ = mean difference of group *i*
n_i = number of observations in group *i*
$_{CS1}$ = Case Scenario 1
$_{CS2}$ = Case Scenario 2
s_i^2 = variance of *i*
s_i^2 = variance of i

$$s_p^2 = \text{pooled variance} = \frac{(n_{CS1} - 1)s_{CS1}^2 + (n_{CS2} - 1)s_{CS2}^2}{n_{CS1} + n_{CS2} - 2}$$

The pooled-variance and separate-variance two-sample *t*-statistics for time to correct diagnosis are calculated and presented below:

$$s_p^2 = \frac{(n_{CS1} - 1)s_{CS1}^2 + (n_{CS2} - 1)s_{CS2}^2}{n_{CS1} + n_{CS2} - 2} = \frac{(2-1)5.19^2 + (2-1)11.24^2}{2+2-2} = 76.64$$

$$t = \frac{\overline{D}_{CS1} - \overline{D}_{CS2}}{\sqrt{s_p^2\left(\frac{1}{n_{CS1}} + \frac{1}{n_{CS2}}\right)}} = \frac{24.43}{\sqrt{76.64\left(\frac{1}{2} + \frac{1}{2}\right)}} = \frac{24.43}{\sqrt{76.64}} = \frac{24.43}{8.75} = 2.79$$

$$t = \frac{\bar{D}_{CS1} - \bar{D}_{CS2}}{\sqrt{\frac{s^2_{CS1}}{n_{CS1}} + \frac{s^2_{CS2}}{n_{CS2}}}} = \frac{24.43}{\sqrt{\frac{5.19^2}{2} + \frac{11.24^2}{2}}} = \frac{24.43}{\sqrt{13.47 + 63.17}} = \frac{24.43}{8.75} = 2.79$$

The pooled-variance two-sample *t*-test formula for degrees of freedom is:

$df = n_{CS1} + n_{CS2} - 2$

In this instance the degrees of freedom would equal two. Again, using Polit and Hungler's (1999) table of *t*-values, the above results fail to exceed 4.303 ($df = 2$, $p = 0.05$), the value needed to reject the null hypothesis of no difference between groups.

The degrees of freedom formula for the separate-variance *t*-test is:

$$df = \frac{\left(\frac{s^2_{CS1}}{n_{CS1}} + \frac{s^2_{CS2}}{n_{CS2}}\right)^2}{\frac{\left(\frac{s^2_{CS1}}{n_{CS1}}\right)^2}{n_{CS1} - 1} + \frac{\left(\frac{s^2_{CS2}}{n_{CS2}}\right)^2}{n_{CS2} - 1}} = \frac{\left(\frac{5.19^2}{2} + \frac{11.24^2}{2}\right)^2}{\frac{\left(\frac{5.19^2}{2}\right)^2}{2-1} + \frac{\left(\frac{11.24^2}{2}\right)^2}{2-1}} = \frac{(13.47 + 63.17)^2}{13.34^2 + 63.17^2} = \frac{5873.69}{4171.89} = 1.408$$

Using Stockburger's (1996) online calculator for critical *t* values, the minimum value at $p = 0.05$ with $df = 1.408$ increases to 9.279, further supporting the null hypothesis of no difference between groups.

As discussed in chapter three, the purpose of performing the two-sample *t*-test is to assess for the possibility of period effects related to the use of two different case scenarios. The results of the matched-pairs (0.552) and two-sample (2.79) *t*-tests are somewhat close. In an experimental study this would suggest the slight possibility of a period effect.

Finally, the pooled-variance and separate-variance two-sample *t*-statistics and degrees of freedom for time to definitive treatment are calculated and presented here:

$$s_p^2 = \frac{(n_{CS1}-1)s_{CS1}^2 + (n_{CS2}-1)s_{CS2}^2}{n_{CS1}+n_{CS2}-2} = \frac{(2-1)2.07^2 + (2-1)3.05^2}{2+2-2} = 6.79$$

$$t = \frac{\overline{D}_{CS1} - \overline{D}_{CS2}}{\sqrt{s_p^2\left(\frac{1}{n_{CS1}} + \frac{1}{n_{CS2}}\right)}} = \frac{25.32}{\sqrt{6.79\left(\frac{1}{2}+\frac{1}{2}\right)}} = \frac{25.32}{\sqrt{6.79}} = \frac{25.32}{2.61} = 9.7$$

$df = n_{CS1} + n_{CS2} - 2 = 2$

$$t = \frac{\overline{D}_{CS1} - \overline{D}_{CS2}}{\sqrt{\frac{s_{CS1}^2}{n_{CS1}} + \frac{s_{CS2}^2}{n_{CS2}}}} = \frac{25.32}{\sqrt{\frac{2.07^2}{2} + \frac{3.05^2}{2}}} = \frac{25.32}{\sqrt{2.14+4.65}} = \frac{25.32}{2.61} = 9.7$$

$$df = \frac{\left(\frac{s_{CS1}^2}{n_{CS1}} + \frac{s_{CS2}^2}{n_{CS2}}\right)^2}{\frac{\left(\frac{s_{CS1}^2}{n_{CS1}}\right)^2}{n_{CS1}-1} + \frac{\left(\frac{s_{CS2}^2}{n_{CS2}}\right)^2}{n_{CS2}-1}} = \frac{\left(\frac{2.07^2}{2} + \frac{3.05^2}{2}\right)^2}{\frac{\left(\frac{2.07^2}{2}\right)^2}{2-1} + \frac{\left(\frac{3.05^2}{2}\right)^2}{2-1}} = \frac{(2.14+4.65)^2}{2.14^2+4.65^2} = \frac{46.1}{26.2} = 1.76$$

In this case, the pooled variance *t* statistic of 9.7 exceeds the minimum value of 4.303 (*df* = 2, p = 0.05) and would allow for rejection of the null hypothesis, suggesting a difference between groups. The minimum value increases to 6.32 with *df* = 1.76 but does not exceed the result for the separate-variance test (also 9.7). The results of the matched-pairs (0.63) and two-sample (9.7) t-tests are dissimilar. In an experimental study this would suggest the possibility of a period effect. This means that cross-over differences may not be distributed at random, possibly due to differences from the use of two different scenarios.

Inferential statistical analysis was also performed using a software package, SPSS® Graduate Pack 10.0 for Windows®. The following tables present data output

generated using this program in two groupings. Output for time to correct diagnosis is offered first and time to definitive treatment follows. For tables 20 through 31 the key below applies:

N = number of observations
SD = standard deviation
SE = standard error of the mean
Sig. = significance
df = degrees of freedom

Tables 22 through 24 present the output generated by SPSS® for the matched pair *t*-test for time to correct diagnosis. Table 23 shows the Pearson correlation coefficient, or Pearson *r*, which determines the strength of the linear relationship between two variables. When using this test both variables should be interval or ratio scale. It is assumed that if there is a relationship between the two variables it is linear and both variables are evenly distributed. In an experimental study the following results would suggest a strong negative correlation ($r(2) = -0.976, p < 0.05$) between the two variables. The results from table 22 would suggest no difference between using versus not using a PDA ($t(3) = 0.552, p > 0.05$). This is consistent with the hand calculation findings.

Table 22

Matched Pair Sample Statistics for Time to Correct Diagnosis

	Mean	N	SD	SE
No PDA	19.975	4	8.352	4.176
PDA	15.613	4	7.554	3.777

Table 23

Matched Pair Correlations for Time to Correct Diagnosis

	N	Correlation	Sig.
No PDA & PDA	4	-0.976	0.024

Table 24

Matched Pair *t*-test for Time to Correct Diagnosis

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	SD	SE	Lower	Upper	t	df	Sig. (2-tailed)
No PDA-PDA	4.363	15.809	7.905	-20.793	29.518	0.552	3	0.619

Tables 25 through 27 display SPSS® output for the two sample *t*-test for time to correct diagnosis. By default, SPSS® calculates Levene's Test for Equality of Variances which is used to test the null hypothesis that group variances are equal. Results of this test direct whether a pooled-variance *t*-test or separate-variance *t*-test should be used when interpreting the data. This is accomplished by performing and analysis of variance on the deviance of each item from the group mean and is presented as an *F* statistic. An advantage of the Levene test is that it is robust to departures of the data from normality.

Table 25

Two Sample Statistics for Time to Correct Diagnosis

	Case Scenario	N	Mean	SD	SE
Cross-over Difference	CS1	2	-7.850	5.190	3.670
	CS2	2	16.575	11.236	7.945

Table 26

Two Sample Levene's Test for Equality of Variances for Time to Correct Diagnosis

	F	Sig.
Cross-over Difference (equal variances assumed)	1.7E+16	.000

Table 27

Two Sample *t*-test for Time to Correct Diagnosis

	t	df	Sig. (2-tailed)	Mean Difference	SE	95% Confidence Interval of the Difference	
						Lower	Upper
Equal variances assumed	-2.791	2	0.108	-24.425	8.752	-62.080	13.230
Equal variances not assumed	-2.791	1.408	0.157	-24.425	8.752	-82.170	33.320

According to the results noted in Table 26 the hypothesis of equal variances would be rejected. In this instance, it would not be appropriate to use a pooled test for comparing means. In Table 27, 'equal variances assumed' refers to the pooled-variance calculation while 'equal variances not assumed' refers to a separate-variance calculation. These results are consistent with previous calculations and would support the null hypothesis of no difference between groups.

Tables 28 through 30 present the output generated by SPSS® for the matched pair *t*-test for time to definitive treatment. In Table 29, while the correlation value is close to −1.0 the p value is greater than 0.05. Therefore, in an experimental study the result above would be indicative of a negative correlation between the variables that is not statistically significant ($r(2) = -.863, p > 0.05$). Table 30 presents the same *t* value calculated

previously by hand. Again, these results would suggest no difference between using versus not using a PDA ($t(3) = 0.63, p > 0.05$).

Table 28

Matched Pair Sample Statistics for Time to Definitive Treatment

	Mean	N	SD	SE
No PDA	24.225	4	6.615	3.308
PDA	19.573	4	8.677	4.338

Table 29

Matched Pair Correlations for Time to Definitive Treatment

	N	Correlation	Sig.
No PDA & PDA	4	-0.863	0.137

Table 30

Matched Pair *t*-test for Time to Definitive Treatment

	Paired Differences					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	SD	SE	Lower	Upper			
No PDA - PDA	4.653	14.770	7.385	-18.850	28.155	0.630	3	0.573

Tables 31 through 33 display SPSS® output for the two sample *t*-test for time to definitive treatment. According to results of Levene's test in Table 32 it would be appropriate to use a separate-variance calculation for comparing group means. SPSS®

Table 31

Two Sample Statistics for Time to Definitive Treatment

	Case Scenario	N	Mean	SD	SE
Cross-over Difference	CS1	2	-8.005	2.072	1.465
	CS2	2	17.310	3.055	2.160

Table 32

Two Sample Levene's Test for Equality of Variances for Time to Definitive Treatment

	F	Sig.
Cross-over Difference (equal variances assumed)	5.8E+15	.000

Table 33

Two Sample *t*-test for Time to Definitive Treatment

	t	df	Sig. (2-tailed)	Mean Difference	SE	95% Confidence Interval of the Difference	
						Lower	Upper
Equal variances assumed	-9.699	2	0.010	-25.315	2.610	-36.545	-14.085
Equal variances not assumed	-9.699	1.759	0.016	-25.315	2.610	-38.153	-12.477

pooled and separate-variance and df values from Table 33 are consistent with previously calculated results. In an experimental study the null hypothesis would be rejected, but the possibility of a period effect would be present.

Inferential analysis of the nominal, dichotomous data from questions nine through twelve using McNemar's test was not performed due to the consistency of results. As described earlier, there was no change in scores across scenarios for each question. The

McNemar test compares changed scores – scores that remain unchanged are not included in the analysis (Jones & Kenward, 1989).

Participant Evaluation Form

A participant evaluation form (see Appendix K) was completed by each of the four participants for both case scenarios yielding a total of eight completed forms. Results for each case scenario are reported separately. The first question of this form asked participants to rate various items during the simulated case scenario as 'very distracting', 'somewhat distracting', or 'not distracting'. These items include the microphone or faculty headset, observation mirror, 'patient voice'/speaker, video cameras, chest sounds, and equipment integrity (degree of reliability and proper functioning). A category of 'other' was also provided. Three out of four participants found chest sounds and one out of four found equipment integrity to be 'somewhat distracting' during CS1. One participant specified 'having to verbalize thoughts' as 'somewhat distracting' in the 'other' category. All other remaining items were rated as 'not distracting' for CS1. For CS2 all items were rated as 'not distracting'.

Question 2 asked participants to indicate their ability to suspend disbelief with respect to various aspects of the simulated environment. For CS1 this included the simulator mannequin, circulating RN, surgeon, scrub technician and the case scenario overall. Participants rated items on a 3-point scale as 'accepted as real', 'partly accepted as real', or 'did not accept as real'. Three out of four participants accepted the circulating RN, surgeon, scrub technician and case scenario as real while one accepted these items as partly real. Half of the participants accepted the simulator mannequin as real with the

other half accepting the mannequin as partly real. For CS2 all participants scored the simulator mannequin, PACU RN, and case scenario as real except in one instance where the simulator mannequin was marked 'partly accepted as real'.

Questions three and four asked if the arrangement of the equipment and personnel, respectively, was realistic. For both case scenarios all participants indicated the arrangement of equipment and personnel was realistic. Regarding question five, none of the participants reported any difficulty interacting with any of the simulation faculty in either case scenario.

The PDA was used by each of the participants for one case scenario. Two participants utilized the PDA for CS1 and two for CS2. Both participants who used the PDA for CS1 indicated in questions one and two that they had difficulty using the PDA from a technical standpoint and were not able to easily incorporate the use of the PDA into their care of the patient respectively. The participants that used the PDA for CS2 reported the opposite. For questions nine and ten, all participants responded positively that use of the PDA was helpful in caring for the 'patient' and a similarly programmed PDA would be useful in the clinical setting respectively.

Videotape Coding Instrument

A panel of three independent, clinical certified registered nurse anesthetists with no experience in high fidelity human simulation was recruited to review the videotaped recordings and complete the videotape coding instrument. Each panel member reviewed all of the videotape recordings for a total of 24 completed instruments, 12 for each case

scenario. Results for each case scenario are reported separately. The kappa coefficient (κ) is reported for categorical data in Table 32.

Question one asked panel members to note each time they found any of the following to be distracting: the microphone or faculty headset, observation mirror, 'patient voice'/speaker, video cameras, chest sounds, and equipment integrity. A category of 'other' was also provided. For CS1 panel members indicated six instances where they found chest sounds to be a distraction. In five instances 'other' was marked. Of these five, one was allocated to 'difficulty finding suction', one to 'bovie noise', two to 'difficulty hearing reference person', and one for the participant having to 'repeatedly ask what he heard when auscultating breath sounds'. For CS2 the microphone/headset was indicated as a distraction twice.

The second question of this instrument asked panel members to rate the above items as 'very distracting', 'somewhat distracting', or 'not distracting'. For CS1 results show one score of 'very distracting' for chest sounds and one score of 'somewhat distracting' for 'other' related to the participant having to 'repeatedly ask what he heard when auscultating breath sounds'. All other items were scored as not distracting. In CS2 all items were scored as 'not distracting' except in two instances for the microphone/headset which was rated as 'somewhat distracting' twice.

Question three asked the reviewer whether the participant appeared to 'suspend disbelief' with regard to various aspects of the simulated environment. Panel members rated items on a 3-point scale as 'accepted as real', 'partly accepted as real', or 'did not accept as real'. For CS1 this included the simulator mannequin, circulating RN, surgeon,

scrub technician and the case scenario overall. For CS2 this included the simulator mannequin, PACU RN, and case scenario. Panel members indicated the participants appeared to 'accept as real' the circulating RN, surgeon, scrub technician and case scenario for CS1 100% of the time. The simulator mannequin was rated as 'accepted as real' 92% of the time and 'partly accepted as real' 8% of the time in CS1. 'Accepted as real' was selected 100% of the time by panel members on all aspects for CS2.

In question four panel members rated whether they were able to 'suspend disbelief' with regard to the same aspects as question three above. Panel members chose 'accepted as real' 100% of the time for all aspects of CS1. Results for CS2 were 100% 'accepted as real' for the PACU RN and case scenario. The simulator mannequin was rated 'accepted as real' 83% (10/12) of the time and 'partly accepted as real' 17% (2/12) of the time.

Panel members responded positively 100% of the time when asked in questions five and six if the arrangement of equipment and personnel was realistic. Question seven asked panel members if there was any indication that the participant had difficulty interacting with simulation faculty – 'yes' was indicated 17% of the time and 'no' was indicated 83% of the time.

Questions 9 through 13 related to PDA use. Question nine queried whether the PDA had been used and was checked 'yes' on 12 instruments with half being from CS1 and the other half from CS2 as expected. Results for questions 10 through 13 from CS1 and CS2 are presented in Figures 10 and 11 respectively.

