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Traditional versus Simulator-based Small Group Teaching: A Comparative Study with Third Year Undergraduate Medical Students

by

Leanna Sue McKenzie

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Traditional versus Simulator-based Small Group Teaching: A Comparative Study with Third Year Undergraduate Medical Students" submitted by Leanna Sue McKenzie in partial fulfilment of the requirements of the degree of Master of Science.

P. Jennett

Supervisor, Dr. P. Jennett, Department of Community Health Sciences

Dr. B. Scott, Department of Pediatrics

Dr. J. G. Descoteaux, Department of Surgery

Dr. N. Schachar, Department of Surgery

April 26/2004

Date

Abstract

In recent years, patient simulators have gained acceptance as teaching aids in medical education, however few studies support their efficacy. In this comparative study, thirty-eight medical students participated in either a traditional or simulator-based small group teaching session to learn the principles and management of pediatric shock and dehydration. Findings: 1. Subjects in both groups experienced a significant knowledge gain, but there was no difference in the degree of knowledge gain between the two groups; 2. No difference was demonstrated between the two groups with respect to long-term knowledge retention; 3. Student satisfaction was uniformly high in both the traditional and simulator-based small group sessions; 4. Video review of the sessions comparing group dynamics between the two teaching styles demonstrated a higher degree of student participation in the simulator-based group. The utility, feasibility, benefits and difficulties of incorporating simulators into undergraduate medical education are discussed.

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Dedication

This thesis is dedicated to my husband Sean, for his endless optimism, support and love; to my beautiful baby Benjamin, my source of greatest inspiration; and to my parents, Al and Jan, who have always believed in me and reminded me that anything can be accomplished with hard work and a positive attitude.

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List of Nomenclature

Learners: Refers to subjects in the experiment who are volunteering third year medical students at the University of Calgary.

Clerkship: The practical year of medical school, usually in the third or fourth year, where students rotate through all specialities acting as a junior assistant on the ward.

High Fidelity Patient Simulator: A lifelike computerized mannequin capable of demonstrating realistic physical signs such as breath sounds, heartbeats, voice, and pulses, and physiologically appropriate responses to interventions such as fluid and medication administrations.

Traditional Small Group Teaching: A type of teaching method used in medical schools consisting of 4-8 students, a facilitator, and involving active participation, face-to-face contact, and purposeful activity. Small group teaching often uses clinical vignettes to act as a starting point for discussion.

Simulator-Based Small Group Teaching: A type of teaching method that utilizes a high-fidelity patient simulator as a tool for student discussion, practice, and evaluation. As with traditional small group teaching, a session consists of 4-8 students and a facilitator, and involves active participation, face-to-face contact and purposeful activity.

Facilitator: A tutor or instructor who leads the small group session. The facilitator's primary responsibilities are to encourage purposeful discussion, prompt important questioning, and guide students in their learning.

Procedural Knowledge Items: Multiple choice questions which assess knowledge related to patient management.

Declarative Knowledge Items: Multiple choice questions testing "lower level" knowledge by recall or recognition.

Test Reliability: A measure of the consistency with which the test produces the same results under different but comparable conditions.

Face validity: The degree to which an instrument appears to measure the intended content or trait.

Content validity: The degree to which an instrument tests a representative sample of a defined content domain.

CHAPTER ONE: INTRODUCTION

A. Identification of Problem

The demand for innovative and creative teaching methods in medical education has prompted a search for alternative educational techniques over the last decade. Chronic deficiencies in medical education have recently intensified due to issues such as enlarging class sizes, increasingly ill patients and time constraints of clinicians. As a result, educators have embraced the use of computers and technology to help mitigate these problems and offer novel solutions.[1,2,3] Medical students, in turn, are increasingly computer-literate and welcome technological advances that enable accessible and interactive options for learning the required curriculum.[4, 5, 6]

Patient simulators are one such example of an innovative technologic teaching aid in medical education that is generating interest in recent years. High-fidelity patient simulators are anatomically and physiologically realistic computer-controlled mannequins. Through the development of computerized patient scenarios, learners may assess physical signs, stabilize a patient with fluids and medications, and learn to treat life-threatening conditions. Because of the wide variety of possible educational and clinical applications, patient simulators are increasingly incorporated in medical education as teaching aids. [1, 2,7]

In North America, the current direction of medical education focuses on small group teaching, a method that has significantly increased in popularity over the last decade. This teaching technique constitutes a learning session composed of a facilitator with approximately four to eight students, and is characterised by active participation, face-to-face contact, and purposeful activity. The many advantages of this teaching style include enhanced problem-solving, experience with leadership and team dynamics, and refinement of interpersonal skills.[8]

The addition of an educational tool such as a patient simulator may add a further dimension to small group teaching. Here, students are able to role-play in a "hands-on" manner and physically practice the technical, problem-solving and communication skills necessary for patient care. The excitement of managing a physiologically "real" patient forces the student to work through complex problems under emotionally stressful circumstances. Furthermore, peer observation provides an additional opportunity for learning since all performances may be examined and discussed after each session in a debriefing period. Thus, the three traditional "domains" of medical education - knowledge, skills and attitudes- may be effectively explored in one venue allowing for enhanced learning opportunities.

Unfortunately, the current body of literature surrounding the efficacy of patient simulators as a teaching aid is both sparse and inconclusive. While the use of the simulator as an evaluation modality has been studied with some rigor,[9,10,11,12,13,14,15,16,17,18] its utility as a teaching tool has received relatively little attention.[19,20,21,22,23,24] Few studies have compared the efficacy of simulator-based teaching versus traditional teaching methods such as lecturing or small group sessions.[20,22] Furthermore, the majority of studies have focused on simulator use in the resident and post-graduate population, with less emphasis on its utility in medical students.[20,22,24] Medical students may arguably be in a position to benefit most from the simulator, since the real-time physiology demonstrated may enhance the learning of basic science principles and clinical management.

B. Purpose of the Study

The purposes of this study were to:

1. Compare student knowledge gain resulting from participation in either a traditional or simulator-based small group teaching session in a sample of third year undergraduate medical students.
2. Evaluate the two teaching methods, traditional and simulator-based small group teaching, with respect to promoting long-term knowledge retention.
3. Assess the degree of student satisfaction with traditional versus simulator-based small group teaching.
4. Describe student and facilitator group dynamics and qualitative responses to the incorporation of simulators into small group teaching.
5. Discuss the feasibility of utilizing patient simulators as a teaching aid in small group teaching at the undergraduate level.

This study aimed to answer the following research question:

> "In teaching the principles and management of pediatric dehydration and shock to a population of undergraduate clinical clerks, does the incorporation of a patient simulator into small group teaching lead to increased knowledge gains over traditional small group sessions?"

C. Importance of the Study

The evaluation of patient simulators used as a teaching adjunct is an area of important educational research for many compelling reasons.[7,10] First, there is an expanding need for innovative and realistic models to enable interactive learning and practice for undergraduate medical students. Perhaps the greatest advantage the patient simulator presents is the opportunity for learners to practice clinical problem solving without patient risk. Importantly, even though simulators are becoming more frequently utilized in teaching hospitals, few studies have focused on student knowledge gain resulting from the incorporation of a simulator teaching aid.[19,20,21,22,23,24] Considering the high price associated with the purchase and maintenance of patient simulators, this is an area of research that warrants careful scrutiny.

This study focuses on the principles and management of pediatric dehydration and shock due to gastrointestinal illness. Dehydration resulting from gastroenteritis is one of the most common causes of pediatric hospital admissions. Despite improved awareness and treatment options, dehydration and hypovolemic shock remain a frequent cause of morbidity and mortality even in the teaching hospitals of North America.[25,26] Internationally, dehydration secondary to diarrhea remains a leading cause of morbidity and mortality in pediatric health care, despite the effectiveness of oral rehydration therapy.[27] Dehydration and hypovolemic shock are therefore among the most commonly encountered conditions in pediatrics, comprise a substantial portion of patients in clinics and hospitals, and last, are topics amenable to small group teaching.

The concept of employing technology to teach medical education has far reaching implications. First, the current population of medical students are not only computer-literate, but generally embrace technology enhanced educational methods;[4,5] ultimately, this may lead to a generation of physician-educators heavily invested in computer-based teaching and learning. The successful development of sophisticated simulators, modules, computers and robots provide learners with experiences previously only encountered by direct clinical practice. This has profound ethical implications and may ultimately challenge the old medical school adage "see one, do one, teach one". Finally, virtual reality is now established in North American teaching hospitals, as evidenced by the advent of telehealth and remote surgical procedures. High fidelity simulators are yet another extension of this technology and the wide variety of applications for this novel invention make it likely that simulators will become prevalent at different stages of medical training.

CHAPTER TWO: REVIEW OF RELATED LITERATURE

The review of related literature is organised under three major sections. First, the instrumental concepts and group dynamics related to small group teaching are reviewed. Next, qualities of effective teaching techniques in medical education are discussed. Third, the body of literature from the last decade examining high-fidelity patient simulators used as a teaching aid in medical education is assessed. In this latter section, three types of studies are reviewed: descriptive studies outlining the utility, advantages, and shortcomings of simulator technology; articles examining the utility of simulators as a teaching tool; and studies examining learner attitudes toward simulator training. Finally, the research questions for this study are defined.

A. Principles of Small Group Teaching

Medical education continues to search for innovative teaching methods that are efficacious, interactive, and efficient. As the paradigm of medical education shifts from didactic to self-directed learning, educators have embraced small group teaching to encourage problem-solving and individualize learning sessions based on student needs. The small group method of teaching generates open communication between a facilitator and a small group of learners. Sessions consist of objective-based discussion in a group atmosphere, aided by a facilitator who guides the session by identifying errors, focusing problems, and engaging in active listening.[8]

Small group teaching has a firmly established role in most North American medical institutions based on a number of favourable arguments and literature findings. The small group format allows difficult concepts to be taught through focused discussion and multiple perspectives. Facilitators are able to guide the learning topics to an appropriate level of detail and difficulty. Case-based sessions add relevant context to the learning process, ultimately resulting in increased student motivation. Unlike other teaching methods, small group sessions are also effective at promoting attitudinal change in participants. Further, small group methods allow purposeful discussion to occur between attending physicians and students, which ultimately may foster the development of teamwork and leadership skills.[28]

Perhaps the greatest utility of the small group method lies in its ability to promote problem-solving and enhance understanding of a topic. Educational concepts adopted from cognitive psychology have focused on the distinction between "deep" and "surface" learning. A "deep" approach to learning focuses on the meaning and context of the material and requires active participation from the students. Conversely, a "surface" approach to learning concentrates on memorizing and detailed recall of facts. In general, psychological studies have demonstrated that deep learning is more easily retained and promotes a greater understanding of the subject. This is postulated to be the result of a rich network of memory associations formed during the encoding process.[29]

Disadvantages to this teaching method clearly exist and are often related to the dynamics and characteristics of the participants and facilitator.[8,28] Passive or introverted learners may become withdrawn or intimidated by more articulate students. Motivated and able learners may feel frustrated or bored by the slow pace of learning. Facilitators who feel uncomfortable with the teaching style may resort to "mini-lectures", speeches which inhibit discussion between students. Last, small groups require a significant time commitment by educators and thus are widely criticized as being less cost effective or efficient than traditional lectures.