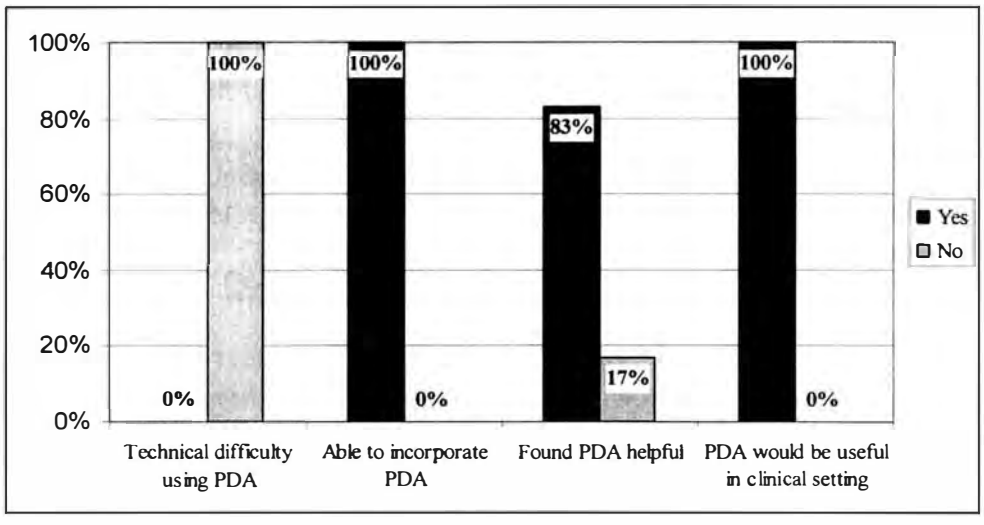

Figure 10. Videotape Coding Instrument, Questions 10-13, CS1

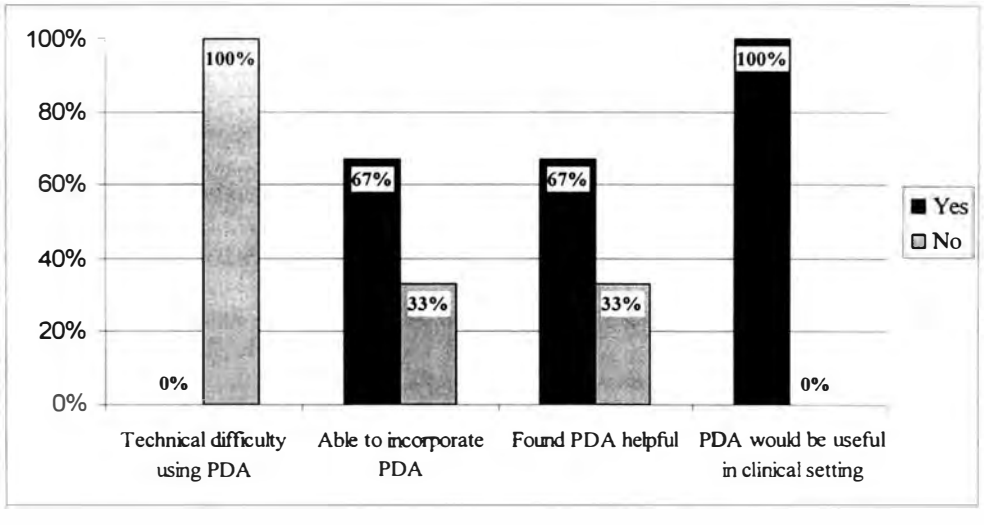

Figure 11. Videotape Coding Instrument, Questions 10-13, CS2

Table 34 presents kappa coefficient (k) results for categorical data.

Table 34

Videotape Coding Instrument Kappa Coefficient Results

Question	κ	
	CS1	CS2
#2 - Level of distraction		
Microphone or faculty headset	1	0.74
Video camera	1	1
One-way mirror	1	1
Questionable integrity of equipment	1	1
Patient voice/speaker	1	1
Chest sounds	0.88	1
#3 - Ability of participant to accept as real		
The "patient"	0.88	1
The "surgeon"	1	NA
The "circulating RN"	1	NA
The "scrub technician"	1	NA
The "PACU RN"	NA	1
The case scenario	1	1
#4 - Ability of rater to accept as real		
The "patient"	1	0.74
The "surgeon"	1	NA
The "circulating RN"	1	NA
The "scrub technician"	1	NA
The "PACU RN"	NA	1
The case scenario	1	1
#5 - Arrangement of equipment realistic	1	1
#6 - Arrangement of personnel realistic	1	1
#7 - Difficulty interacting with scenario staff	0.66	1
#10 - Technical difficulty using PDA	1	1
#11 - Able to incorporate PDA	1	0.32
#12 - Found PDA helpful	0.66	0.32
#13 - PDA useful in clinical setting	1	0.32

Qualitative Results

In contrast to quantitative procedures, qualitative data collection, analysis, and interpretation can occur simultaneously. Qualitative research is inductive and interpretive by nature. The researcher serves as the primary instrument for data collection and must be open to identifying her own biases, values and prejudgments. This acknowledgement is considered useful and positive as the data is channeled through the researcher (Creswell, 1994). As described in chapter three, the primary researcher engaged in a period of bracketing, or epoche, prior to any new instance of data collection or review. This section presents the process and results of the qualitative elements of this research in the following order: participant perceptions of the simulated environment, participant perceptions of PDA use, and diagnostic reasoning by anesthetists.

Briefly, participant perceptions of the simulated environment and PDA use were analyzed in the following manner. The process of intuiting was initiated as verbal data from the group interviews and written, qualitative data from participant evaluation forms were transcribed by the primary investigator. All transcriptions were read and a general description of the experience was written. The transcriptions were then reviewed a second time so that any additional thoughts or ideas could be added.

Horizonalization (division of data into statements), reduction and elimination (deletion of overlapping, repetitive, vague expressions), and clustering (categorization of statements) were then performed. Another review of the original data was carried out to ensure completeness before identification of themes and textural descriptions were written for each cluster. Following a period of reflection a structural description of

possible meanings and perspectives was written. Finally, a complete, exhaustive description of the meaning of the experience was written. Results from this process are presented first for perceptions of the simulated environment and then for the PDA.

Perceptions of Simulated Environment

The first qualitative research question asked "What are the anesthetist's perceptions of the simulated environment and case scenarios?" The following themes emerged and are presented with textural descriptions of what was experienced.

Participants expressed feelings of *anticipation*, knowing that "something was going to happen". It did have some effect on their normal routine – "I didn't bother to sit down because I knew that there was something that was going to happen". It also made them question themselves in that they wondered if they were "missing something obvious" or "picking up on all the right things".

Anxiety was another core theme that presented itself. All participants reported feeling anxious about being in the simulated environment. Feelings of self-consciousness, apprehension, tenseness, and performance anxiety were expressed. There was an "awareness that others are observing" and concerns of wanting "to do well'. One participant commented "I was relaxed by familiar faces yet tense that I wouldn't perform well in front of those I knew". This anxiety also contributed to the feelings of apprehension described earlier.

Participants also reported feelings of *pressure*. This was partly due to the patient's deteriorating condition (in CS1), but there was also a feeling of underlying

pressure to 'solve the problem'. In CS2, where the patient was more stable, one participant felt pressured "that I should do something".

Role unfamiliarity was also a concern for some participants. Comments were made in reference to not feeling comfortable in their role as it related to the case scenarios. Some participants would have liked more background information regarding their functional role and position in the operating room hierarchy.

Overall, participants perceived the OR case scenario as realistic (*CS1 realistic*). Certain aspects such as verbal interactions with the surgeon and circulating RN and Bovie smoke added to the realism. Some indicated the ease with which they fell into their role as an anesthetist. There was also general agreement regarding certain *CS1 discrepancies*. The inconsistency between the breath sounds heard while auscultating the mannequin's chest and those reported by the resource person was distracting and sometimes confusing. One participant reported it was easier to pretend to auscultate the lungs and then ask the resource person what he was hearing. One participant also suggested that a patient with that degree of decreased lung compliance would be more hypotensive. Another stated the feeling of the reservoir bag during hand ventilation was not consistent with what would be expected with such high peak airway pressures. So, despite general agreement of the participants that CS1 was realistic overall, there were some aspects reported in retrospect they felt detracted from that realism.

The second case scenario (CS2, the PACU scenario) was also felt by participants to be realistic (*CS2 realistic*) and well suited for simulation. They felt the "PACU RN did a good job" and that his dialogue was convincing. One participant commented "the

war stories that the PACU nurse was telling us about 'my patient last week had this', that is perfectly real". It was also expressed that it was 'good to have a non-acute, more of a thinking situation'.

One theme particular to CS2 that arose was that the lack of diaphoresis (*lack of diaphoresis misleading)*. In one of the group interviews a participant brought up the fact that the 'patient' was not diaphoretic, which he would have expected if the patient had been hypoglycemic. Even though he knew the simulator could not sweat, he did not think to ask about it. He stated "if I had grabbed the simulator's arm and it was cold and clammy and diaphoretic I would have instantly thought hypoglycemia". The other participant in the group agreed with his comments but it had not occurred to her until that point. This was not mentioned in the other group interview.

Participants expressed feeling *less anxious in CS2*. Possible reasons given for this were "I had a better idea what to expect" and that it was the "second scenario of the day", a "different environment", and "it was a consult, not your case". Also, the patient was described as being more stable and the situation as less acute than in CS1.

There was general agreement that the *simulated environment is ideal for research and education.* Participants felt the simulated environment provided an excellent venue for this research project, as well as any other investigation into problem solving or critical incidents. Not having to involve actual patients was cited as a very positive factor ("nobody gets hurt"). The ability to easily and frequently induce rare events was another ("being able to run through critical incidents that we see once a year max is invaluable").

Some minor themes that emerged included *can't accept mannequin as real*, *nonjudgmental environment*, and *think aloud protocol distracting*. One participant felt strongly that "a dummy is always only partly accepted as real", and felt strange indicating he accepted the mannequin as real (on the participant evaluation form). Another expressed that having to verbalize thoughts was "disconcerting". Comments were also made that the overall environment was nonjudgmental – "I would do it again, even given all the negative aspects of it".

The following is a structural description of how the simulated environment was experienced by the participants. The structures that affect participant perceptions of the simulated environment are expressed in terms of ones relationship to self and to others and ones own clinical experiences. How the simulated environment is perceived is affected by how one perceives him or herself and how one feels they are perceived by others. Feelings of apprehension, anxiety, and pressure seem to be rooted in the individuals desire to perform well, not only up to their own expectations, but to other's expectations as well. Awareness of being purposefully observed heightens these feelings. The degree of anxiety appears to be tied to the condition of the patient as well. The more acutely ill, deteriorating patient evokes greater concern by and increased pressure on the participant due to his or her desire to correct the problem and perform acceptably.

The perceived realism of the simulated environment seems to be influenced by individual expectations based on previous experience. Deviations from what would normally be expected in the clinical setting were seen as distractions. Efforts were made

through intentional acts to behave as they would in the clinical environment to enhance the realism of the experience.

The utility of the simulated environment for research and education appears to be rooted in its perceived benefit by the participants. Again, this originates from their clinical experiences and what they see as potentially improving their clinical performance. This would in turn affect how they, and their peers, view them as practitioners.

In summary, an exhaustive description, or overall report of the essence of the experience is presented here. The experience of the simulated environment in this research project is a paradoxical one. Participants become immersed in their role and the realism of the scenario, yet also notice discrepancies that take away from that realism. Negative feelings of anxiety, apprehension, and pressure are balanced by a nonjudgmental atmosphere and the benefit of research to the public and the profession. These negative feelings stem from concern about how their actions will viewed by others and whether they will perform up to their own and other's expectations. These concerns are strongest early in the scenario but then fade with time as the individual becomes engrossed in the problem at hand.

Reactions to the two case scenarios were also paradoxical. The OR scenario (CS1) was seemingly more intense, stressful, and anxiety producing with a clinically unstable 'patient'. There was a strong desire to identify and correct the problem and stabilize the 'patient', even though the 'patient' was not real. Frustration was expressed at not being able to immediately identify the cause of the problem. The PACU scenario

(CS2) was a more temperate, almost relaxed atmosphere with a stable 'patient'. Resultant feelings of pressure were related more to a notion that they should at least do **something**, although as time passed it became apparent that there was a problem to be addressed. Feelings of frustration were expressed here as well in not being able to identify the problem. However, the experience of that frustration did not seem to be as urgent as in CS1.

Items that detracted from realism of the scenarios were also experienced differently. In CS1 the use of the resource person was evident from the beginning of the scenario and throughout its course. The thought 'this is not real' when interacting with the resource was experienced and acknowledged during the scenario. The absence of diaphoresis was not considered at the earliest until the end of the scenario when the cause of the problem was identified.

Perceptions of PDA Use

The second qualitative research question was "What are the anesthetist's perceptions of the use of handheld computer based aid?" The following themes emerged and are presented with textural descriptions.

Participants felt the *PDA was easy to use*. The device was easy to navigate and they felt comfortable using it. One participant reported feeling "hesitant to go to it, but then was not a problem once I did refer to it." Another expressed "I was able to incorporate the PDA well in providing care to the patient."

Research subjects also found the *PDA useful*. There was unanimous agreement that the PDA was valuable and helpful. It was referred to as a "safety net", "checklist

reminder", and "second brain". Participants found it comforting and reassuring to have the PDA in that they weren't overlooking anything. It presented possible causes that the participant "would not have thought of otherwise".

Technical issues were pointed out by some of the participants. Comments were made regarding small print, making it 'hard to read'. One participant had to put their reading glasses on. The auto-dim feature was distracting to some participants – 'the light kept going off', while others felt the unit was well lit and 'easy to see'. The unit was supposed to be on but apparently powered off automatically on a couple occasions so it had to be turned on by the participant. He stated "I fumbled with it a little bit" and it did eventually turn on.

While all participants felt the PDA was useful regardless of which scenario they had it for, there seems to be some agreement that it was more helpful in the second scenario *(PDA more helpful in CS2)*. According to one participant who had the PDA in CS1, "in the second one [CS2] I would have more benefited from it". A participant who had the PDA in CS2 stated "I don't know if it would have been beneficial for me in the first scenario."

Overall, comments regarding the *format* of the PDA catalog were positive – "I liked the way the algorithms were presented and organized", "I liked the format", and "it was good indenting so I could go through quickly". Suggestions were made for a more compact presentation of differential diagnoses with drop-downs and links to drug dosages or a drug database.

Participants commented they felt it was not second nature to reach for the PDA and not necessarily their first resource choice *(PDA not first resource choice).* One participant stated "even though you told me 'go to the PDA', as a situation is unfolding it's not [snaps fingers] the first thing I would do." Another expressed "reluctance to rely on a PDA when this should be knowledge I possess as a CRNA."

A theme specific to CS1 was difficulty with managing the patient and using the PDA (*Difficult to use PDA and manage patient simultaneously in CS1).* Participants did not always feel they had time to read through the algorithms when the patient's clinical condition was deteriorating as evidenced by this comment: "in acute developing situations or rapidly developing problems, you're not going to take the time to pull this thing out and flip through your algorithms". The consensus was that in rapidly developing situations it would be more useful if there was a second person, even a nurse anesthesia student, who could at least physically manage the patient while the other used the PDA.

One participant felt the PDA format did not match the way she typically approached a problem in that she thought more globally, checking several things at once *(algorithmic format did not match though processes).* She stated that having to read through the algorithm interrupted her thought processes.

There was agreement that the *PDA will grow in utility and popularity.* Participants felt the use of PDAs will become more common, particularly as more programs become available and technology improves. They think it could "reduce human error" and "improve patient safety". One caveat is that those who have always

practiced without them may be slow to add them to their practice. It was suggested that some may reject the PDA because they feel they should already possess the knowledge they need.

The following is a structural description of how the PDA was experienced by the participants. The structures that shape participant perceptions of the PDA are rooted in how the individual feels he or she can benefit from the PDA, the individuals sense of responsibility to the patient, and in using it how they will be perceived by their peers. Feeling as though the PDA offered some benefit or advantage appeared to take two forms: it seemed to offer comfort and reassurance, thereby decreasing stress and anxiety felt by the individual, and improvement in performance by suggesting possibilities the individual had not thought of. Sense of responsibility affected perception of the PDA in two ways: immediate physical management needs of patient overrode use of PDA, but clinicians also want to feel as though they are taking advantage of all possible resources to provide optimum care to the patient.

In conclusion, the exhaustive description of perceptions of PDA use is presented here. Even though participants were instructed to use the PDA there was a feeling of hesitancy to utilize the device. It did not feel like a natural action to pick up the device and begin using it. However, once participants familiarized themselves with the technology and viewed the content they found it offered reassurance as a resource in caring for the 'patient'. Positive feelings about the PDA spanned both scenarios, although it was sometimes difficult during CS1 to physically manage the 'patient' and use the PDA. The 'patient' in CS1 seemed to require more mental and physical

involvement than in CS2, and tending to the immediate needs of the 'patient' took precedence over operating the PDA. After participating in both scenarios, those who had the PDA in CS1 felt the PDA would have been more useful in CS2. Those who had the PDA in CS2 felt the PDA would have been useful in CS1 as well, but not necessarily **more** useful.

The perception of the PDA becoming more popular was unanimous. Participants cited its benefit for the independent clinician and in group care settings as a valuable resource and guide to help improve care and minimize clinician error. Improved user-friendly technology, programs, and content will increase use. While the anesthetist feels a strong responsibility to have the knowledge necessary to care for his patient, the reality of not being able to know everything about everything is acknowledged.

Diagnostic Reasoning

The third qualitative question addressed was "What are the problem solving thought processes of anesthetists?" Data to answer this question were obtained from think-aloud protocols and video-stimulated recall sessions. Each transcription was coded and categorized using the methods described in Chapter 3.

For CS1 protocol analysis commenced when the participant verbalized one of the following occurrences: a decrease in oxygen saturation, an increase in peak airway pressures, or the presence of wheezing. Protocol analysis began in CS2 when the participant, in their dialogue with the recovery room nurse, asked their first question. Verbalizations not pertinent to participant problem solving were removed. Examples of this include comments by the simulation faculty not made in response to a question by

the participant (i.e. Surgeon – 'Is there anything I can do to help out down here?'), acknowledgement by simulation faculty of comments made by the participant (i.e. 'Okay.'), and instructions or requests by the participant or simulation faculty such as how to dilute a medication (i.e. 'I'd like the ampoule diluted in 10ccs.'), or asking for an item (i.e. 'Could you bring me a blanket please?').

In instances where the participant requested information related to the problem, the answer by the simulation faculty was retained and coded as a cue. If the participant repeated the response by the simulation faculty to their question, the faculty's response was removed and the verbal acknowledgment of the information by the participant was retained and coded as a cue. For example, in the following dialogue:

1. Participant – And let's check the twitcher here, see how many twitches he has.
2. Resource – Zero twitches on the train-of-four.
3. Participant – Okay, so zero twitches.

Statement one would be coded as an information search unit, statement three would be coded as a cue and statement two would be deleted. If the participant did not make statement three, statement two would be retained and coded as a cue.

In some cases participants made narrative comments that, while related to the scenario problem, did not seem to fit into the categories of information search unit, cue, or hypothesis. These included statements to scenario faculty as to the status of the 'patient' and verbalizations of current mechanical settings, which were retained in the

verbal protocol and labeled as 'general statements'. Examples of this include 'The isoflurane is at 1 ½ %' and 'Okay, everything looks good'.

Corresponding simulation and video-stimulated recall transcriptions were then integrated and are shown in Appendix R. Video-stimulated recall statements were only added to the simulated case scenario protocol if they were consistent with the case scenario dialogue (Elstein, Schulman & Sprafka, 1978). Redundant video-stimulated recall statements were not included. No video-stimulated recall statements had to be excluded due to conflict with the case scenario dialogue.

Categorization of integrated protocols for CS1 and CS2 are presented in Tables 35 and 36 respectively. It is important to note that coding scheme units designated as hypotheses may include discussion of the same hypothesis at different points throughout the protocol. Therefore, Tables 37 and 38 indicate the actual number of distinct hypotheses entertained by the participants for CS1 and CS2 respectively. Hypotheses in bold were present in the PDA catalog of events (see Appendix C) specific to the case scenario (CS1 – Airway pressure increasing or too high; CS2 – Delayed awakening). Those not in bold are hypotheses considered by the participant not listed in the catalog of events specific to the case scenario.

For both scenarios (in the operating room and post anesthesia care unit), when the PDA was not provided an average of 5.75 hypotheses were entertained versus an average of 9.75 hypotheses when the PDA was provided.

Table 35

Categorization of Integrated Protocols – CS1

	B - PDA	C - PDA	A - no PDA	D - no PDA
Information search units	42	19	17	25
Cues	60	41	40	33
Hypothesis	29	13	10	10
General statements	6	4	6	2

Table 36

Categorization of Integrated Protocols – CS2

	B - no PDA	C - no PDA	A - PDA	D - PDA
Information search units	62	41	23	19
Cues	58	44	26	26
Hypothesis	21	15	17	20
General statements	3	0	2	1

Table 37

Hypotheses Entertained in CS1

Hypothesis list	B - PDA	C - PDA	A - no PDA	D - no PDA
Kinked/defective ETT	x	x		
Obstructed ETT	x	x	x	
Circuit defect	x	x		
Ventilator malfunction		x		
Tidal volume too high	x	x		
Light anesthesia	x	x	x	x
Bronchospasm	x	x		x
Endobronchial intubation	x	x	x	x
Surgical compression	x			
Positioning factors	x			
Pulmonary edema	x	x	x	x
Pneumo/hemothorax	x	x	x	
Ascites				
Aspiration	x			
Anaphylaxis			x	
Reactive airway disease	x	x		
Total	13	11	6	4

Table 38

Hypotheses Entertained in CS2

Hypothesis list	A - PDA	D - PDA	B - no PDA	C - no PDA
Prolonged sedation	x	x	x	x
Drug intoxication/abuse	x	x	x	
Drug interaction				x
Residual neuromuscular blockade	x	x	x	x
Hypotension	x	x		
Hypothermia	x	x		
Hypoxia	x	x		
Hypercapnia	x	x		x
Glucose abnormality	x	x		x
Electrolyte abnormality	x			
Pre-eclampsia				
Sepsis				
Renal/adrenal/hepatic insufficiency				
Neurologic injury	x	x	x	x
Neuromuscular disease			x	
Central anticholinergic syndrome			x	
Allergic reaction			x	
Total	10	9	7	6

In summary, the verbal protocols were coded and classified using the categories set forth by Elstein, Shulman and Sprafka (1978) in their cognitive model of diagnostic reasoning by physicians. This is an indication that diagnostic reasoning by anesthetists can be described using this model, and that anesthetists solve problems in a hypothetico-deductive manner similar to physicians.

Summary

This chapter presented the empirical quantitative and qualitative results of this research. Quantitative analyses of the sample data were performed using descriptive statistics. Inferential analysis of quantitative data was performed as an exercise for the

benefit of the researcher – conclusions will not be drawn from these results. Analysis of qualitative data was performed using a phenomenological approach. A discussion of these findings and conclusions are presented in Chapter 5.

CHAPTER 5 – SUMMARY & DISCUSSION

Introduction

This chapter summarizes the results of this research and provides discussion regarding the findings. Results are examined in relation to the theoretical framework and quantitative and qualitative results are brought together and compared. A discussion regarding synthesis of quantitative and qualitative results is presented first. Quantitative and qualitative results are then discussed in separate sections as they relate to the research questions and theoretical framework. In each of these sections, integration of either quantitative or qualitative data is performed and explored as appropriate. The methodology is then examined in detail. Finally, limitations, implications of the study, and suggestions for future research are presented.

Synthesis of Quantitative and Qualitative Results

The rationale for using a quantitative/qualitative mixed-methodology design was complementarity and triangulation. In general, the complementarity of various methods of data collection allowed for more information than could have been obtained with a single tool or methodology to provide a better understanding of problem solving using a computer-based aid. An added benefit was more detailed insight into use of the simulated environment as the research setting, scenario development, and training of simulation faculty. The mixed-methodology also allowed for triangulation of the results

from quantitative versus qualitative data collection on the same or similar area(s). In most cases qualitative and quantitative data were congruent, but there were some areas contradiction.

Quantitative Results

The first quantitative research question asks if the use of handheld computer-based aid results in faster accurate diagnosis by anesthetists during critical patient care events. In the operating room scenario (CS1) the amount of time it took from the start of the scenario to accurate diagnosis was faster for participants that did not have the PDA (16:15 and 10:42 versus 22:13 and 20:26; respectively, in min:sec). The opposite occurred in the PACU scenario (CS2); it took less time for participants to state the correct diagnosis if they had the PDA (5:29 and 14:19 versus 29:16 and >30:00; respectively, in min:sec). One participant did not reach the correct diagnosis within the maximum scenario time of 30 minutes.

While inferences may not be drawn from these results, they do raise several questions. Why was the correct diagnosis reached faster in one scenario without the PDA and in the other scenario with the PDA? Was it due to differences between CS1 and CS2 or the design of one of them in particular? Design issues will be discussed in this section, while differences between CS1 and CS2 that may have contributed to the paradoxical performance with the PDA are discussed later in the qualitative section of this chapter. Further evaluation of CS1 did reveal inconsistencies in scenario management. In the scenario runs where the participant did not have a PDA, crackles (an abnormal lung sound produced by the flow of air through liquid in the alveoli) were introduced earlier

(approximately 10 minutes into the scenario) than in those where the participant did have a PDA (approximately 18 minutes into the scenario). A 'Scenario Management Timeline' (see Appendix A) was developed for each scenario but was not consistently followed in these instances. An explanation for these discrepancies was explored.

Due to the nature of the scenario, the symptom of crackles could only be introduced if the participant sought this type of information by auscultating the lungs. According to the Scenario Management Timeline, the introduction of crackles was not to occur until at least 15 minutes into the scenario. If the participant did not auscultate the lungs at or near the designated point on the timeline this could account for the discrepancy. However, in reviewing the case scenario times in Table 9, crackles were introduced almost five minutes too early in two of the scenarios. Therefore, other reasons must be considered, including lack of communication between the control center and the resource person, inadequate instruction of the management timeline to the resource person, or error by the resource person.

To explore this issue further, additional calculations were made related to the effect of early introduction of crackles. Table 39 first shows the mean and standard deviation of recorded scenario times (based on a zero start time) for first mention of pulmonary edema, administration of furosemide, and introduction of crackles. Next, the time at which crackles were introduced was subtracted from the time for first mention of pulmonary edema and then for administration of furosemide. These results were then averaged and the standard deviation was calculated. When the discrepancy of the

Table 39

Variability of Response Time and Introduction of Crackles

	Mean	SD
	min:sec	
Crackles introduced	14:08	4:26
Mentions pulmonary edema	17:24	5:07
Administers furosemide	22:37	5:26
First crackles to mention of pulmonary edema	3:16	2:14
First crackles to administration of furosemide	8:29	2:17

Key: SD – standard deviation

introduction of crackles is removed the variability in time to these key events is reduced by more than half. This threat to internal validity underscores the importance of clear communication and instruction of the research team when conducting research in the simulated environment.

It is also possible that differences in PDA experience between participants could account for longer times with PDA use in CS1, but more efficient PDA use in CS2. However, all participants reported owning their own PDA (although not the model used in this investigation) for at least two years prior to the study, making that an unlikely possibility.

The second quantitative research question inquires as to whether the use of handheld computer-based aid results in faster effective treatment by anesthetists during critical patient care events. Results were similar to those of first question in that participants without the PDA provided treatment in less time in CS1 (16:59 and 20:15 versus 23:31 and 29:43) while participants with the PDA treated faster in CS2 (10:32 and 14:31 versus 29:16 and >30:00). When the delayed introduction of crackles to those in

CS1 with the PDA is accounted for as in Table 39 the variability in time scores is again reduced by more than half.

The third quantitative research question asks if anesthetists using handheld computer-based aid have a higher the rate of correct diagnosis and treatment than those not using handheld computer-based aid. All participants reached correct diagnosis and provided treatment with and without the PDA in CS1. In CS2 one of the participants without the PDA did not reach the correct diagnosis within the maximum scenario run time (30 minutes). Another discrepancy, this time in CS2, should be pointed out. In one no-PDA CS2 run the lab order form was filled out by the recovery room nurse based on what was requested by participant B. In the other no-PDA CS2 run, the lab order form was filled out by participant C. The lab order form included a glucose level as one of the test options – seeing this when personally completing the order form may have stimulated the participant C to order this particular test. This raises the question of whether participant C would have ordered a glucose level if the recovery room nurse had completed the form (and vice versa for participant B). In an experimental study on a larger scale these discrepancies would weaken validity of the results. Interestingly, this example is illustrative of the potential of what is being tested. The idea is that the PDA triggers anesthetist behavior by directing focus toward what might be the correct diagnosis and/or intervention.

Additional quantitative data was collected on PDA use, occurrence of skill-based and knowledge-based errors, and researcher impressions of participant reactions to PDA use and the simulated environment. Overall, the number of PDA uses (each time the

participant started using the PDA and then stopped using it constituted one use) and amount of time spent using the PDA did not appear to vary much between scenarios or participants. However, the time from the start of the scenario to when the participant picked up the PDA for the first time was earlier for CS2 versus CS1. This highlights a difference in the way the problem was presented in the two scenarios. In CS1 the problem gradually developed and was 'discovered' by the participant. In CS2 participants called in to consult on a perceived problem as reported to them by the recovery room nurse.

No skill-based errors by participants were detected in any of the scenarios. Interestingly, in CS2 the second recovery room nurse handed a syringe labeled 'vecuronium' to a participant who had asked for narcan. The participant read the label on the syringe, pointed this out and requested narcan again. This was not a planned event, but it does demonstrate the manner in which skill-based errors can evolve and undoubtedly occur in the clinical setting.

The determination of whether a knowledge-based error has occurred is a more challenging task. As described earlier, the working definition of knowledge-based error takes place when an action occurs as planned but is inappropriate in that it fails to produce the intended consequences. Judgments as to whether an error occurred are made in hindsight. The goal would be to make the process as objective as possible, but due to the complexity of human performance, particularly in the field of anesthesia, some degree of subjectivity remains. For instance, in CS1 the desired result was to decrease the increasing airway pressures caused by worsening pulmonary edema. The administration

of albuterol, thiopental, epinephrine, and increasing the anesthetic agent were carried out as planned but not appropriate for the treatment of pulmonary edema. One could argue the administration of albuterol was not an error as it was provided for symptomatic treatment of wheezing. The wheezing, however, was an early symptom of pulmonary edema. This concept can be illustrated with the metaphor of a rusting car. If the task is to define and correct the underlying issue (as it was in this study) the application of paint to the rusting auto would treat the symptom, even perhaps disguise it, but would not treat the problem. Likewise, albuterol might mask (like propranolol masking the manifestation of light anesthesia) the problem at hand. In the clinical environment this may occur frequently and could be responsible for some morbidity and mortality.

Reason (1990) describes the conundrum of knowledge-based performance. When the solution is not initially obvious, and in the absence of a 'lucky guess', individuals move forward via trial and error. Success depends on identifying the correct diagnosis, recognizing incorrect diagnoses, and correcting deviations in the process of resolving the problem. If the administration of albuterol was part of the process of identifying the correct diagnosis is it still an error, particularly if it does not cause harm to the patient? Pulmonary edema can lead to bronchospasm so, while the administration of albuterol did not resolve the wheezing or treat the underlying cause of the problem, it could be seen as a prophylactic measure to prevent bronchospasm. That being said, it would be necessary to know the intent of the participant. If the outcome is desirable, is it still an error if the reasoning is flawed?

Increasing the dose of anesthetic agent was also intended to treat the wheezing, but in this instance it exacerbated part of the underlying cause of problem (anesthetic agent-induced myocardial depression). Thiopental was administered by one participant to deepen the anesthetic, thinking the wheezing may have been due to a light anesthetic, but thiopental may also cause myocardial depression. Administration of a very small therapeutic dose of epinephrine was also an information-seeking act in trying to discern the cause of the wheezing and increasing peak airway pressures. In CS2 the administration of romazicon and narcan were based on the erroneous diagnoses of benzodiazepine and opiate intoxication. Whether any of these acts would have resulted in permanent injury to a 'real' patient under the same circumstances is unlikely but in the end unknowable. This discussion highlights the complexity of detecting and assigning error in a dynamic problem-solving situation.

Collection of data regarding PDA use and the simulated environment by a variety of both quantitative- and qualitative-type strategies (Simulation Observation Data Collection Tool, Participant Evaluation Form, and group interviews) allows for triangulation of data in these areas and evaluation of the data collection methods. Quantitative data from collected by the primary researcher using the Simulation Observation Data Collection Tool and the independent panel using the Videotape Coding Instrument was consistent in some areas with quantitative and qualitative data obtained from the Participant Evaluation Form and group interviews, but inconsistent in others.

According to results from the Simulation Observation Data Collection Tool all participants appeared to easily incorporate the PDA into their care of the patient and had

no difficulty using to the PDA. This conflicts with results from the Participant Evaluation Form, where both participants who used the PDA in CS1 found the PDA difficult to use and incorporate into care of the patient. Results from the Videotape Coding Instrument also indicated some difficulty in using and incorporating the PDA by one of the participants, but in this case during CS2. Scoring on these items for CS2 also showed poor interrater reliability as well. One possible reason for these inconsistencies could be researcher bias. Another is that outside observation is not a reliable or valid method to capture this type of information. The Participant Evaluation Form results were congruent with qualitative data from the group interviews and appear to be the most appropriate quantitative instrument for measuring these items.

Data on whether participants appeared to 'suspend disbelief' during the simulated case scenarios or seemed distracted by the simulated environment was collected using these same methods as well. The Simulation Observation Data Collection Tool showed all participants as apparently being able to 'suspend disbelief', or accept the simulated environment as real. According to results from the Participant Evaluation Form and Videotape Coding Instrument, all participants were at least able to 'partly accept as real' all aspects of the simulated environment, but scores were more favorable for CS2 than CS1. Results from these tools were also consistent on chest sounds being a distraction in CS1. Again, the Simulation Observation Data Collection Tool was not an adequate method for measuring these items. Results from the Videotape Coding Instrument were more consistent with those from the Participant Evaluation Form on most items, and qualitative results supported and elaborated on these finding.

Qualitative Results

The first qualitative research question was directed toward the anesthetist's perceptions of the simulated environment and case scenarios. Regardless of the fact that the participants had previous experience with high-fidelity human simulation and agreed to take part in this study, all experienced feelings of anxiety related to performance and anticipation of an impending adverse event. One participant reported that typically he would sit down after he had received report, assessed the patient, and organized his work area, but in this instance he did not. How much of an effect this had on what would be considered their normal care-giving behavior in the clinical environment would be difficult to determine. Another participant expressed concern about not knowing his role within the (simulated) institution and standing in the operating room hierarchy. These feelings could be likened to those felt when starting a new job.

Despite these feelings of anxiety and anticipation, participants found the simulated environment and both scenarios to be realistic. Factors detracting from realism of the scenarios stemmed primarily from limitations of the simulator and were discussed at length in chapter four. Through qualitative analysis variations between CS1 and CS2 became evident. Participants described the tone of the scenarios differently, with CS1 being more intense and demanding while CS2 seemed more relaxed and less urgent. These differences did not appear to detract from the perceived realism of either scenario, but it did stimulate discussion related to use of the PDA.