The focus on "student-centered learning" has prompted educators to develop novel approaches for measuring group dynamics in the small group teaching milieu.[30,31] In a 1998 study from Hong Kong, Prinz et al measured the participation of first year medical students learning anatomy in small groups by two methods: recording the length of individual contributions using a keyboard as a timer, and recording the sessions with an audiotape which allowed analysis of individual contributions.[30] These techniques allowed quantification of the degree of student and teacher interaction. In general, analysis revealed three common dynamics: "mini-lectures" by teachers, "question and answer" sessions involving both students and facilitators, and "mini-presentations" by students. In addition, the degree of student contribution was compared to performance on a written examination and no clear relationship was demonstrated. The authors concluded that both the techniques described were useful in providing an objective measure of student participation, and the information gleaned is especially valuable to educators trying to promote interactive learning.

A second study by R.J. Taylor from Scotland focused on the interplay between teachers and students by videotaping new professors delivering seminars to undergraduate medical students.[31] Systematic observation of the videotape allowed quantification of the proportion of: teacher to student communication, teacher communication which was "student-centered", and student-initiated communication.

Though this article was primarily descriptive in nature, the author suggested that this type of communication analysis is valuable for lecturers interested in improving their small group teaching skills by highlighting "student-centred" learning opportunities.

Since the hallmark of small group teaching is student-driven discussion and participation, the addition of a simulator as a teaching tool into such a session may further enhance "active learning" by students. Patient simulators can create excitement, motivation, and enhance participation in the teaching session; all of these factors may ultimately promote "deep learning". Cognitive psychology theory suggests that learning is enhanced in a mentally or emotionally stimulating environment.[29] Furthermore, it is hypothesized that the physical act of practicing patient management during knowledge acquisition encodes further cues which may help in the retrieval process. Ultimately, this may result in improved recall, comprehension and problem-solving ability.

B. Qualities of Effective Medical Teaching

Regardless of the specific method utilized, certain teaching characteristics appear to be essential in promoting efficient and effective student education. Efficiency is defined as accomplishing a task with minimal expenditure of energy, effort, or time, whereas effectiveness relates to the ability to cause the intended result. Not surprisingly, the balance of achieving efficiency and effectiveness in a teaching method is difficult at all levels of medical education. Ideally, a new teaching tool such as a patient simulator should enhance both of these properties. To enable assessment of simulators as a teaching tool, the literature examining the characteristics of effective and efficient teaching methods is summarized.

Research into educator qualities and methods promoting effective teaching has garnered intense interest by medical educators over the past decade. In a 1994 article by Irby, the researcher explored educator attributes and techniques which promote teaching excellence.[32] Recommendations from the article included encouraging educators to: actively involve learners, ensure the learning is engaging and enjoyable, connect the teaching case to broader concepts, ascertain the topics are practical and relevant, be selective and realistic when planning a session, and finally, provide feedback and evaluation.

Similarly, a 1996 editorial by Chastonay et al explored the efficacy of medical education and suggested that educators should focus on enabling learners to solve health problems rather than encouraging recall of basic science knowledge.[33] The authors explored the concept of relevance in medical training, and asserted that medical education must focus on problem-solving and responsibility to community health needs. Again, the authors stressed that learning is made enjoyable by ensuring that topics are practical, relevant, and important to the student.

A review by Irby in 1995 identified a number of suggestions to enhance learning in the clinical teaching environment.[34] These included setting clear and realistic expectations, modelling and teaching to the learners' needs, giving specific feedback based on observation of student performance, creating a positive learning environment, and encouraging time for reflection. Unfortunately, although this review concisely highlighted the key concepts of successful medical teaching, no mention was made of the measured effectiveness of implementing the aforementioned suggestions.

Heidenreich et al performed a literature review focusing on articles from 1995-2000 that examined effective and efficient clinical teaching; eleven frequently used teaching strategies in medical education were identified.[35] The effective teaching methods discussed included: orienting the learner before patient encounters, prioritizing learning needs, priming, questioning, and feedback. Unfortunately, empirical data demonstrating efficacy of these methods were lacking, and efficiency of the methods was not extensively assessed.

In reviewing the literature surrounding characteristics of effective and efficient teaching methods, recurrent concepts emerge. First, learning should ideally occur in an enjoyable, non-threatening environment. The concept of orientation and practice are important, in addition to interactive techniques such as priming and questioning. Last, feedback and reflection appear paramount in consolidating key teaching points and developing skills of critical analysis.

The teaching techniques highlighted in the abovementioned articles are primarily applicable to the clinical learning environment. The incorporation of patient simulators into small group teaching may enable these desired teaching techniques to be utilized in the undergraduate population without direct patient contact. This discussion will be further explored in the upcoming literature review surrounding the use of patient simulators as a teaching tool in medical education.