The second qualitative research question delved into the anesthetist's perceptions of the use of handheld computer based aid. Participants exposed the reality that it would

be nearly impossible for a single individual to use such a device effectively while managing a rapidly deteriorating, critical patient event. This provides further insight into the types of situations and circumstances under which such a device would be most useful and ideas for future research and may also offer an explanation as to why anesthetist performance with the PDA was better in CS2 than in CS1.

The third qualitative research question looked into the problem solving thought processes of anesthetists. The transcribed verbal protocols were coded and classified using a representative system consisting of three categories: information search unit, cue, and hypothesis. There were some statements made by the participants that, while related to the problem at hand, did not seem to fit into any of the categories. As explained in chapter four, these were retained and coded as 'general statements'. The question is whether these statements are an indication that the protocols do not fit within the representative system. Whether or not these 'general statements' needed to be retained in the protocol is arguable.

In order to obtain data regarding the problem solving thought processes of anesthetists 'think aloud' instructions were given (see Appendix F) to all participants. Participants were also instructed to 'think-aloud' so simulation faculty could more easily direct simulator responses based on verbal reports of actions by the participant. This describes most of the verbalizations that were coded as 'general statements'. Ultimately, it was decided to keep them to provide a more complete presentation of the verbal protocol and scenario. The 'general statements' are few in number and do not appear to

detract from the overall categorization of the protocols into the representative system of information search unit, cue, and hypothesis.

Theoretical Framework

Information processing theory (IPT) postulates that the problem solver operates as an information processing system (IPS) within a task environment. The introduction of an external problem solving aid into the task environment for use by the IPS produced results that encourage further study. In IPT the concept of bounded rationality refers to the inherent limits of cognitive processing, specifically that humans have the capacity to negotiate 7 +/- 2 alternatives (Miller, 1956). For both scenarios without the PDA, participants considered between four and seven hypotheses during their problem solving efforts. With the PDA, participants evaluated between nine and thirteen. This could also be an explanation for why participants with the PDA in CS1 longer to reach the correct diagnosis and provide treatment. However, in CS2 participants with the PDA considered more hypotheses yet reached the correct diagnosis and provided treatment faster than those without the PDA. This illustrates how differences in the task environment can affect speed and accuracy of the IPS. This would include not only use of the PDA, but also the type of patient care scenario.

These results are intriguing and suggest that use of the PDA as a decision making aid allowed for the consideration of a number of hypotheses beyond the generally accepted limit. They suggest that problem solving behavior by anesthetists fits the diagnostic reasoning and information processing model presented earlier in chapter two. These findings also support the use of handheld computerized decision making aids for

complex problems where time is less important (e.g. minutes versus seconds, for example, when patient has stopped breathing versus one who with a gradually increasing heart rate). Additional research to confirm and elaborate on these findings is needed.

Methodologic Inquiry

A final question for this research project asks "Is the methodology used for the pilot study feasible for future research?" Based on the conduct of the pilot study and results of the qualitative and quantitative results the answer is yes and no. It was proposed that the high-fidelity human simulation environment would provide a realistic, yet safe environment for this research project. This was confirmed by responses obtained from the participants and independent reviewers and supports previous research findings (Chopra et al., 1994; Holman et al., 1992; Howard, Gaba, Fish, Yang, Sarnquist, 1992; Jacobsen, et al., 2001; Morgan, Cleave-Hogg, Guest, & Herold, 2001; Murray et al., 2004; O'Donnell, Fletcher, Dixon, & Palmer, 1998). Perhaps one of the most important aspects regarding conduct of this study was that participants found the process and atmosphere to be nonjudgmental.

The rationale behind using a cross-over design with matched pair sampling is to allow for a smaller sample size while retaining the statistical accuracy of a parallel group design with a larger sample size. Even with the small pilot study sample size the matched pair sampling process was very challenging. Simply finding four clinicians available during the week to participate in the study was difficult. Since the nature of the study necessitated having matched pair participants serve as each others control, as opposed to a traditional cross-over design where each participant serves as their own

control, some of the advantages of this design were lost due to between-participant variation. It would be necessary to take this into account in determining the appropriate sample size for an experimental study using this design.

Given the difficulty of recruiting matched pairs, other alternatives might be considered. One would be to utilize a parallel group design, where individuals are randomized to participate in a single case scenario either with or without a PDA. Time to correct diagnosis and treatment would be compared between the treatment (with PDA) and control (without PDA) groups. This would require a larger sample size to provide sufficient power to detect differences between the two groups. For this reason, data collection may need to be conducted over an extended period of time. However, the threat of drop-out would be less problematic in the parallel group design.

The cross-over design with matched pair sampling could also be conducted over a longer period of time. Matched pairs need not even participate on the same day. Should a participant drop out of the study, there would be the opportunity to recruit another matching volunteer. In either case, when carrying out a study of this nature over an extended period of time maintaining confidentiality of the case scenarios would be critical. Threats to internal validity related to any learning by the participant over time are also possible. For example, partway through the study an educational presentation of the problem upon which the scenario was designed was given.

Another option would be to study anesthesia residents and/or nurse anesthesia students instead of practicing clinicians. This would alleviate problems with recruitment and provide a steady stream of participants. It would not provide the same information

as the current study or be generalizable to practicing clinicians. The focus of the study would need to be revised due to the lack of base knowledge by the participants. In the present study the issue of external validity was prioritized, thus necessitating and rationalizing the use of established clinicians.

Scenario design also needs to be considered in conjunction with the type of problem solving to be studied. While the PDA was well received by the participants overall, they found it more helpful in CS2 where the patient was more stable. This raises the question of whether the PDA can be effectively used by a single individual in a rapidly developing critical event. Time pressure and complexity, variability, acuity and instability of the situation may affect the clinician's ability to utilize and attend to this type of resource. In this type of scenario it might be more appropriate to look at group problem solving with and without the PDA. The alternative scenario of introducing a second anesthetist was discussed during the group interview and is deserving of future study.

Limitations

There are several limitations of this study. A significant limitation is use of the high-fidelity simulated environment. Current technology does not yet provide for a full-body simulator mannequin that perfectly mirrors a human being. What is available to us now does lack features and abilities that detract from its realism. Also, no matter how lifelike the mannequin or realistic the environment, the fact of it being a 'simulation' appears to evoke some degree of anxiety in participants whether they have had

experience with the simulated setting or not. This heightened awareness and anxiety poses threat to internal and external validity.

The question of whether the simulated environment in and of itself leads to clinician error is important but possibly unknowable. This detracts from transferability of results obtained from the simulated to the clinical environment. However, the alternative of designing a study with similar goals in the clinical environment could jeopardize patient safety. Despite its limitations, the high-fidelity human simulation environment provides a nonhazardous setting for investigation into clinician behavior during critical events.

The small sample size limits generalizability of the results and precluded the use of inferential analysis. The cost of conducting the study was the primary reason for restricting the number of participants. The expense of faculty time to run the simulation, compensation for the participants, and technology costs quickly exhausted all grant funds.

Limiting the scenario run time to 30 minutes was necessary but did truncate the results. In reality, a participant could accurately diagnose and treat if given more time. Allowing the scenario to run longer could have led to stronger results suggesting a greater effect size and provided more guidance for future study.

The use of matched-pair sampling presents another drawback of this study. Ideally, in a cross-over design the participant serves as their own control, eliminating between-participant variation. As discussed earlier, the anesthetist could not participate in the same scenario twice. Therefore, participants were matched on the following

characteristics: sex, years of experience as an anesthetist, and familiarity with the simulation center. This is not to suggest these are the only possible confounding variables. Other factors may have exerted an influence, such as age, prior PDA use, years of experience as an RN, or practice setting. In fact, other unknown variables may have had a direct or indirect influence on the results. If it is decided to use a matched-pair strategy in a larger-scale future study, these issues must be considered thoroughly. Based on the experience of this study, attempting to match on more than a few characteristics would be time-consuming.

Another limitation relates to the exploration into diagnostic reasoning by anesthetists. The verbal protocols were coded and evaluated only by the primary researcher. This introduces the risk of bias. A concerted effort to maintain consistency and objectivity, in part through repeated periods of bracketing, was made by the researcher to minimize this risk. The preliminary results from this section of the study warrant more in depth investigation in this area.

Additional limitations were revealed during triangulation of data from the various tools used for data collection. In some instances, information pertaining to a particular item of interest was question in more detail on one tool than the other. One example of this is involved whether participants appeared to 'suspend disbelief' during the simulated case scenarios. With the Simulation Observation Data Collection Tool, these data were collected using yes/no-type questions while the Participant Evaluation Form and Videotape Coding Instrument collected data on several aspects of the simulated

environment using a 3-point scale. More consistency between tools would further strengthen the results.

Implications & Future Research

Reduction of error by health care professionals and increased patient safety has been given a high priority by clinicians, health care administrators, policymakers, patients and their families. Implications of this study will assist researchers in the conduct of future investigations into handheld computer-based problem solving aids, anesthetist problem solving, and clinician error. The mixed-methodology design allowed for a more detailed critique of the pilot study, offering specific recommendations and suggestions for improvement, and was addressed in the previous section. Many questions and new research ideas were raised by the participants as well as the researchers.

Another direction for future research from this study is further exploration into diagnostic reasoning by anesthetists. Result from this study show that anesthetists do activate diagnostic hypotheses. Future research could be directed at comparing groups with varying levels of experience, the timing of hypothesis activation, and data acquisition strategies.

Group problem solving also deserves attention in future research. This has been touched on in Anesthesia Crisis Resource Management (ACRM), a program of study designed to teach individuals how to better manage critical events through effective resource management. ACRM exercises are designed to include the availability of a 'second responder', another anesthesia clinician to assist the primary anesthetist if help is requested. It would be worthwhile to explore the effect of a problem solving aid in the

form of a handheld computer in this situation. On a related note, it would be desirable to expand the event catalog and perhaps make some changes to the format as suggested in the group interviews. Development and/or tailoring of additional scenarios should also be undertaken to provide for a broader research base.

Summary

The purpose of this chapter was to describe the results of this research in a manner that is useful to anesthesia researchers, educators, and clinicians, policy makers and regulators. This study has shown handheld, computer-based, problem solving aid may be helpful in improving patient care and the high-fidelity human simulation environment provides an ideal setting for research in this area. More research is necessary to determine optimal use of this technology.

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Appendix A

Case Scenario 1 Profile

Setting:	Operating room as a Rural hospital (85 beds, 2 ORs, 2 CRNA (CRNA1 & CRNA2)-only practice) Music playing softly in background. Scenario starts at approximately 1045.
Procedure:	Right Inguinal Hernia Repair
Patient:	Gregory Boston, a 72 yo white male, NKDA Hx of HTN, BPH, vascular insufficiency Standard monitors plus Foley (due to hx of BPH and urinary retention after anesthesia)
Scenario:	Gradually increasing airway pressures and decreasing oxygen saturation indicative of pulmonary edema due to fluid overload and Forane-induced myocardial depression. Gradual decrease in BP and increase in HR will also occur. If inserted CVP will be 16.
Anesthetist:	Locums CRNA filling in for CRNA1. Locums CRNA relieves CRNA2 so that she can leave for the day (no other cases to go)
Surgeon:	Pleasant but focused, not conversational. Helpful when asked but provides vague answers – patient was a referral and was only seen once briefly by surgeon. Approximately 15 min into scenario will ask circulator to call office and inform them that she should be their in about 30 min.
Circulator:	Pleasant and helpful but busy with paperwork and surgeon requests. About 5 min into start will ask anesthetist for start times – otherwise does not directly address the anesthetist.
Scrub Tech:	Pleasant but focused on surgeon and task (recently hired). Responds only to surgeon.

Data Collection:

Initial recognition of abnormal event (includes but is not limited to):

Verbalization of increased peak airway pressures
Verbalization of decrease in oxygen saturation
Hand ventilation
Manipulation of ventilator settings
Inspection of ETT

First indicates correct diagnosis (includes but is not limited to):

Verbalization of suspicion of pulmonary edema
Verbalization of symptoms of pulmonary edema

Appropriate intervention

Definitive – administration of Furosemide
Partial – turn down/off Forane

Scenario Management Timeline:

Start of scenario

PAP - 30-35
SaO2 - 97%

~ 5min into scenario

PAP - 35-40
Lung sounds - slight wheezing
SaO2 - 96%

ABG
- pH – 7.40
- PCO2 - 37
- PO2 - 80
- BE - .1
- HCO3 – 24
- %O2 - 97
- Hgb – 11.2

~ 10min into scenario

PAP - 37-42
Lung sounds - slight wheezing
SaO2 - 94%

ABG - pH – 7.38
- PCO2 - 39
- PO2 - 72
- BE - .2
- HCO3 - 25
- %O2 - 95
- Hgb – 11.1

~ 15min into scenario

PAP - 40-45
Lung sounds - slight crackles and slight wheezing
SaO2 - 92%

ABG - pH – 7.37
- PCO2 - 40
- PO2 - 68
- BE - .2
- HCO3 - 25
- %O2 - 93
- Hgb -11.0

~ 20min into scenario

PAP - 47-50
Lung sounds - increasing crackles
SaO2 - 91%

ABG - pH -7.36
- PCO2 - 41
- PO2 - 58
- BE - -.1
- HCO3 - 24
- %O2 - 91
- Hgb – 10.9

~ 25min into scenario

PAP - 50-55
Lung sounds - diffuse crackles
SaO2 - 89%

ABG
- pH – 7.34
- PCO2 - 43
- PO2 - 53
- BE - -.2
- HCO3 -25
- %O2 - 89
- Hgb – 10.8

Appendix B

Case Scenario 2 Profile

Setting:	PACU in a rural hospital (85 beds, 2 ORs, 2 CRNA (CRNA1 & CRNA2)-only practice). Scenario starts at approximately 1220.
Procedure:	Laparoscopic Cholecystectomy
Patient:	Janet Simmons, 28 yo white female, mildly obese, hx of motion sickness Standard monitors
Scenario:	Delayed emergence due to hypoglycemia as a result of stimulation of an early, undiagnosed insulinoma (no symptoms up until this point) during surgical procedure. Patient is spontaneously breathing with a nasal airway. Responds only to painful stimuli with soft moaning and arm movement.
Anesthetist:	Locums CRNA filling in for CRNA1. CRNA2 left for the day after finishing this case (no other cases to go)
PACU RN:	Helpful and cooperative, confused by patient's failure to emerge.
Other:	Second PACU RN and a nursing assistant will be available only when asked for to obtain a requested item or run a sample to the lab for analysis

Data Collection

Initial recognition of abnormal event (includes but is not limited to):

Request for glucose reading

First indicates correct diagnosis (includes but is not limited to):

Ideal – verbalization of suspicion of hypoglycemia
Upon reading glucose reading

Appropriate intervention:

Definitive – administration of Dextrose

Scenario Management Timeline

Start of Scenario

Vital signs normal
No sign of respiratory distress
Responds only to painful stimuli

~ 5min into scenario

Vital signs normal
No sign of respiratory distress
Responds only to painful stimuli

Glucose – 55

ABG
- pH – 7.36
- PCO_2 – 38
- PO_2 – 162
- BE – .2
- HCO3 – 24
- $\%O_2$ – 98
- Hgb – 12.2

Electrolytes
- K – 3.8
- Na – 142
- Cl – 98
- Ca – 8.5

~ 10 min into scenario

Vital signs normal
No sign of respiratory distress
Responds only to painful stimuli

Glucose – 52

ABG
- pH – 7.37
- PCO_2 – 38
- PO_2 – 159

- BE – .1
- HCO_3 – 24
- $\%O_2$ – 97
- Hgb – 12.1

Electrolytes
- K – 3.9
- Na – 142
- Cl – 99
- Ca – 8.6

~15 min into scenario

Vital signs normal
No sign of respiratory distress
Responds only to painful stimuli

Glucose – 48

ABG
- pH – 7.37
- PCO_2 – 38
- PO_2 – 162
- BE - .2
- HCO_3 – 25
- $\%O_2$ – 98
- Hgb – 12.2

Electrolytes
- K – 3.9
- Na – 145
- Cl – 100
- Ca – 8.7

~20 min into scenario

Vital signs normal
No sign of respiratory distress
Responds only to painful stimuli

Glucose – 44

ABG
- pH – 7.37
- PCO_2 – 39
- PO_2 – 167
- BE – .2
- HCO_3 – 23

- $\%O_2$ – 98
- Hgb – 12.3

Electrolytes
- K – 3.7
- Na –143
- Cl – 99
- Ca – 8.8

~25 min into scenario

Vital signs normal
No sign of respiratory distress
Responds only to painful stimuli

Glucose – 41

ABG
- pH – 7.40
- PCO_2 – 40
- PO_2 – 168
- BE – .3
- HCO_3 – 25
- $\%O_2$ – 98
- Hgb – 12.3

Electrolytes
- K – 4.0
- Na – 142
- Cl – 98
- Ca – 8.6

Appendix C

Catalog of Events

Air Embolism

Signs/Symptoms:

- Respiratory
  - Dyspnea
  - Tachypnea
  - Cyanosis
  - Acute respiratory distress
- Cardiovascular
  - Classic finding – mill wheel murmur upon auscultation of heart
  - Chest pain
  - Hypotension
  - Circulatory shock or sudden death with severe venous air embolism
  - EKG findings
    - Right axis deviation
    - Right ventricular strain
    - ST depression
- CNS - altered sensorium, disorientation
- Laboratory/diagnostic study findings
  - ABG
    - hypoxemia, hypercapnia, metabolic acidosis
    - increased end-tidal to arterial CO_2 gradient (normal < 5)
  - CXR – normal or may show air in pulmonary arterial system, pulmonary artery dilation, pulmonary edema

Possible causes/contributing factors:

- Patient positioning – increased incidence of air embolism in seated or head-up position
- Complication of surgical procedures
  - Neurosurgery
    - Incidence 5-50 %, higher with seated positioning
    - Posterior fossa surgery – may require seated positioning
  - Cardiovascular - following separation from CPB after AVR
  - Hepatic procedures using venovenous bypass

- Thyroid – can occur if large vein is opened
- Urologic
- Posterior spinal procedures
- Bone marrow harvesting
- Laparoscopy
- Radical pelvic procedures

- Epidural or caudal catheter insertion
- Central venous catheterization (IJ or SC)
- Pressure infusion of fluids or blood
- Open/blunt chest/abdominal trauma
- Pregnant patient
  - Can occur during spontaneous vaginal or operative delivery
  - Frequently associated with placenta previa
  - Incidence as high as 29%
- Paradoxic air embolism (entry of air into the systemic system)
  - Patients with ASD or VSD
  - Patients with patent foramen ovale

Interventions

- Terminate any central line procedure and clamp the catheter
- Withdraw the catheter **only** if it cannot be clamped
- Notify surgeon upon detection
  - Flood surgical field with saline
  - Wax bone edges
- Discontinue N_2O
- Administer 100% O_2, intubate if necessary
- Perform valsalva maneuvers or compression of jugular veins
- Trendelenberg and rotate toward left lateral decubitus position
- If CVL already present, aspirate from distal port
- Support BP with volume and vasopressors
- If circulatory collapse, initiate BLS & ACLS
- Consider admission to ICU

Airway Pressure – Decreasing or too low

Disconnection of breathing circuit from patient or machine?

Fresh gas flow too low?

- Increase fresh gas flow
- Determine why flow is too low
- Pipeline failure? Use backup cylinder

Leak in the breathing circuit

- Rule out disconnect. Examine circuit, fittings, CO2 absorber for leaks
- Are circuit attachments (e.g., humidifier, PEEP valve) leaking?

Leak in flow meters or vaporizer?

Is a negative pressure source attached to breathing circuit or patient airway?
- Check scavenging system
- Nasogastric tube malpositioned in trachea?

Replace machine or go to AMBU bag if problem not remedied

Airway Pressure – Increasing or too High

- Possible causes:
- ETT problem
  - Kinked or defective (cuff herniation)
  - Obstruction from secretions, foreign body
  - Endobronchial, esophageal, submucosal intubation
- Circuit factors
  - Kinks or misconnected hoses
  - Stuck valves or O2 flush control or PEEP valve on inspriratory limb
- Decreased pulmonary compliance
  - Increased intra-abdominal pressure
  - Aspiration
  - Bronchospasm
  - Atalectasis
  - Pulmonary edema
  - Pneumothorax
- Drug-induced
  - Narcotic induced chest wall rigidity
  - Inadequate neuromuscular blockade
  - Malignant hyperthermia
- Light anesthetic

Management:
- 100% O2
- verify increased airway pressures, check with manual ventilation
- disconnect and check circuit, correct circuit factors
  - Pressure relief valves working?
  - Check "pop off" and scavenger system
  - Kinks or obstructions? Unidirectional valves opening/closing ok?
  - Ventilator malfunction. Leak in ventilator bellows
  - If not readily fixed, go to AMBU bag, call for new machine, use IV anesthesia

- Auscultate lungs
  - Bilateral with symmetrical rise/fall chest?
  - If unilateral consider endobronchial intubation, reposition ETT
- Pass suction catheter
  - clear any obstruction or replace
  - assess secretions
- Light anesthesia
  - Remove patient from ventilator, hand ventilate, compliance ok?
  - BP, HR, level of muscle relaxation, sweating, tearing, etc? "Deepen" patient.
- Bronchospasm or air-stacking
  - Remove patient from ventilator, hand ventilate, compliance ok?
  - Increase I:E ratio from 1:2 to 1:2.5 or 1:3.0
  - Auscultate, wheezing? ET CO2 upstroke ok?
  - Bronchodilator needed?
- Tidal volume too high
  - Decrease TV. Increase rate to maintain appropriate minute ventilation?
  - Consider hand ventilating patient
- Surgical compression, Positioning factors (e.g., Trendelenberg)
  - Ask surgeon not to press on chest or abdomen. Mechanical compression from retractors or packs?
  - Flatten patient out or slight head up position if possible?
- Pulmonary edema
  - Fluid overload, incompetent capillary alveolar membrane?
  - Auscultate chest, measure A-a gradient
  - Decrease fluids, consider diuretics (if intravascular volume is high)
  - Consider PEEP
- Pneumothorax / hemothorax
  - Associated findings: hypotension, tachycardia, diminished breath sounds, neck vein distension. Hand ventilate, avoid barotrauma.
  - CXR possible? Consider tension pneumothorax.
  - Discontinue N2O. Careful with myocardial depressants
  - Needle evacuation 4th intercostals midaxillary line or 2nd intercostals midclavicular line
- Ascites
  - Examine abdomen. Intraabdominal pressure on diaphragm?
  - Inform surgeon. Consider abdominocentesis. Hand ventilate.
- Aspiration
  - Pulmonary consult. Consider steroids. Increase FiO2. Treat bronchospasm.
  - Postoperative CXR and observation

Amniotic Fluid Embolism

Risk factors:

- Short or tumultuous labor or delivery
- Large fetus
- Cephalopelvic disproportion
- Older parturient
- Uterine stimulants used
- Multiparous parturient
- Placenta previa

Manifestations:
- Decreased SaO_2 and cyanosis
- Dyspnea, pleuritic chest pain, coughing, hemoptysis
- Hyperreflexia, convulsions, coma
- Hypotension
- Pulmonary hypertension
- Cardiovascular collapse
- Cardiac arrest (EMD, asystole)

Also consider:
- Thrombotic or venous air embolism
- Aspiration
- Eclampsia
- Toxic reaction to local anesthetics
- Hemorrhagic, septic, or anaphylactic shock
- Acute heart failure
- Intracranial bleed

Interventions:
- Inform obstetrician, call for assistance
- Follow ACLS guidelines for cardiac arrest
- Maintain LUD
- Prompt delivery of fetus indicated
- Ensure adequate oxygenation and ventilation
  - o 100% O_2 via NRB in awake patient
  - o intubation if LOC, respiratory failure, cardiovascular collapse
  - o controlled ventilation with 100% O_2
- Support and monitor circulation
  - o Expand circulating volume with NS, 5% albumin boluses
  - o At least two large bore IVs
  - o Vasopressors
  - o Consider inotropes
  - o Insert A-line and PA catheter
  - o Insert foley catheter

- Consider corticosteroids
- Check ABGs, CBC, coags
- Blood and FFB as indicated

Anaphylaxis

Does patient have history of allergic reactions?

Possible symptoms:

- Cardiovascular
  - Hypotension (may be only initial sign in anesthetized patient)
  - Cardiovascular collapse
  - Pulmonary hypertension
  - Arrhythmias
  - Pulmonary edema
- Respiratory
  - Bronchospasm
  - Increased airway pressure
  - Hypoxemia
  - Stridor
  - Laryngeal edema
- Cutaneous
  - Rash, flushing, hives
  - Pruritis
  - Angioedema

Administration of anaphylactic or anaphylactoid triggers?

- Antibiotics
- Narcotics
- Protamine
- Ester local anesthetics
- Latex
- Blood and blood products
- Iodine contrasting agents
- Neuromuscular blocking agents

Interventions

- Stop administration/use of possible triggers
- Maintain airway and support oxygenation, ventilation
  - 100% FiO_2
  - intubate if necessary
- Inform surgeons
  - determine if surgeon administered/instilled any substance

  - consider termination of procedure if no response to treatment
- Decrease or discontinue anesthetic agent if hypotension present
- If bronchospasm present consider volatile anesthetic agent to counteract
- Expand circulating volume rapidly with crystalloid
- Insert large bore IV if not already present
- Administer IV epinephrine
  - 10-50 mcg increments
  - for cardiovascular collapse, 0.5 – 1 mg boluses
- Administer H_1 antagonist – IV diphenhydramine 30 mg
- Administer corticosteroids
  - IV Dexamethasone 20 mg
  - IV methylprednisolone 100 mg
- In absence of other discernable causes consider latex allergy -Remove all latex products in contact with patient
  - Surgical gloves
  - Indwelling latex catheters/tubes/drains (foley, chest tube, penrose)
  - LMAs
  - Latex rubber stoppers
- Consider placement of invasive monitors as necessary

Apnea—unexpected

- Ensure adequate oxygenation and ventilation
- Is it a normal consequence of drug intended to be given (opiate, inhaled anesthetic, etc)
- If an error in drug administration is recognized immediately: stop IV carrying drug, try and aspirate or drain IV tubing
- Maintain normocapnia
- Increase O2 flow to breathing circuit and reduce vaporizer setting to enhance elimination of inhaled anesthetic if that is viewed as the culprit.
- Check neuromuscular function with nerve stimulator. If residual blockade is present, consider reversing. Consider synergistic effects of muscle relaxants and aminoglycosides (consider giving CaCl, 0.5-1.0 gram)
- Review doses of medications given, consider possibility of syringe or ampoule swap
- If not muscle relaxant consider reversal of specific drugs such as opiates (naloxone), benzodiazepines (flumazenil), anticholinergics (physostigmine)
- Send blood samples for ABG, serum electrolyte and glucose levels
- Perform neurological examination to rule out CNS injury or pathophysiology as cause

Bleeding/Coagulopathy

Recognize causes of pre-existing coagulopathies
- Drug therapy inhibiting platelet function (aspirin, dipyridamole)
- Hepatic dysfunction

- Anticoagulant therapy
- Thrombolytic therapy
- Chronic renal failure
- Myeloproliferative disorders
- Thrombocytopenia

Reconfirm patients with pre-existing clinical or subclinical coagulation disorders
- Obtain preoperative coagulation studies
- Discuss risks/benefits of proceeding with surgery
- Institution of anticoagulants – FFP, coagulation factors may be indicated
- Communication with blood bank to ensure availability of blood products
- Consider large-bore IV access

Procedure associated with major blood loss?
- Vascular, cardiac, or thoracic
- Major trauma
- Retroperitoneal surgery or injury

Reconfirm lab results – Hcb/Hct, coags

Assess surgical environment
- Check surgical area for accumulated blood loss (drapes, floor, abdominal cavity, OR table)
- Monitor extent of suctioning and check suction containers
- Check surgical sponges
- Check for bleeding from IV insertion sites, wounds, mucous membranes, drains, chest tubes

Reevaluate unexplained decreases in BP, CVP, PAP
- Consider increased fluid requirements
- Assess BP response to increase IV fluid administration
- Assess BP response to vasopressor administration
- Monitor urine output
- Assess for skin discoloration

Consider existing circulating anticoagulant
- Inadequate heparin neutralization
- Heparin rebound
- Protamine overdose (check to see if administered by surgeon)

Blood transfusion coagulopathy
- Due to administration of blood lacking coagulation factors

- FFP, platelets, cryoprecipitate may be necessary

Impaired platelet function
- Discontinue any platelet-impairing agents
- Consider platelet transfusion

Disseminated intravascular coagulation (DIC)
- FFP
- Heparin or aminocaproic acid to treat fibrinolysis

Other possible causes
- Dilutional thrombocytopenia
- Hemolytic transfusion reaction
- Prolonged CPB time
- Pericardial tamponade
- Hypothermic technique
- Placenta abruptio

Delayed Awakening or Delirium

Consider relevant factors:
- Preoperative patient status
- Intraoperative events
  - Cardiac arrhythmias
  - Hypertension
  - Hypotension
  - Agents given
  - Surgical risk for neurologic injury

Possible causes:
- Prolonged drug effect
  - Prolonged sedation
  - Drug intoxication
  - Drug abuse – over or covert
  - Prolonged neuromuscular blockade
- Nonneurogenic abnormality
  - Hypotension
  - Hypothermia
  - Hypoxia
  - Hypercapnia
  - Glucose abnormalities
    - Hypoglycemia
    - Diabetic ketoacidosis

    - Hyperosmolar nonketoid coma
  - Electrolyte abnormalities
    - Hyponatremia (TURP, hysteroscopy)
    - Hypocalcemia (thyroid/parathyroid surgery)
  - Preeclampsia
  - Sepsis
  - Renal, Adrenal, Hepatic insufficiency
- Neurologic injury
  - Postanoxic, ischemic encephalopathy
    - Hypotension treated by inotropes
    - Circulatory arrest
    - Asphyxia
    - Hemorrhagic shock
  - Intracerebral hematoma, Subarachnoid hemorrhage
    - Carotid endarterectomy
    - Post AVM removal
    - Preeclampsia
    - Anticoagulation therapy
  - Acute ischemic stroke
    - Cardia arrythmias
    - Acute MI
    - Cardioversion
    - Embolis (CABG, valve, peripheral vascular, aortic, orthopedic procedures)
    - Diabetic dysautonomia
    - Previous cerebrovascular accidents
  - Increased ICP
  - Seizure and/or postictal state

Interventions

- Monitor vital signs and temp – treat possible causes (hypothermia, hypo/hypertension, arrhythmias)
- Review perioperative medications, TOF
- Reversal of anesthetic agents (naloxone, flumazenil, physostigmine, neostigmine)
- Rule out nonneurogenic causes
  - Laboratory tests (ABGs, Electrolytes, glucose, renal/hepatic profiles)
  - Cardiac – ECG, echocardiogram
  - Sepsis
- Rule out neurologic causes
  - Neurology consult
  - CT, MRI, Angiogram, EEG
  - If increased ICP suspected, intubate, hyperventilate, maintain tight BP control

Hypercapnia

Underventilating the patient?
- Increase minute ventilation by hand or machine
- Leak in system---check for disconnection at all possible sites
- Obstruction in system---check for patency (e.g., kinked ETT)

Rebreathing of CO2?
- CO2 absorber exhausted?
- Check function/competency of unidirectional valves (especially expiratory valve)
- If using older machine, is CO2 bypass valve open?
- If using Mapleson or Bain circuit, fresh gas flow may need to be increased

CO2 production high in the patient?
- Rule out malignant hyperthermia – (if MH, invoke MH protocol)
- Rule out thyroid storm
- Rule out other possible hypermetabolic process
- Sepsis? Febrile process?

Underlying patient pathophysiology
- Is patient a chronic CO2 retainer?

Exogenous source of CO2?
- Is CO2 being insufflated by surgeon (laparoscopy)?
- Glucose solutions (vs. saline) induce modest increases in CO2 production

Hyperparathyroidism

Mild
- Hypertension
- Mild osteopenia
- Non-specific mental depression
- Mild weakness

Severe
- Renal calculi
- Crippling bone disease

Look for:
- Signs/symptoms of hypercalcemia
- General – polydipsia,, anemia

- Renal - polyuria, hematuria, calculi, back/ pain
- Musculoskeletal - arthralgias, factures, muscle weakness
- GI – nausea, vomiting, anorexia, constipation, epigastric pain, ulcers
- CNS – depression, weakness, stupor, psychosis, NDNMB sensitivity
- CV – HTN, EKG changes if Ca > 14 mg/dl (prolonged PR, shortened QT)

Primarily affects women in middle to late life

Preoperative treatment/considerations:
- Lower Ca to 12-14 mg/dl
- Vigorous hydration – monitor U/O, dialyze if needed
- Consider CVP, PAP, A-line
- If cardiac dysrhythmias or CNS symptoms are present:
  - Consider IV calcitonin – rapidly lowers Ca but is short-lived
  - Consider Mithramycin – works within 12-36 hrs, lasts 3-5 days
  - Surgical parathyroidectomy is definitive treatment

Hyperthermia

Iatrogenic – assess external warming devices, room temperature

Malignant Hyperthermia
- Increased $EtCO_2$, muscle rigidity, dyskinesia, autonomic lability, elevated CK
- Withdraw potentially causative agents – succinylcholine, volatile inhalation agents
- Initiate Malignant Hyperthermia protocol

Blood transfusion reaction
- Acute hemolytic transfusion reaction – stop transfusion, check unit, obtain blood sample, insert urinary catheter, administer osmotic diuretic, monitor and treat blood loss
- Febrile nonhemolytic reaction - no evidence of hemolysis – give leukocyte-poor blood for future transfusions
- Transfusion related acute lung injury – FiO_2 $\leq$ 50%, ventilatory support, avoid high peak airway pressures, consider PEEP, symptoms usually resolve in 24-48 hrs

Genetic factors
- Osteogenesis imperfecta
- Riley Day syndrome
- Arthrogryposis

Other Disease states
- Bacteremia/sepsis – tachypnea, tachycardia, metabolic acidosis

- Thyrotoxicosis/thyroid storm – tachycardia, atrial fibrillation, hypotension, hypokalemia, CHF
- Pheochromocytoma – tachycardia, hypertension, arrhythmias, ischemia, CHF *no inc. $EtCO_2$
- CNS dysfunction -brainstem or hypothalamic injury, intraventicular hemorrhage, hypoxic encephalopathy, status epilecticus

Drug induced
- MAOI given with meperidine
- MAOI given with SSRI
- Ecstasy, Cocaine, LSD, PCP

Hyperthyroidism/Thyrotoxicosis

Review history:
- Thyroid function tests, anemia, increased LFTs, abnormal coags
- Medications – propothiouracil (PTU), methimiazol (MMI), iodides
- Duration of treatment – euthyroid requires 2-3 months

Clinical manifestations/evaluations:
- Increase metabolic state – increased BP, temperature, HR
- Atrial fibrillation, CHF
- Goiter – CT may show difficult airway
- Myopathies – tight 'girdle' muscles
- Nervousness
- Grave's disease (exophthalmos)
- Dehydration (diarrhea)
- Pregnancy, molar pregnancy – increase risk for thyroid storm