C. Patient Simulators in Medical Education

1. Descriptive Studies

a. General Description of Patient Simulators

Initial reports on patient simulators used in medical education are descriptive in nature, and focus on the history, implementation, reported advantages and obstacles presented by the technology.[36,37,38] To begin, a brief description of the simulator and its introduction into medical education is discussed. While initial simulators were awkward and unrealistic,[39] current full-sized pediatric and adult mannequins are equipped to demonstrate a multitude of authentic physical signs and physiological reactions. The newly created "high-fidelity" simulators demonstrate pupillary dilatation, central and peripheral pulses, respiratory effort, heart sounds, and speech. Learners may practice airway management, trauma resuscitation, management of shock and cardiovascular instability, and cardiac arrhythmias. The administration of medical therapies such as fluids, oxygen or medications results in immediate physiologic reactions appropriate for the age and weight of the simulated patient. However, despite the sophistication of the current patient simulators, they are unable to portray certain physical signs such as color, skin turgor, and abdominal rigidity; learners are oriented to these shortcomings before the teaching session commences.

Scenarios are developed by medical personnel in conjunction with technicians; cases take considerable time and effort to implement, however once developed, each scenario may be used repeatedly. A usual session begins with an introduction where students gain familiarity with the simulator. This is followed by a simulation case scenario managed by the learners, and ended by a debriefing period, where students and facilitators interact by discussion, questions, and analysis. The simulations may also be videotaped to allow for individual critique.

b. Uses for Patient Simulators

Patient simulators are reported to have a wide variety of applications within the realm of medical education. Long before the development of patient simulators, aviation and military simulators were created specifically to train novices in risky or critical situations.[40] Medicine has adopted the same strategy, and institutions primarily use the patient simulator as a teaching tool to allow "practice without harm". Accordingly, the critical care specialties of anaesthesia, intensive care, and trauma first embraced this new technology.[7] In recent years, the growing acceptance of simulators in medical education has led to an expansion in the populations and specialities utilizing this teaching tool. Teaching may occur in an individual or group setting, and may focus on expert or novice levels. The development of a child simulator has especially impacted the specialty of paediatrics due to the difficulties and limitations in learning opportunities unique to this population.

Though this study focuses on its use as a teaching aid, alternate uses for the simulator have emerged, including its utility as an evaluation and research tool. The complexity of evaluation in medical education is well documented, and patient simulators may provide a novel alternative to current assessment techniques. Evaluation studies comprise the largest portion of patient simulator research.[9,10,12,13,14,18] Studies have generally focused on the measurement of technical and behavioural aspects of physician performance and on the development of reliable and valid evaluation instruments. Though advances have been made in this area, most studies have concluded that measuring complex clinical behaviours by simulation technology is difficult and a significant amount of research and refinement is required before its use in a "high stakes" examination.[9] Research is a third possible use for a patient simulator in medical education; for example, the causes of physician error in critical incidents were examined in a study using simulator technology.[16]

c. Advantages of Simulator-based Medical Education

i. Student-centered learning

High student interaction in simulation-based learning may promote increased understanding of a topic. Previous studies have examined the effect of different teaching methods on learning outcomes, and suggest that increased student participation may enhance knowledge gain.[28] Many studies have qualitatively reported on the high student interaction and satisfaction with simulator-based teaching.[19,21,23,38] Further, some researchers argue that this increased "student-centered learning" results in improved knowledge gains and clinical performance.[20,21,38] Unfortunately, no previous studies have rigorously measured student participation or group dynamics in a simulator-based teaching session to support these claims.

ii. The Utility of Practice and Feedback

Much has been made of the usefulness of repetitive practice in learning, and one of the greatest strengths of simulator-based education is the opportunity to rehearse patient management in a safe environment. The development of expertise is an area of focused research, and recent literature demonstrates that superior performance is largely due to "acquired characteristics resulting from extended deliberate practice".[41] Practice has been shown to improve accuracy and speed of performance on cognitive, perceptual and motor tasks. However, studies have also demonstrated that practice is not inherently enjoyable, may be stressful, and generates costs associated with the teaching environment.[41]

Feedback is closely related to practice, and learning on a patient simulator theoretically allows both beneficial techniques to occur. Marquis et al found that providing feedback during a computer simulation was an integral part of the learning process.[42] Conversely, those who received no feedback did not demonstrate improvement on problem-solving skills. Thus, patient simulators may fill a void in medical education by allowing unlimited practice and feedback, two techniques that appear paramount in developing expert skills. Furthermore, communication, technical skills, team dynamics, and leadership skills may dramatically improve after practising with the simulator. Arguably, these are the most difficult skills for a student to learn, however they may be ultimately most important in the practice of medicine.

iii. Education "on-demand"

The wide range of clinical applications for patient simulators presents great opportunity for all levels of medical education. Simulators may be used for teaching basic concepts to undergraduates as in this study or rehearsing resuscitation drills by a lone family physician in a remote town. Further, a patient simulator provides an exceptional opportunity to learn the management of rare or uncommon problems that are infrequently encountered, but often life-threatening. For undergraduate students, the simulator allows access to "the good teaching case" that may not have been encountered on the wards. Thus, access to a simulator may provide "education on-demand" by allowing students to experience clinical problems that may not be otherwise available in their medical career.[43]

iv. Encoding specificity

A further theoretical advantage to simulator-based learning relates to the theory of "encoding specificity". The encoding specificity principle of memory provides a general theoretical framework for understanding how contextual information affects memory. The principle suggests that memory is improved when information available at encoding is also available at retrieval.[29] This theory would predict that subjects learning with a simulator in an emergency room environment would demonstrate improved knowledge and recall when tested with similar contextual cues in a resuscitation environment. Thus, students learning on a simulator may demonstrate improved knowledge and performance in a hospital environment over those taught in a traditional small group format.