Assess urgency of surgery:
- Elective
  - Consult endocrinologist
  - Delay until patient is euthyroid – then anesthetic technique of choice
- Emergent
  - Consider A-line, CVP, PA catheter with standard monitors
  - Titrate esmolol/propanolol to keep HR <90
  - **Caution** – overzealous beta-blockade can precipitate CHF, bronchospasm, hypoglycemia
  - Consider corticosteroids
  - Plan ICU admission postop – thyroid storm usually occurs 6-18 hrs postop
  - GETA (preferred if poorly controlled hyperthyroidism)
    - Avoid agents that stimulate the SNS, anticholinergics, hyperthermia, hypercapnia
    - If goiter present consider awake intubation, armored ETT, protect eyes

- Regional
  - Sedation recommended
  - Avoid local anesthetics with epinephrine
- **Watch for Thyroid Storm**

Potential perioperative complications:

- Thyroid storm
  - Signs/Symptoms – hyperthermia, restlessness, agitation, tachycardia, CHF, dehydration (similar to MH)
  - Precipitation events – infection, trauma, surgery, withdrawal from treatment
  - Interventions (life-threatening – must treat promptly)
    - Antithyroid drugs (in large doses)
      - PTU 800-1200 mg/d PO or NG or MMI 80-120 mg/d PO or NG
      - Sodium idodide o.5-1 g IV or Lugol's10 gtts PO (after starting PTU or MMI)
    - Esmolol 2-5 mg IV or Propanolol (beta-blockers will not prevent thyroid storm, they only reduce the symptoms)
    - Corticosteroids
    - Hydration
    - Supportive measures (cool, sedate patient)
    - Plasmapheresis or peritoneal dialysis
    - Dantrolene (has been used successfully when mistaken for MH)
    - Treat CHF
- Thyroid surgery complications
  - Airway obstruction
    - Superior/recurrent laryngeal nerve injury
    - Tracheomalacia
    - Glottic edema
    - Hematoma
  - Hemorrhage
  - Hypoparathyroidism – hypocalcemia, tetany, treat with IV calcium
  - Hypothyroidism
  - Venous air embolism
  - Cerebral ischemia
  - Pneumothorax
  - Carotid sinus reflex

Hypothermia

Possible causes:

- Internal redistribution of heat due to anesthetic induced vasodilation
- Anesthesia induced impairment of thermoregulatory control
- Decreased metabolism
- Cold OR environment

- Cold IV fluids/blood/blood products

Interventions
- Increase ambient temperature to at least 21°C
- Warm irrigation fluids
- Utilize external warming devices (warming blankets, heat lamps)
- Utilize fluid warming devices
- Warm inspired gasses
- Cover exposed areas when possible

Minimize exposure of viscera

Hypothyroidism

Review history:
- Review thyroid function tests
- Review labs (CBC, coags, electrolytes, glucose, BUN, creatinine)
- CXR
- ECG
- Medications, duration of treatment

Clinical manifestations/evaluation:
- Decreased metabolic rate – decreased BP, HR, temperature
- Airway – goiter, hoarseness, large tongue, difficult airway
- CHF, pericardial effusions, angina
- Musculoskeletal – myopathy, decreased DTRs, muscle aches
- CNS – lethargy, fatigue
- Integument - dryness of skin and hair
- GI/GU – GERD, delayed hepatic, renal function

Assess urgency of surgery:
- Elective
  - Delay until euthyroid – then anesthetic technique of choice (consider corticosteroids)
  - If patient has CAD the need for thyroid hormone must be balanced against the risk of angina and MI
  - Consider omitting pre-op thyroid replacement prior to CABG procedures
- Emergent
  - Standard monitors plus A-line, consider CVP, PA catheter
  - Avoid pre-op sedation – decreased ventilatory response to hypoxia/hypercapnia
  - Regional or GETA with RSI can be used
  - IV T_3 or T_4 - monitor ECG for dysrhythmias, ST changes (use with caution w/CAD)
  - Corticosteroids
  - Glucose
  - Avoid overhydration

- Utilize fluid warmers, warming blankets, humidified, warmed gasses

Perioperative complications:
- Delayed emergence
- Apnea
- Hyponatremia
- Bleeding
- Myxedema coma
  - Signs/symptoms – stupor, hypothermia, hypoglycemia, hyponatremia, hypoventilation
  - Treatment – thyroid hormone replacement (IV thyroxine)

Hypoxia

Airway patent, is there obstruction?

ETT in correct place?---auscultate, verify ETCO2

FiO2 sufficient? Increase flow of oxygen.
- Consider flow meter or source failure
- Consider using E-cylinder back-up supply if in doubt

Minute ventilation sufficient for patient and condition?

Effects of general anesthesia on pulmonary physiology
- Reduction in FRC
- Increased venous admixture
- Effects on closing capacity
- Redistribution of blood

Underlying patient pathophysiology?
- V/Q mismatch exacerbated by anesthetic care
- Diffusion impairment (e.g., pulmonary edema)
- Shunt (complete failure of ventilation of perfused lung)
- Reduction in O2 carriage (CO poisoning, severe anemia)

Blood loss---observed or occult

Fall in cardiac output
- Hypotension
- Arrhythmia
- Pump failure
- Insufficient intravascular volume

- Shock state

Increased Intracranial Pressure

Signs/Symptoms:
- Sustained increase in ICP above 15-20 mmHG
- Headache
- Nausea/vomiting
- Papilledema
- Focal neurological deficits
- Altered ventilatory function
- Decreasing level of consciousness
- Seizures
- Coma

Possible causes/treatments:
- False measurement?
  - Realign pressure transducer appropriate to ventriculostomy or subarachnoid bolt
  - Confirm clinical signs
- Cerebral mass, hematoma, contusion, or lesion
- Obstructive hydrocephalus
- Aneurysm or AV malformation
- Pseudotumor cerebri
- Pheochromocytoma
- Alcohol intoxication/withdrawal
  - Administer benzodiazepines
  - Administer thiamine, folate, MVI
- Cerebral vascular accident with edema
  - Limit IV fluids, avoid hypotonic solutions
  - Administer corticosteroids
  - Administer furosemide and mannitol
  - Maintain normo/hypocapnia
- Seizures
  - Administer benzodiazepines
  - Administer dilantin infusion

Interventions:
- Positioning – maintain slight head-up position
- Hypoventilation/hypercapnia:
- Bag ventilate and increase minute ventilation

- Maintain $EtCO_2$ between 25-30 mmHg

- PEEP – consider other measures to maximize oxygenation (inc. FiO_2 or TV)
- Laryngoscopy
  - Pretreat with lidocaine or narcotics
  - Ensure adequate depth of anesthesia
  - Limit duration of laryngoscopy
- Succinylcholine
  - Avoid unless strongly indicated
  - Pretreat with defasciculating dose of nondepolarizing neuromuscular blocker
- Ketamine, Volatile inhalation agents – hyperventilate prior to use
- Hyperglycemia – treat with insulin

Malignant Hyperthermia

Confirm diagnosis of MH:
- Review anesthetic history of patient and family
  - History of masseter muscle spasm?
  - History of musculoskeletal disease – muscular dystrophy, osteogenesis imperfecta, Kin Denborough syndrome?
- Signs and symptoms
  - Increasing EtCO2 – check response to hyperventilation
  - Unexplained tachycardia, cardiovascular instability, arrhythmias
  - Tachypnea in spontaneously breathing patient
  - Muscle rigidity
  - Sweating
  - Decreasing SaO2 – check for cyanosis
  - Increasing temperature – late sign
  - Metabolic acidosis, hyperkalemia, elevated CK, myoglobinuria
- Check ABGs, K^+, CK levels

Differential diagnosis
- Light anesthesia
- Fever 2^o infection, hyperthyroidism, pheochromocytoma
- Aggressive use of warming devices
- Injury to hypothalamus
- Drug reactions causing tachycardia or hyperthermia
  - MAO inhibitors
  - Cocaine
  - Atropine
  - Scopolamine
- Neuroleptic malignant syndrome (rare, triggered by antipsychotics, prochlorperazine, metoclopramide, droperidol, promethazine)

- Other causes of elevated $EtCO_2$

Declare MH emergency
- Notify surgical team and terminate procedure ASAP
- Call for assistance
- Call for MH cart

Interventions
- Turn off volatile agents and N_2O, discontinue succinylcholine
- Administer 100% O_2
  - Use an O_2 tank and self-inflating bag to ventilate patient
  - Assign one person to hyperventilate patient
- Assign one or more individuals to mix Dantrolene
  - Must be reconstituted with sterile water
  - Administer 2.5 mg/kg boluses to maximum of 10 mg/kg
  - Titrate to heart rate, muscle rigidity and temperature
- Cool patient
  - Ice packs to axilla, groin
  - Iced saline lavage
  - Cooling blanket
- Administer IV HCO_3 1-2 meq/kg as indicated by ABG data
- Correct hyperkalemia
  - IV Furosemide
  - IV glucose/insulin
- Place urinary catheter - if decrease U/O or myoglobinuria
  - IV mannitol and/or furosemide
  - Increase IVF rate
- Treat arrhythmias
  - Metabolic correction will usually resolve
  - Procainamide agent of choice if necessary
- Monitor blood values
  - Arterial and venous blood gasses
  - CK
  - Potassium
  - Coags
- Insert A-line, consider CVP, PA catheter

*****At any time call MH Hotline at [redacted]**
(on-call physicians available 24 hrs a day)

Methemoglobinemia

- Associated with the use of prilocaine local anesthesia

- Prilocaine metabolized to ortho-toluidine-→ cyanosis / methHgb
- Seen in adults with doses >8mg/kg; infants particularly susceptible
- Cyanosis, short of breath, tachycardia, headache, vertigo

- Rx: Support airway, give 100% oxygen 1% methylene blue, 1-2 mg/kg, can repeat hourly (7 mg/kg max)

Narrowed Pulse Pressure

- Cardiac tamponade
- Aoritc/mitral/severe pulmonic stenosis
- Hypovolemia/shock states
- Positive pressure ventilation
- Pain – administer additional anesthesia
- Age-onset (elderly likely to have narrowed pulse pressure)
- Citrate toxicity

Nausea/Vomiting - Postoperative

If level of consciousness or reflexes depressed—protect the airway

Hypoxia?
- Check the airway
- Check SaO_2, assure ventilation, administer oxygen

Review medical history, operative procedure, anesthetic technique.
- Search for contributing factors
- Obtain laboratory values if indicated (e.g., Na, K, glucose)

Hemodynamically unstable?
- Assess heart rate and blood pressure, temperature, skin color and feel
- Does position (standing, sitting, lying flat) influence? Fluid deficit?
- Intravenous fluids, cardiac output
- If ambulatory surgery, consider admission

Drug induced?
- Opiates, chemotherapy, digoxin, aminophylline, known or unknown alcohol use
- Consider antiemetics
- If ambulatory surgery, consider admission

Drug related?

- Consider acute withdrawal from opiates or alcohol (possible treatment is to administer agent patient is in withdrawal from)
- If ambulatory surgery, consider admission

Other possible causes:
- Acute MI - fully evaluate (ECG, chest pain?, enzymes, consult)
- Sepsis?
- Pregnancy related - evaluate, OB consult, are antiemetics appropriate?
- Increased intracranial pressure - fully evaluate, consult
- Hypoglycemia - give dextrose, is patient diabetic?
- Bowel obstruction?
- Hematemesis - consider gastric or esophageal bleeding or swallowed blood from procedure.

Oliguria

- Identify and treat cause, replace fluids
- Assess foley catheter – relieve kinks or obstruction, change if in doubt
- Assess patient position – if trendelenberg consider repositioning to head-up
- Assess fluid administration – IV patency, osmolarity of fluids
- Assess for hypovolemia – blood loss, third-spacing, tissue damage, evaporative loss
- Consider labs for UA, serum BUN, creatinine, electrolytes, CBC, ABG
- Assess for internal obstruction – blood clot, UTI, mucous plug, calculi, BPH, nephrogenic bladder, pelvic tumor, uterine fibroids, fecal impaction, lymphomas, scar tissue, neoplasms, renal transplant
- Assess for hypoperfusion – CHF, renal artery thrombosis (rare), hypovolemia (see bove)
- Extravasation – surgical mishap to bladder or ureters, pelvic trauma, * requires surgical correction
- Drug induced – chemotherapy (vinplastin, bleomycin, cisplatin), amphoteracin B, captopril, chronic NSAID/Tylenol use

Pheochromocytoma

Signs/symptoms:
- Awake patient – HTN (paroxysmal vs. persistent), tachycardia, diaphoresis, postural hypotension, tachypnea, dyspnea, flushing, cold, clammy skin, severe HA, angina, palpitations, visual disturbances, paresthesia, N/V, epigastric pain, constipation
- Anesthetized patient – HTN (paroxysmal vs. persistent), tachycardia, ventricular dysrhythmias
- 1/1000 HTN patients have pheochromocytoma

Consider time when paroxysmal attack was provoked:
- Palpation of tumor
- Postural changes
- Emotional trauma
- Following administration of beta-blocker

Consider other possible causes:
- Medullary thyroid carcinoma
- Parathyroid adenoma
- Neurofribromatosis
- Cholelithiasis

Diagnostic testing:
- Evaluate for cardiomyopathy and CHF
- Measurement of urine catecholamines and metanephrine
- Measurement of plasma catecholamine (>2000pg/ml is diagnostic)
- Clonidine suppression test
- Phentolamine test – 5mg IV will cause decrease in BP >32/25 within 2 min
- Modified phentolamine test – 10% D5W infusion initiated 30 min prior to phentolamine administration
- CT, dye scintigraphy, MRI to localize tumor

Consider possibility of false positive results:
- False positive phentolamine test – uremia, stroke, malignant HTN, patients on diuretics and phenothiazines
- False positive urine VMA/HMA – patients on Rauwolfia alkaloids, methyldopa, catecholamines, ingestion of foods with high in vanilla

Interventions:
- Preoperative management
  - Cancel elective surgery
  - Oral phenoxybenzamine for 10-14 days (start 10 mg BID, gradually increase until mild postural hypotension develops)
  - As alpha blockade develops, increase hydration
  - Consider alpha-methyltyrosine
  - May give beta-blockers for persistent tachycardia or tachydysrhythmias
- **Always** give in conjunction with alpha antagonist to avoid unopposed alpha activity
- **Always** begin alpha compounds first
- Labetalol agent of choice
- Intraoperative management
  - A-line, CVP, PAP in addition to standard monitoring
  - Thiopental or midazolam induction agents of choice
  - IV lidocaine prior to laryngoscopy

- Vecuronium neuromuscular blocker of choice (avoid histamine releasing NMBs)
- Maintain deep anesthetic with volatile agents
- Treat paroxysmal HTN with IV phentolamine 1-5 mg or nitroprusside infusion
- Labetalol, propranolol for tachydysrhythmias
- Lidocaine for ventricular ectopy

Emergence

- Consider Beta-blocker (esmolol, labetalol in divided doses)
- Nitroprusside infusion
- Maintain normo/hypocapnia
- Deep extubation

Pneumothorax

- Can occur under many obvious and not so obvious circumstances

- Signs & Symptoms
  - unilateral decrease in breath sounds
  - asymmetrical chest movement
  - increased ventilatory pressure
  - progressive tracheal deviation
  - wheezing
  - sudden or progressive cardiovascular changes
  - hypoxemia
  - anxiety, discomfort, changed sensorium (if awake)

- Simple pneumo
  - no communication exists with atmosphere
  - treatment determined by size and degree of patient response (<15% lung = "small"; >60% lung = "large")
  - discontinue nitrous oxide
  - hyperoxygenate
  - support circulation
  - needle evacuation with 14-16 gauge needle on syringe into pleural space at 2^{nd} or 3^{rd} intercostal space at mid-clavicular line, or 4^{th} or 5^{th} intercostals space at axillary line
  - chest tube may be required
- Communicating pneumo
  - air in pleural cavity communicates with atmospheric air
  - sucking chest wound
  - severe ventilatory disturbance
  - cover wound with occlusive dressing
  - discontinue nitrous oxide
  - hyperoxygenate
  - support circulation
  - remove pleural air (see above – needle evacuation)

- Tension pneumo
  - air progressively accumulates under pressure in pleural cavity
  - rapid intervention (see above – needle evacuation) is critical to avoid death.

- As pneumothorax grows mediastinum continues to shift with compression of other lung, great vessels and heart venous return falls and respiratory and cardiovascular disturbance gradually or rapidly ensues.