iv. The Ethical Imperative

Finally, with the increased availability of high-fidelity patient simulators, educators are now considering the "ethical imperative" of using this tool in medical education.[44] Medicine has been slow to adopt the use of high-fidelity simulators compared to other high-risk professions such as the military and aviation. In a 2003 article, Ziv et al. discussed the ethical analysis of simulation-based medical education and argued that since patient simulators have the potential to decrease medical errors, enhance patient safety, decrease reliance on vulnerable patients for training, and facilitate open communication in training situations, medicine is ethically bound to use simulators as a complementary training tool.[44] This issue is becoming increasingly relevant as many previously acceptable patient-related methods of training are now regarded as objectionable or dangerous.

d. Obstacles to Simulator Implementation

i. Cost

Although great enthusiasm exists regarding the use of patient simulators in training, evaluation and research, a number of important considerations such as cost, personnel, and time requirements have been studied to outline the drawbacks of this educational technology. Disadvantages and unforeseen problems clearly exist in the incorporation of a patient simulator into undergraduate medical education. While the purchase price of a patient simulator is an estimated $250,000- $300,000 CND, the construction costs of a simulation centre costs a further estimated $665,000 CND.[37] Maintenance of the simulation centre adds an additional $167,000 per year when salary for technical expertise is included.[37]

ii. Personnel and Time Intensity

Perhaps one of the greatest disadvantages of simulator-based education is the personnel and time intensity required for successful operation. Trained staff must be readily available to provide technical maintenance, create realistic medical scenarios, and teach both educators and students. Simulator training sessions seem to be most successful in groups of 3-6 students, where pupil interaction is enhanced and each participant can play an active role. Unlike traditional small group teaching, only one group can use the simulator at any time, as opposed to numerous small groups operating in synchrony. Last, simulators are most useful if they are "on-site" in the teaching venue, allowing the sessions to be organized in a convenient and accessible manner. Though most simulators are "mobile" for transport in a specially-designed motor home, simulators are restrictive in terms of location, and usually require students and facilitators to travel, as in this study.

2. Learning Gains Derived from the Simulator as a Teaching Tool

Examination of the efficacy of patient simulators as a teaching aid is of utmost importance in appraising its utility in medical education. However, only six studies have focused on the ability of a patient simulator to enhance student learning. Knowledge gains were rigorously measured in only four studies,[19,20,22,23] and only two studies used a control group or comparison teaching method.[20,22] The use of a pediatric simulator is currently the subject of a single study, and its efficacy was not directly compared with an alternate or standard teaching method.[23] This section of the literature review will discuss each of these six studies in detail, summarizing the findings to date on the use of simulators as a teaching tool in medical education.

The first study to address the issue of learning gains derived from a simulator-based teaching session was performed in 1994 by Chopra et al.[19] Twenty-eight anaesthetists and trainees were taught a control session on the simulator, followed by a second simulator lesson using either scenario A or B. The physicians were then tested on scenario B and were evaluated by time to response and treatment decisions. The group taught scenario B before the final test was shown to perform significantly better in both response time and treatment decisions than those taught scenario A. Unfortunately, this study was significantly flawed due to the fact that a control group without simulator teaching was not employed, and more importantly, the recent teaching of scenario B to the simulator group may have refreshed physicians on the management of scenario B, regardless of any effect of simulator teaching.

A study by Gilbart et al (2000) randomised volunteering clinical clerks to learn trauma management skills by either simulator-based or seminar-based teaching groups.[20] A control group with no extra teaching was also used. The primary outcome measure was comparing the three groups' Observed Standardized Clinical Examination (OSCE) trauma scores, composed of both a patient encounter and written component. The results demonstrated that both the trauma simulator and seminar teaching groups performed better than the control group on the patient encounter portion of the OSCE, but no differences existed on the written component between all three groups. No differences in marks were present between the performances of the simulator and seminar teaching groups. However, students did feel the simulator was more enjoyable, more realistic and made learning easier than traditional methods.

Marshall et al (2001) examined the use of a patient simulator in the development of resident trauma management skills.[21] Twelve surgical interns divided into three teams participated in a simulator-based pre-test, followed by a two day standard Advanced Trauma Life Support (ATLS) course, and then participated in a simulator-based post-test.

Interns were evaluated on the pre/post test in three areas: critical treatment decisions, potential for adverse outcomes, and team behaviour. In general, trauma management improved between pre- and post-test in all three areas of evaluation. Self-confidence scores also rose significantly after the course. The authors suggest that the use of a patient simulator before and after ATLS training significantly improved the development of resident trauma skills. However, this study lacked a control group, and the improvement in scores demonstrated may have been due solely to the standard ATLS course rather than the use of the simulator.

Of particular interest is a 2002 article from Morgan et al comparing the efficacy of video-assisted to simulator-assisted learning of anaesthesia in undergraduate medical students.[22] The students were randomly allocated to either simulator-based or video-assisted teaching. For evaluation, both a pre- and post-test on the simulator was performed, in addition to a written final examination. As expected, there was a significant improvement in scores between the pre- and post-test. Interestingly, there was no statistically significant difference in the scores between subjects participating in the simulator session versus the video-based session in either the simulator examination or the written exam results. Last, students completed a questionnaire related to their experience and indicated that the simulator experience was considered more valuable and enjoyable than the video-assisted learning. A control group without intervention was not used in this study due to ethical considerations, and the researchers questioned whether the similarities between the teaching methods contributed to the lack of significant difference in the marks.

Tsai (2002) reported the sole study to use a pediatric simulator mannequin, and examined the learning gains of pediatric residents resulting from a high-fidelity simulation teaching session.[23] Eighteen residents participated in a simulator-based pre-test, a simulator training session, followed by a simulator-based post-test. The residents were evaluated using a reliable and validated scoring system. Improvement was noted in the clinical performance of the residents from pre- to post-test, suggesting the simulator was efficacious as a teaching tool. No control group or other teaching method was used for comparison. These findings correlate well with other studies that focused primarily on using the simulator as an evaluation tool;[13,14] improved student performance with increased practice on the simulator. Also in accordance with other studies with was the high learner satisfaction demonstrated; 95% of participating residents enjoyed the simulation and 95% found the simulation similar to actual patient encounters.

Finally, a study conducted by Euliao et al (2002) implemented a patient simulator into a traditional problem-based learning session.[24] Similar to this study, the patient simulator was used as an adjunct to a well established learning technique. Both problem-based learning and small group teaching are considered "student-driven" and are organized around learning objectives and a case. The simulator was incorporated into the PBL case, which provided a more interactive and "hands-on" experience for the students. Though no evaluation of student learning gains was performed, the researcher suggested that the simulator was advantageous as a teaching tool, since it enabled practice of management techniques and the ability to critique and modify student performance.

At this point, the evidence is minimal and inconclusive whether or not simulator-based teaching is an effective and efficient modality. Current literature suggests that using a simulator as a teaching tool is likely as effective as other teaching methods, however superiority has not been adequately demonstrated. Unfortunately, recent studies continue to demonstrate methodological flaws such as small sample sizes, lack of control groups or randomization, confounding variables, and poor reliability and validity of the assessment tool. It is possible that some evaluation methods administered were not sufficiently sensitive to measure the learning achieved. Students may be learning skills such as crisis management or procedures rather than sole knowledge, which may not have been adequately tested in the evaluation. In addition, the studies are heterogenous with respect to learner population, content taught, and outcome measures. Last, it may be that the instructional sessions with simulators were simply too brief to demonstrate any significant effect on knowledge gain or performance.

3. Learner Attitudes with Simulator Teaching

In general, qualitative studies focusing on student and educator reactions to simulator teaching sessions have garnered positive results. Gordon et al (2001) exposed 27 third and fourth year medical students and 33 educators to the simulator in order to survey their experiences with both a questionnaire and written comments.[38] The general response was overwhelmingly positive, with 85% of the students rating the experience as "excellent" and 85% of the educators describing the tool as either "excellent" or "very good". Over 80% of both learners and professors felt that the use of this technology should be mandatory.

Written comments from participating students and educators were also examined in this study. Other than five comments regarding the limitations of the scenario (n=3) and an unrealistic experience (n=2), all of the comments were positive. Students cited the main advantages of the simulator included the opportunity to gain confidence and practice, allow medical student autonomy in making decisions, and enable a transition between observation and practice. Educators felt the simulator developed problem-solving and team building skills; numerous applications for the simulator were identified with respect to material taught and level of training. Last, an independent group of educators deemed that "practice without risk" is the main advantage of the simulator.

Although the study by Gordon et al. currently represents the largest study on learner/educator reaction to patient simulators, a number of problems are inherent within the study. First, neither the questionnaire nor the results were adequately presented in the article and therefore few conclusions can be made regarding the validity and reliability of the measuring instrument. While the written comments provided a rich reservoir of sentiments, few negative comments were displayed, suggesting the possibility of leading instructions or social desirability. Nonetheless, this study was the first in this area devoted entirely to the learner/educator evaluation of the patient simulator.

Two further studies assessed student and educator satisfaction with simulator-based teaching as a secondary outcome measure.[19,21] In 1994, Chopra et al revealed a less sophisticated prototype simulator to both anaesthetists and trainees.[19] The questionnaire was composed of eleven questions that were rated on a 10-point scale. Again, the results were uniformly positive except those regarding the poor realistic quality of the mannequin and its surroundings. Similarly, in 2001, Marshall et al studied the use of a simulator with interns learning trauma skills.[21] After the experience, the interns underwent a course evaluation questionnaire about the relevance and effectiveness of the scenarios. It was well received and scored an average 8.3/10, with positive comments on the value of repetitive practice to improve self-confidence. Unfortunately, this study also lacked important details outlining the formulation, administration and psychometrics of the evaluation questionnaire.

D. Research Questions

The primary purpose of this study was to compare the student knowledge gains on the concepts of pediatric shock and dehydration after participating in either a traditional or simulator-based small group teaching session. Since small groups are used extensively to teach undergraduate medical school curricula, it is hypothesized that the addition of a patient simulator may add a further element of student interaction to the learning process and thus enhance "deep learning", promoting greater knowledge acquisition and retention.

In this study, the following research questions were addressed:

1. In learning the concepts of pediatric shock and dehydration, will students taught with simulator-based small group teaching demonstrate increased declarative and procedural knowledge gain over those taught with traditional small group teaching?
2. Will students taught by simulator-based small group teaching demonstrate superior knowledge retention at a later date than those taught via traditional small group teaching?

3. Is there a difference with student satisfaction between the two methods of teaching?
4. Will students taught with simulator-based small group teaching have a greater sense of self-confidence in their management of pediatric dehydration and shock than those taught using traditional small group teaching?
5. Are group dynamics different in simulator-based small group teaching than in traditional small group teaching?
6. What are the students' and facilitators' qualitative responses to the two types of teaching methods?