Polyuria

- Excessive fluid administration – verify tonicity/osmolality, dextrose content, colloid/crystalloid
- Assess for hyperglycemia
- Consider error in diuretic administration if given
- Neurosurgical trauma to pituitary – polyuria usually not seen until 12 hours postoperatively
- Non-oliguric renal failure – check UA, serum BUN, creatinine, electrolytes, ABG
- Post-obstruction relief urine output
- Central Diabetes Insipidus – treat with vasopressin
  - Acquired – brain tumor, head trauma, post-neurosurgical, infection (encephalitis), vascular disorder (sarcoidosis)
  - Idiopathic
  - Familial

- Nephrogenic Diabetes Insipidus – treat cause
  - Fluorinated volatile anesthetics, particularly methoxyflurane
  - Congenital
  - Acquired – hypokalemia (from diuretics), hypercalcemia, nephrocalcinosis, osmotic diuresis, recovery from oliguric renal failure, chronic pyelonephritis or hydonephrosis
- Drug induced – demeclocycline, gentamycin, lithium, amphoteracin B
- Other possible causes
  - Hypertension
  - Cirrhosis
  - Malnutrition
  - Sickle cell anemia
  - Amyloidosis

Postdural Puncture Headache

- Mechanism: persistent leakage of CSF through dural defect
- Vol/P is lost, when upright, traction on meninges and intracranial vessels
- Onset several hours to 48 hours post dural puncture (or even longer)
- 90% resolution with conservative measures
- HA is bifrontal & occipital. Nuchal stiffness & pain. Pain is postural
- Subdural hematoma rare but can occur. Displacement --> tearing vessels
- Bedrest, hydration, abdominal binder, analgesics, caffeine
- Epidural blood patch using 20mL aseptically drawn autologous blood
- ACTH has been advocated but is untested

Prolonged Neuromuscular Blockade

Depolarizing neuromuscular blocking agents:
- Atypical pseudocholinesterase
- Phase II block
- Deficiencies in normal pseudocholinesterase activity (anticholinesterase agents – ecothiopate, pesticides
- Genetic variance
- Liver disease
- Pregnancy
- Hypermagnesemia

Non-depolarizing neuromuscular blocking agents
- Intense neuromuscular blockade
- Inadequate reversal – ensure IV patency
- Residual volatile anesthetics (esp. isoflurane)
- Delayed excretion (renal insufficiency)

- Acute respiratory acidosis
- Hypothermia
- Potentiation of block by other agents (magnesium, furosemide, dantrolene, aminoglycosides)
- Underlying neuromuscular disorder (myasthenia gravis, familial periodic paralysis)
- Electrolyte disorders (hypocalcemia, hypomagnesemia, hypokalemia)

Seizures

- Support the airway, protect the airway, give 100% oxygen
- If due to hypoxia: oxygen therapy
- If do to local anesthetic toxicity often brief and self-limiting
- Consider other causes: electrolytes, glucose, intracranial pressure ok? Intracranial mass? Hypo-hypercapnia?
- Is there a history of seizure activity? Have seizure medications been taken? Are they at therapeutic levels?
- Persistent airway obstruction, succinylcholine with intubation
- If seizure persists, thiopental, midazolam or diazepam IV
- If cardiac effects CPR may be required (ACLS)
- Bupivicaine ventricular arrhythmias—Rx with bretylium (not lidocaine)
- Enflurane and hypocapnia can precipitate seizures.

Sinus Bradycardia

Possible causes:

- Vagal stimulation
  - Carotid sinus
  - Oculocardiac reflex
  - Abdominal/thoracic viscera
  - Pain
- Hypoxia
- Deep anesthetic
- Narcotics
- Drug effects/interactions/errors/withdrawal
- Electrolyte imbalance
- Hypothermia
- Sinus node dysfunction
- Myocardial infarction/ischemia

Possible interventions:

- Treat cause
- If unstable call for assistance, initiate ACLS algorithm

Sinus Tachycardia

Possible causes (consider patient history):
- Early hypoxia
- Hypovolemia/blood loss
- Fever (consider malignant hyperthermia)
- Light anesthesia
- Hypercapnia
- Hypoglycemia
- Catecholamines
  - Pain – surgical, positional, laryngoscopy
  - Type of surgery – renal, pituitary, thyroid
  - Electrocution
  - Electrolyte imbalance
  - Acid/base imbalance
  - Drug effects/interactions/errors/withdrawal/surgical
    - Local anesthetics with/without epinephrine
    - Pancuronium
    - Tricyclics
    - MAO inhibitors
    - Cocaine
- Embolis (air, thrombus)
- Tension pneumothorax
- Cardiac tamponade
- Thyrotoxicosis/thyroid storm
- Pheochromocytoma
- Myocardial infarct/ischemia
- CHF
- Mitral valve prolapse
- Autonomic neuropathy (diabetic?)

Possible interventions:
- Treat cause (i.e. cardiac tamponade – pericardiocentisis)
- If unstable call for assistance, initiate ACLS algorithm
- Beta-blockade
- Narcotics, deepen anesthetic
- Volume
- Consider serum ABG, CBC, electrolytes, glucose

Spinal Hematoma

- Rare but potentially catastrophic occurrence following neuraxial anesthesia
- Signs vary depending on level that at which the injury occurs
- New onset numbness, weakness, bowel/bladder dysfunction, radicular back pain
- Spontaneous occurrence seen: malignancy, preexisting coagulopathy
- Pathophysiologic or drug induce coagulopathy predispose to risk
- If suspected: rapid consultation with neurologist/neurosurgeon
- CT / MRI scans, full neurological exam
- Decompressive laminectomy
- Overall prognosis: full neurological recovery <40%

ST Segment Changes

Verify ST segment changes (lead placement, EKG settings, multiple leads, 12 lead if possible)
Review previous EKGs
Ensure adequate oxygenation/ventilation (consider ABGs)

ST elevation (myocardial injury)
- Treat associated factors (tachycardia, high/low BP, hypoxia)
- Consider nitroglycerin, beta-blockers, heparin
- Consider possible causes:
  - CAD (acute MI)
  - Pericardial injury (pericarditis, blunt trauma, cardioversion)
  - Hyperkalemia
  - Digitalis

ST depression, T wave inversion (myocardial ischemia)
- Treat associated factors (tachycardia, high/low BP, hypoxia)
- Consider heparin, aspirin, nitroglycerin, beta-blockers
- Consider possible causes
  - CAD – acute MI
  - Drug therapy (digitalis, quinidine)
  - Acute Cor Pulmonale
  - Cardiomyopathy
  - Athletic heart
  - LBBB

Abnormal Q-wave
- Transmural MI
- R&L ventricular hypertrophy
- R&LBBB
- Cor Pulmonale
- Cardiomyopathy

- Idiopathic hypertrophic subaortic stenosis
- Pneumothorax
- Emphysema

Inform surgeon
- Discuss early termination of procedure
- Consider transfer to ICU
- Consider cardiology consult

TURP Syndrome

Risk Factors:
- Prolonged procedure time (greater than 60 min.)
- Excessive bleeding
- Irrigant hung higher than 60cm above pt.
- Hypovolemia
- Hypotension

Manifestations:
- Restlessness and mental confusion
- N&V
- Dizziness
- Headache
- Decreased responsiveness
- Visual changes
- Seizure
- Hemodynamic changes: Hypertension, Bradycardia, Arrhythmia
- Increased airway pressure
- Cyanosis

Also Consider:
- Thrombotic Embolism
- Toxic reaction to local anesthetics
- Hemorrhagic, septic, or anaphylactic shock
- Acute heart failure
- CVA

Interventions:
- Notify Surgeon and terminate procedure
- Switch bladder irrigant to warmed normal saline
- Support ventilation PRN

- Obtain baseline labs: CBC & Chemistry, Coags if excessive bleeding
- Treat seizure with Benzodiazepines, Thiopental, Phenytoin
- Furosemide
- Maintain intravascular volume with NS
- Consider 3% Saline for severe symptoms
- Consider Art line, PA, CVP
- Monitor serum potassium as diuresis progresses
- Reassure patient

Wheezing - Perioperative

History of bronchospastic disease?
- Asthma, COPD, Cystic Fibrosis
- Review medical management and patient compliance

Aspiration
- Increase FiO2
- Trendelenberg
- Suction pharynx and trachea
- Treat bronchospasm
- Postoperative CXR
- Pulmonary consult

Bronchospasm
- Ensure adequate anesthetic depth
- Increase FiO2
- Increase I:E ratio
- Consider aerosolized Beta-2 agonists and IV steroids
- Consider sedation if emotional component
- Avoid histamine releasing agents

Light anesthesia
- Assess BP, HR, level of neuromuscular blockade
- Observe for tearing, sweating
- Deepen anesthetic level

Vagal stimulation
- Check ETT cuff inflation
- Consider repositioning ETT
- Assess surgical stimulation
- Assess depth of anesthesia

Other possible causes:

- Histamine releasing agents – thiopental, succinylcholine, morphine, mivacurium
- Inflammatory/infectious disease affecting airway
- Secretions in upper airway or ETT – pass suction catheter, consider new ETT if unable to clear
- Pulmonary emboli
- Pulmonary edema
- Foreign body in bronchus
- Congestive heart failure – decrease fluids, consider diuretics
- Congenital heart disease
- Enlarged pulmonary artery causing mainstem bronchial compression
- Vascular ring surrounding trachea

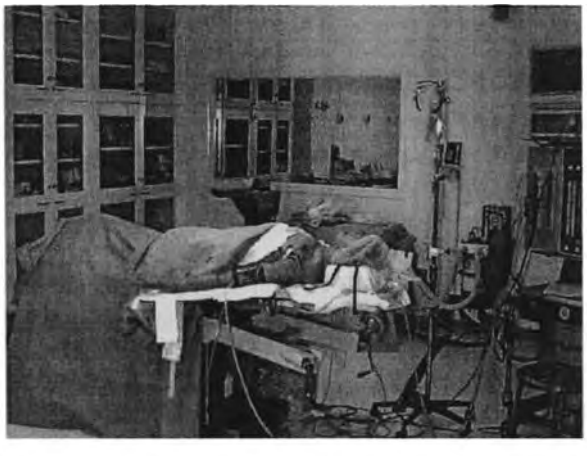
Appendix D

Facility Orientation

Center for Research in Human Simulation

Department of Nurse Anesthesia
Virginia Commonwealth University

Facility Orientation



Department of Nurse Anesthesia

2003

Introduction

Welcome to the Department of Nurse Anesthesia's "Center for Research in Human Simulation" (CRHS). The facility occupies over 1300 square feet of space in the Department of Nurse Anesthesia, within the School of Allied Health Professions. The Center can be configured to resemble any clinical setting; including the OR, PACU, ICU, ER or pre-hospital setting.

Features of the Center include two full-body Patient Simulators, MedSim and Laerdal, which can be used in a variety of patient settings. The recent addition of the MPL / Laerdal SimMan™ Universal Patient Simulator allows for simulation training at remote locations and offers unique airway anatomy that provides health care providers the opportunity to practice flexible fiberoptic skills.

The Department of Nurse Anesthesia acquired the Immersion Medical Accutouch® Endoscopy Simulator that delivers realistic, procedure-based training of fiberoptic skills and bronchoscopy procedural cognitive and motor skills.

For pediatric training, the CRHS purchased the Laerdal Baby Code trainer, which offers instruction in ECG rhythm recognition as well as a variety of heart sound and lung sounds. An external speaker permits training of larger groups in heart and lung sound recognition. The Pediatric Simulator permits standard airway training for oral airways, nasal airways, intubation, mask ventilation as well as oral gastric tube placement. IV access can be obtained for either peripherally IV or through an IO.

Four ceiling mounted cameras offer the unique ability to capture simulation sessions from a variety of angles. Ceiling mics record room noises and conversations and individual lapel microphones record participant conversations clearly and accurately.

The MedSim Patient Simulator is a high fidelity training device that offers the opportunity to perform realistic medical scenarios for clinical training. The mannequin has palpable pulses, audible heart and breath sounds, and a realistic airway and lungs, which exhale carbon dioxide. Additional trauma upgrades allow the simulator to move his arms, blink his eyes and respond to pain as a patient would. His eyes respond to hypoxia, medications and light. The mannequin's special chest allows CPR and the insertion of chest tubes and PA catheters for use in training scenarios. The simulator responds appropriately to over 80 different drugs. With the Drug Editor, the instructors can add new drugs or agents to the program. The Center offers the ability to operate the simulator at bedside or a remote location with the use of a new Remote Pen Tablet computer.

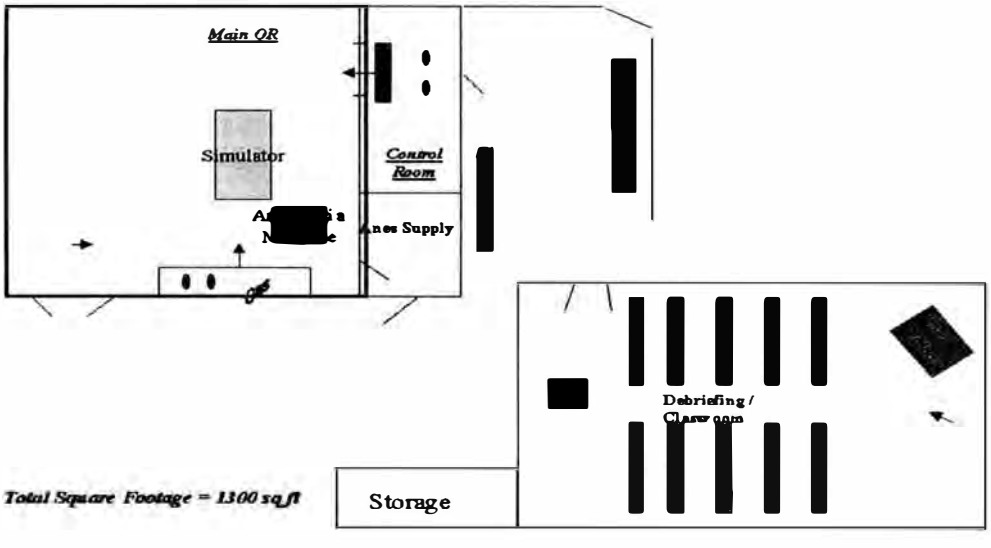
The Laerdal SimMan™ Universal Patient Simulator is capable of monitoring non-invasive blood pressure, EKG, CO_2, respiratory rate, temperature and pulse oximetry.

The simulator has a variety of heart, breath, bowel and vocal sounds. The assortment of sounds allows for the development of numerous scenarios that can be tailored specifically to the simulation participant's level. A unique feature of the SimMan™ is the portability of the system. A laptop computer interfaces with the patient simulator and the remaining hardware can be placed in a portable duffle bag. Such portability allows for simulation training in remote locations.

Facility

The CRHS is located on the East Wing of the 11th Floor, West Hospital and occupies 1300 square feet of space within the department.

Figure 2. Example of architectural design of a Simulation Center.



Lounge Area

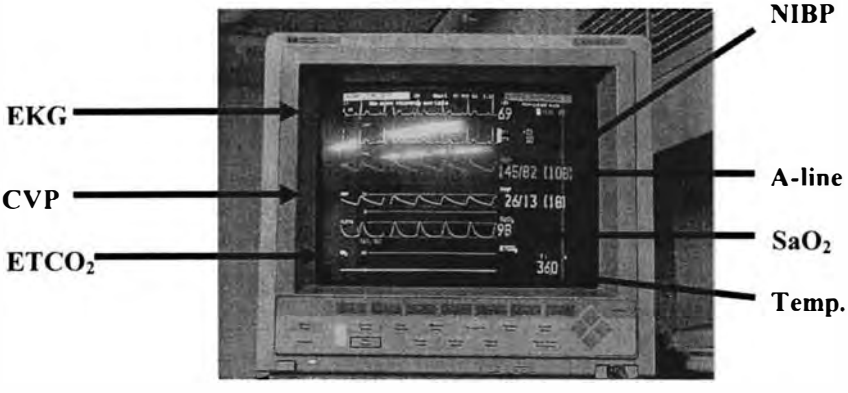
A lounge area is located in the rear of the wing and offers a soda machine, coffee maker, bottled water, microwave and full size refrigerator.

Scrubs

Each simulation course participant is responsible for providing their **own personal scrubs** for their sessions. Participants normally change in either the restrooms or faculty offices.

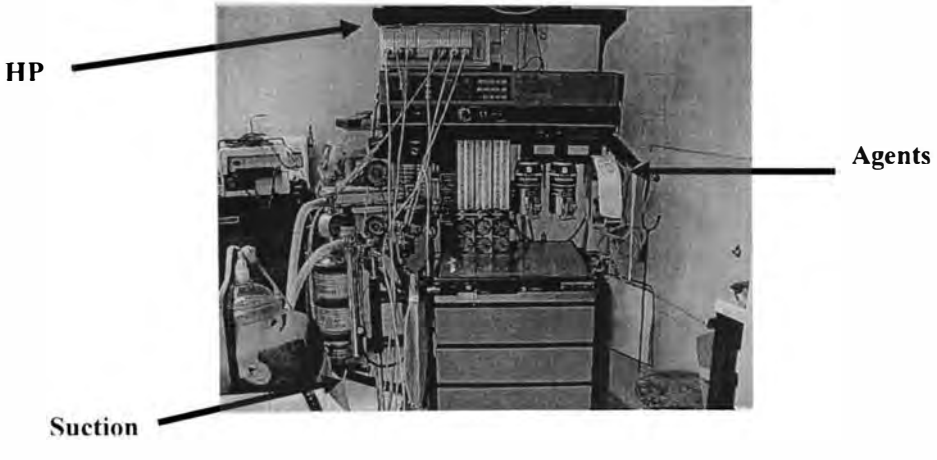
Simulation Center Equipment

Monitor

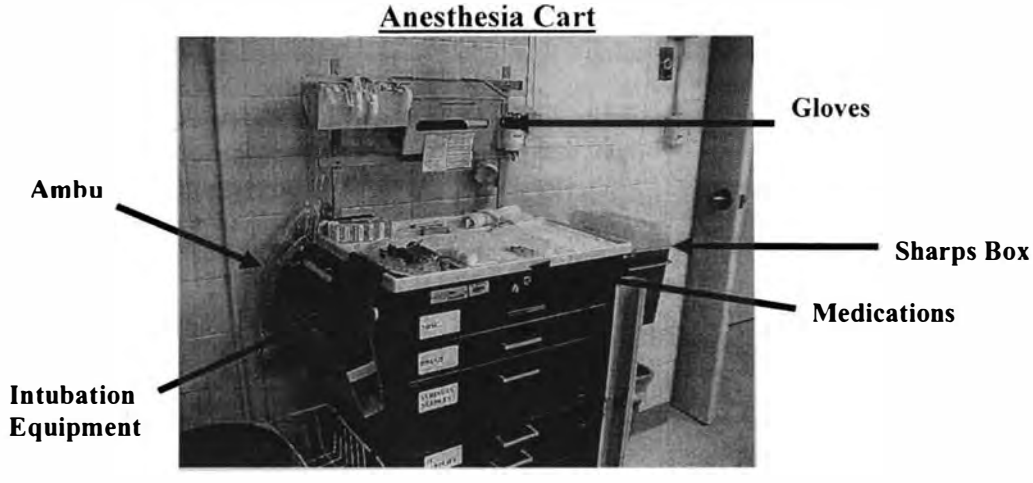


Standard HP monitors are used for simulated patient monitoring. HP's have the capability to monitor ECG (all leads), non-invasive BP, arterial pressures, CVP and PA pressures. Also, CO_2, pulse oximetry, temperature and CO can be measured on the monitors.