CHAPTER THREE: METHODOLOGY

A. Study Design

Two teaching methods, traditional small group and simulator-based small group, were compared using an experimental study design. The primary outcome of the study quantified the difference in student knowledge gain between the two teaching methods. Secondary outcomes of the study evaluated the two groups with respect to student declarative and procedural knowledge gain, long-term knowledge retention, student satisfaction, student confidence, group dynamics, and comments from participating students and facilitators. Accordingly, both quantitative and qualitative approaches were utilized in this study to address the main research questions.

The teaching method was the independent variable manipulated in this study; subjects participated in either a traditional or simulator-based small group teaching on identical subject matter. This study may be classified as a single variable experiment, since the presence or absence of a simulator in the small group teaching session was the sole treatment variable. The primary dependent variable measured was student knowledge gain, as assessed by a written examination. The pre-test scores quantified the students' baseline declarative and procedural knowledge related to pediatric shock and dehydration, whereas the post-test scores represented their knowledge after the teaching session. Accordingly, the measured difference between the two scores represented the knowledge gain due to the effects of the independent variable.

Further dependent variables were measured in this study. The magnitudes of change in both the declarative and procedural subsets of scores were compared between the two groups. Long-term knowledge retention was assessed by using a subset of questions related to shock and dehydration on the final pediatric clerkship examination. Other dependent variables included student satisfaction, confidence after the teaching session, group dynamics and qualitative responses from the participants.

1. Population and Sample

The desired sample size of sixteen subjects per group was determined using a power calculation to detect a difference as large as 10, assuming a standard deviation of 10, with the usual alpha of 0.05 and beta of 0.20. The standard deviation was drawn from the results of a pilot study using undergraduate medical students. Overall, thirty-eight subjects were enlisted for participation in this study. Each treatment group was comprised of nineteen subjects; this fulfilled the minimum number required as estimated by the sample size calculation.

All thirty-eight subjects enrolled were third-year University of Calgary medical students engaged in their pediatric rotation at Alberta Children's Hospital at the time of participation, corresponding to the period of November 2002 to April 2003. Because the study spanned six months, subjects participated in the study at different times in their clerkship year; however, all were involved during their six week pediatrics rotation. The teaching session was organized on one weekday during each clerkship rotation. Subjects were enlisted on a volunteer basis and informed consent was obtained. If the student did not wish to participate in the study, the student was permitted to either participate in the teaching session without further involvement, or continue clinical duties on the ward.

Each cohort of clerks in a block was assigned in an alternating manner to either traditional or simulator-based small group teaching (for example, Block 5-small group, Block 6-simulator, Block 7-small group, Block 8-simulator). Two groups were created from each clerkship block of 10-12 students, creating eight groups in total (four traditional and four simulator-based small groups). Students were randomized to one of the two facilitator groups created from their clerkship block. The students were not randomized with respect to teaching method due to limited simulator and facilitator availability.

The facilitators were enlisted on a volunteer basis from Alberta Children's Hospital. All were staff physicians and considered "experts" in their field; three of the four physicians were pediatric gastroenterologists, while the fourth was a pediatric emergency medicine physician. Each physician acted as a facilitator for one traditional and one simulator-based small group. One of the four physicians had previous experience working with a simulator.

Prior to the experiment, all facilitators underwent training sessions to review the subject matter and ensure equal treatment of the two intervention groups. To minimize differences in the content of the sessions, the facilitators received identical standardized agendas outlining the objectives and important discussion points (Appendix A-D). Before teaching the simulator-based session, each facilitator underwent a brief in-service on the mannequin to ensure a level of familiarity with the technology.

2. Interventions

The principles and management of pediatric shock and dehydration were taught using two clinical cases as focus points for discussion (Appendix C). Since shock and hypovolemic dehydration represent two of the most common, yet poorly managed patient presentations in pediatrics, they were chosen as the topics of interest. Further, gastrointestinal illness such as diarrhea and bleeding are among the most common causes of shock and dehydration, and therefore were incorporated into the case scenarios. Care was taken to develop cases that reflect the knowledge and level of experience expected for third year undergraduate students during their pediatrics rotation. The two clinical cases, teaching session objectives, and teaching manuals were reviewed by consultant pediatricians to ensure that the material was appropriate for the target audience, the language was understandable, and the breadth of knowledge acceptable. The simulator scenario was developed, pilot tested with physicians, and revised accordingly before the study intervention occurred.

Shock and dehydration are concepts amenable to teaching in either a traditional or simulator-based small group setting. Though both types of teaching sessions were expected to cover identical content, it was expected that the style, mechanics, and level of participation would differ somewhat between the two groups. Students receiving the simulator-based sessions were encouraged to role play and physically practice the management of a pediatric patient, whereas those learning with traditional small group teaching focused primarily on discussion.

The study was performed in two different venues that were necessitated by the type of teaching session. The traditional small group teaching sessions were conducted in board rooms in the Telehealth division at the University of Calgary Medical School. The rooms were equipped with tables, chairs and a white board with markers for student or facilitator-led teaching. The simulator-based sessions were taught in the STARS (Shock Trauma Air Rescue Society) airport hanger, which is the usual site of the simulator. These sessions were taught in either a control room or mobile home which was constructed specifically to represent a hospital or emergency room environment. The examinations and questionnaires were written at desks in an adjacent classroom.