Anesthesia Machine



A Drager Narkomed anesthesia machine is located within the CRHS. Simulated patients may be placed on nasal O_2, mask ventilated or intubated and placed on the ventilator. Participants are encouraged to examine all equipment prior to participating in the course.



The CRHS Anesthesia Cart is stocked with standard equipment and drugs. Each drawer is labeled for content and additional supplies are located either in the room or in the adjacent pharmacy room. *Note CRHS uses *expired* medications.

- **Drug Drawer**:

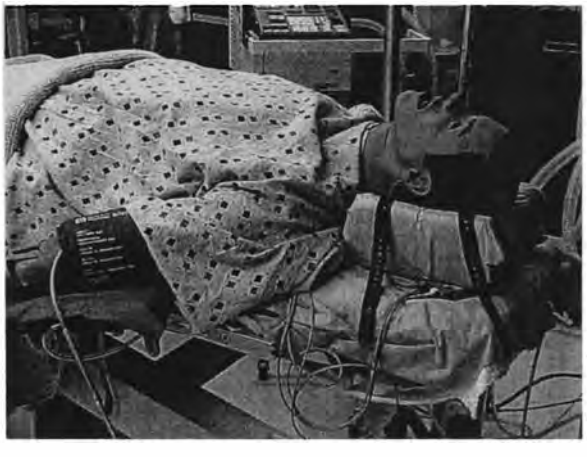
Medications are labeled and alphabetized in the drawer.

- **Supplies:**

Additional supplies such as needles, syringes, blood tubes, airway equipment etc. are located within the cart and labeled.

Simulators

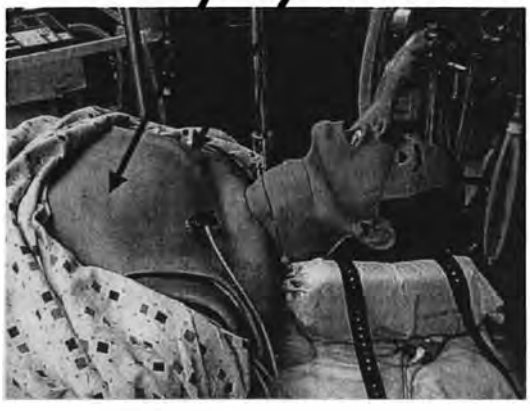
"SAMMY" Simulator 1 (MedSim):



Features:

- **Spontaneously blinks; pupils respond to light, drugs and hypoxia**
- **Dynamic Airway – Able to:**
  - ✓ **Swell tongue and posterior oropharynx**
  - ✓ **Cords close**
  - ✓ **Lock head and / or jaw in various positions**
  - ✓ **Perform surgical or needle cricothyrotomy**
  - ✓ **Accept any alternative airway products such as LMA, COPA, Trach Light, Bullard, etc.**
- **Heart Sounds / Breath Sounds**

- ✓ **Variety of sounds allows for realistic presentation of a variety of clinical conditions**
- ✓ **MUST listen to heart and breath sounds *directly* above each nipple.**



- **Spontaneous movement of left arm**
- **Right thumb twitch response to Peripheral Nerve Stimulator**

Features Cont'd:

- **Palpable left radial and bilateral carotid pulses**

- **IV access Left or Right periphery as well as Left Antecubital**
  - ✓ **Able to administer any intravenous product thru peripheral or central lines**
- **Invasive Monitoring:**
  - ✓ **A-Line**
  - ✓ **PA / CVP**
- **Exhales CO_2**
  - ✓ **Generates accurate CO_2 reading and wave form**
- **Voice**
  - ✓ **Responds verbally to participants**
- **Chest Tube / Needle Decompression RIGHT Chest *only***
- **Interfaces with standard monitoring equipment:**

- ✓ **HP Monitors**
- ✓ **Life Pak Monitors**
- ✓ **Defibrillators**

Limitations:

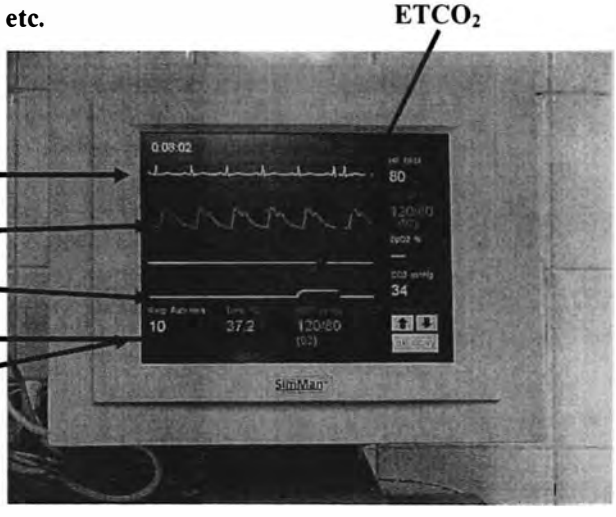
- **Simulator 1 <u>Does Not</u>:**
  - ✓ **Sweat**
  - ✓ **Produce secretions**
  - ✓ **Vomit**
  - ✓ **Change skin color or temperature**
  - ✓ **Allow for full CPR compressions**
    - **Chest compressions must be done very lightly**
  - ✓ **Offer portability out of simulation center**

"JACK" Simulator 2 (SimMan™):

Features:

- **Dynamic Airway - Able to:**
  - ✓ **Swell tongue and posterior oropharynx**
  - ✓ **Cords close**
  - ✓ **Demonstrate Trismus**
  - ✓ **Lock head and / or jaw in various positions (remotely)**
  - ✓ **Perform surgical or needle cricothyrotomy**
  - ✓ **Accept any alternative airway products such as LMA, COPA, Trach Light, Bullard, etc.**
  - ✓ **Perform flexible fiberoptic intubation**
- **Wide variety of heart, breath, bowel and vocal sounds**
  - ✓ **Numerous speaker locations throughout the chest and abdomen**
- **Palpable left radial, bilateral carotid, bilateral femoral and left brachial pulses**
- **IV access right periphery or centrally – administer any IV product**
- **Full CPR chest compressions / Interfaces with standard Defib Monitors**
  - ✓ **Accepts actual joules from any defibrillator**

- **Invasive Monitoring:**
  - ✓ **A-line**
- **Exhales CO_2**
  - ✓ **Wave form is standard wave form regardless of patient profile**
- **Voice**
  - ✓ **Responds verbally to questions etc.**
- **Chest tube / needle decompression**
  - ✓ **Left or right side**
- **Monitoring Equipment**
  - ✓ **Specific Monitor to display**
    - **ECG**
    - **NIBP**
    - **A-line**
    - **SaO_2**
    - **CO_2**
    - **Temp**
    - **Respiratory Rate**



Limitations:

- **Simulator 2 <u>Does Not</u>:**
  - ✓ **Sweat**
  - ✓ **Produce secretions**
  - ✓ **Vomit**
  - ✓ **Change skin color or temperature**
  - ✓ **Monitor PA pressures**
  - ✓ **Change CO_2 wave forms according to clinical conditions**
  - ✓ **Interface with standard monitors except for ECG functions**
  - ✓ **Respond to Peripheral Nerve Stimulator**
  - ✓ **Spontaneously move**

CRHS Faculty

Mimi Hotchkiss, MSNA, CRNA
Assistant Professor and Director
Center for Research in Human Simulation
Department of Nurse Anesthesia

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Graduate Nurse Anesthesia Student
Class of 2004

Directions to the Center for Research in Human Simulation:

Heading South on I-95
Take Exit 74 C (West Broad Street, Left Lane)
Turn Right onto 11th Street
Turn Right onto Clay Street
Straight ahead past 12th Street
to the patient and visitor parking deck

Heading North on I-95
As you enter the city stay in the right lane and take Exit 74 C (West Broad Street Exit – merge to the Left of the exit). *Follow the directions given to the left.*

Come to Main Floor of Hospital
Straight ahead will be Gift Shop and Information Booth next to it.
Pass Information Booth toward opening (cappuccino booth around corner)
Keep straight through catwalk.
Continue through clinic; you will approach a closed door with a sign (West Hospital)
Continue through to corridor with elevators.
Take elevator to the 11th floor, East Wing

For additional information, please contact Mimi Hotchkiss at [redacted] or the Department of Nurse Anesthesia at [redacted]

Appendix E

Schedule of Activities

Center for Research in Human Simulation
Schedule of Activities

0800-1415

Introduction and Orientation	0800 - 0915
Break	0915 - 0930
First simulation run – Participant A	0930 - 1000
First recall session – Participant A	1000 - 1030
Second simulation run – Participant B	1030 - 1100
Second recall session – Participant B	1100 - 1130
Lunch – Participant B Third Simulation run – Participant A	1130 - 1200
Third recall session – Participant A	1200 - 1230
Lunch – Participant A Fourth simulation run – Participant B	1230 - 1300
Fourth recall session – Participant B	1300 - 1330
Group interview – Participants A & B	1330 – 1415

Every attempt will be made to adhere to this schedule. Time required to complete the day's activities has been slightly overestimated to ensure completion by 1415. Your participation in this investigation is greatly appreciated.

Appendix F

Think Aloud Instructions

During the simulation runs please "think aloud". Try not to plan what to say, or speak after the thought, but rather let your thoughts speak as though you really were thinking aloud. Be as spontaneous as possible. It is not necessary to explain, interpret, or justify your actions. Just verbalize your thoughts at the moment.

Appendix G

Simulation Observation Data Collection Tool

Circle as appropriate:
Case Scenario - Increased airway pressure/Failure to emerge
PDA present - Yes/No
Participant ID - ____

	Time to achieve (from start of scenario, in min-sec)
1. First recognizes abnormal event	
2. First indicates correct diagnosis	
3. Institutes first appropriate intervention	

PDA use	Start time (from start of	Finish time scenario, in min-sec)	Actual time (in min-sec)
4. First use			
Second use			
Third use			
Fourth use			
Fifth use			
5. Total time			

	# of occurrences (slash mark)	N/A
6. PDA uses (complete at end)		
7. Skill-based errors (accidents or execution failures)		
8. Knowledge-based errors (mistakes or planning failures)		

	Yes	No
9. Anesthetist appears to easily incorporate use of PDA		
10. Anesthetist appears to have difficulty using the PDA		
11. Anesthetist appears to "suspend disbelief" in the simulation environment		
12. Anesthetist appears distracted by simulation environment		

Notes & Comments:
(continue on back if necessary)

Appendix H

Researcher Observation Form

To be filled out by primary investigator during each simulation run

Participant ID ____ Scenario setting (circle) – OR/PACU

Observational Notes	
Descriptive Notes	***Reflective Notes***
Additional Information	

Appendix I

Semi-structured Group Interview Question/Topic Guide

Research question:

What are the perceptions of certified registered nurse anesthetists of PDA use and the simulation experience?

PDA questions:

1. Did you feel comfortable using the PDA?
2. Were you easily able to incorporate its use in providing patient care?
3. Did you find the algorithms helpful?
4. Did you like the presentation and organization of the algorithms?
5. What are your predictions for the use of the PDA in clinical anesthesia?
6. Do you think the device (PDA) and the content (algorithms) presented would be usable and helpful in the clinical environment?
7. Do you think it has the potential to improve patient outcomes? To reduce human error?
8. Do you have any suggestions for improvement of the device and its content?

Simulation environment questions:

1. How did you feel in the simulated environment?
2. How well did the simulated environment represent the natural environment?
3. Was there anything that distracted from the simulated environment, making it seem less real?

4. Do you have any suggestions as to how to make the experience seem as real as possible?

5. How do you feel about using high-fidelity human simulation as a method to study the area of interest?

Appendix J

Videotape Coding Instrument

Please indicate the scenario being depicted: ____ OR _____ PACU

1. Note all distractions with a slash each time it occurs:

Microphone or faculty headset
Video camera
One-way mirror
Other (please describe)

Patient voice/speaker
Chest sounds
Questionable integrity of equipment

2. Please indicate how distracting you found the following items:
(circle your response)

	Very distracting	**Somewhat distracting**	**Not distracting**
Microphone or faculty headset	3	2	1
Observation mirror	3	2	1
Patient voice/speaker	3	2	1
Video camera	3	2	1
Chest sounds	3	2	1
Questionable integrity of equipment	3	2	1
Other (add from above)	3	2	1
	3	2	1

Please elaborate for any scores of "3" or "2":

3. Did the participant appear to "suspend disbelief" with respect to:
(please circle your response)

	Accepted as real	**Partly accepted as real**	**Did not accept as real**	**Not applicable**
The "patient"	3	2	1	0
The "surgeon"	3	2	1	0
The "circulating RN"	3	2	1	0
The "scrub technician"	3	2	1	0
The "PACU RN"	3	2	1	0
The case scenario	3	2	1	0

Please elaborate for any scores of "2" or "1":

4. Were you, as an observer, able to "suspend disbelief" with respect to:
(please circle your response)

	Accepted as real	**Partly accepted as real**	**Did not accept as real**	**Not applicable**
The "patient"	3	2	1	0
The "surgeon"	3	2	1	0
The "circulating RN"	3	2	1	0
The "scrub technician"	3	2	1	0
The "PACU RN"	3	2	1	0
The case scenario	3	2	1	0

Please elaborate for any scores of "2" or "1":

5. Was the arrangement of equipment realistic? ____ Yes ____ No
If "no" please describe:

6. Was the arrangement of personnel realistic? ____ Yes ____ No
If "no" please describe:

7. Was there any indication that the participant had difficulty interacting with simulation faculty in a particular role? ____Yes ____ No
If "yes" please describe:

8. Please provide a brief, overall assessment of this simulation experience. Any impressions, specific information, or suggestions for improvement would be appreciated.

9. Was a PDA used during this simulation? ____ Yes ____ No
(if "yes" please continue with questions 10 - 14)

10. Did the participant appear to have any difficulty using the PDA from a technical standpoint?
____ Yes ____ No
If "yes" please describe:

11. Did the participant appear to easily incorporate the use of the PDA into their care of the "patient"?
____ Yes ____ No
If "no" please describe:

12. Did the participant appear to find use of the PDA to be helpful in caring for the "patient"?
____ Yes ____ No
Please elaborate:

13. Do you think a similarly programmed PDA would be useful in the clinical setting?
____ Yes ____ No
Please elaborate:

14. Please provide a brief, overall assessment of the PDA. Any impressions, specific information, or suggestions for improvement would be appreciated. Thank you again for participating

Appendix K

Participant Evaluation Form

Please circle the simulation location and complete the form accordingly:

OR PACU

1. Please indicate how distracting you found the following items:
(circle your response)

	Very distracting	**Somewhat distracting**	**Not distracting**
Microphone or faculty headset	3	2	1
Observation mirror	3	2	1
Patient voice/speaker	3	2	1
Video camera	3	2	1
Chest sounds	3	2	1
Questionable integrity of equipment	3	2	1
Other (add from above)	3	2	1
	3	2	1

Please elaborate for any scores of "3" or "2":

2. Were you able to "suspend disbelief" with respect to: (please circle your response)

	Accepted as real	**Partly accepted as real**	**Did not accept as real**	**Not applicable**
The "patient"	3	2	1	0
The "surgeon"	3	2	1	0
The "circulating RN"	3	2	1	0
The "scrub technician"	3	2	1	0
The "PACU RN"	3	2	1	0
The case scenario	3	2	1	0

Please elaborate for any scores of "2" or "1":

3. Was the arrangement of equipment realistic? ____ Yes ____ No
If "no" please describe:

4. Was the arrangement of personnel realistic? ____ Yes ____ No
If "no" please describe:

5. Did you have any difficulty interacting with simulation faculty in a particular role?
____ Yes ____ No
If "yes" please describe:

6. Please provide a brief, overall assessment of this simulation experience. Any impressions, specific information, or suggestions for improvement would be appreciated.

Was a PDA available for your use during this simulation? ____ Yes ____ No
(if "yes" please continue with questions 7 - 11)

7. Did you have any difficulty using the PDA from a technical standpoint?
____ Yes ____ No
If "yes" please describe:

8. Were you easily able to incorporate the use of the PDA into your care of the "patient"?
____ Yes ____ No
If "no" please describe:

9. Did you find use of the PDA to be helpful in caring for the "patient"?
____ Yes ____ No
Please elaborate:

10. Do you think a similarly programmed PDA would be useful in the clinical setting?
____ Yes ____ No
Please elaborate:

11. Please provide a brief, overall assessment of the PDA. Any impressions, specific information, or suggestions for improvement would be appreciated. Thank you again for participating

Vita