The simulator used in the experiment was a life-sized child mannequin developed by METI Corporation (Medical Education Technologies Inc.). Features included realistic heart and breath sounds, pupillary dilatation, palpable pulses, voice, and physiology appropriate for an eight year-old boy. A monitor attached to the mannequin was capable of demonstrating oxygen saturation, heart rate, blood pressure, temperature, respiration rate, as well as a number of other more complex physiologic parameters not used in this study. At the start of each clinical scenario, the simulator was programmed to represent a child with either profound dehydration or shock. With each resuscitative act, the mannequin responded in a physiologic manner. Medication and fluid boluses infused into the mannequin resulted in immediate hemodynamic changes appropriate for an eight year- old boy. Since practicing intravenous access on the simulator was not possible, a separate intraosseous model was available for demonstrating vascular access in a young child.

The organization of the two hour teaching session differed somewhat depending on intervention type. Traditional small group sessions commenced with the reading of the case, followed by discussion of the related pathophysiology, differential diagnosis and management. The simulator-based sessions began with an orientation to the mannequin, where the students were familiarized with its capabilities as well as shortcomings which could not be adequately demonstrated (i.e. skin color change). The case simulation was first managed by the participants, followed by an assessment and critique of the simulation. After a discussion of case-related pathophysiology, differential diagnosis and treatment, the students repeated the management scenario on the simulator.

At the beginning of each session, students in both study arms participated in an identical twenty minute written pre-test to assess baseline knowledge on pediatric shock and dehydration. Students then rewrote the examination as a post-test at the end of the two hour teaching session. Following the written examination, students completed a questionnaire and all four facilitators and approximately fifteen volunteering students were then interviewed. The author was available during all teaching sessions to administer the examinations and questionnaires, act as support, and ensure the teaching sessions were running smoothly.

B. Instrumentation and Data Collection

1. Quantitative Instruments

A written examination was developed as the chief assessment tool since student knowledge gain, both declarative and procedural, was the primary measured outcome. Prior to administration, the written test was assessed with respect to instrument validity. Face validity was evaluated by two attending physicians and three undergraduate medical students not otherwise involved in the study. Any ambiguous language or inappropriate questions were revised. Content validity was ensured by cross-referencing each question with its associated objective, and then pilot testing on both an expert (attending physician) and non-expert (student) group. The expert group demonstrated higher marks than the non-expert group. Internal consistency of the written examination will be discussed in the results section.

The pre/post written examination described above was comprised of twenty single best answer multiple choice type questions that were based directly on the objectives for the teaching session (Appendix E). Ten declarative knowledge items tested information requiring lower-level cognitive processing, such as memorization of facts and recall of physiology. The other ten items were vignette in style and tested procedural knowledge, which required higher cognitive processing such as making management decisions and problem-solving.

All subjects also wrote the final pediatric clerkship examination at the end of their pediatrics rotation, from two to five weeks after the teaching intervention. This was a pre-existing multiple choice certifying examination, and its development was unrelated to the study. To measure long-term retention, the six questions pertaining to pediatric shock and dehydration in this examination were identified, and a score was calculated for each participating subject (Appendix G). The subjects' performances on these six questions from the final clerkship examination were compared between those exposed to traditional versus simulator-based small group teaching.

2. Qualitative Instruments

Demographic data, such as age, gender, and clerkship block were collected on participating subjects to allow for comparison of baseline characteristics between the two intervention groups. Students' identification numbers were collected for the sole purpose of connecting marks from the clerkship final examination to the teaching intervention received.

Student satisfaction was assessed through the use of a seven item Likert-style questionnaire (Appendix H), where students were asked to indicate their responses to statements using a five point scale: (1) Strongly Disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly Agree. Qualifying descriptors were present above each number to strengthen the value of the questionnaire.[45] Perceived confidence with the students' management skills of pediatric shock and dehydration after the teaching intervention was assessed using a single item statement. Students from both interventions completed the questionnaire to allow for comparison between session types. Prior to administration, the satisfaction questionnaire was reviewed for face and construct validity by pediatricians not directly involved in the study.

In order to generate student and facilitator responses to the different teaching styles, approximately fifteen volunteering students and each of the four facilitators were interviewed at the end of the sessions regarding the positive and negative qualities of the teaching method utilized. Interview questions were created by the author to discuss qualities of both traditional small group and simulator-based teaching methods (Appendix I).

Group dynamics were assessed by reviewing videotapes of the teaching session to compare the two teaching methods. The group dynamics form was created after review of the literature and was modified after pilot testing with a videotaped teaching session. Interactions such as the number of student-proposed questions, the number of facilitator-driven questions, and the number of facilitator "mini-lectures" were assessed in the two treatment groups using an observation form (Appendix J). Videotape review was performed with careful scrutiny by the researcher; observations were tallied on a form, and a stopwatch was used to accurately time the "mini-lectures".

3. Data Collection

The multiple choice examinations and questionnaires results were administered using scanner sheets for accuracy and ease of data collection and analysis. The participants' subset of marks from the final pediatric clerkship exam were extracted with student consent and categorized into session type. All raw data were transferred into SPSS databases for analysis. Interviews with facilitators and students performed after the teaching session were recorded on an audiotape which was transcribed after each session.

C. Data Analysis

Descriptive statistics were utilized to explore the findings of the pre- and post-test results in the two intervention groups. These included measures of central tendency, ranges, and standard deviations. To assess the primary outcome of the study, the difference between the pre- and post-test scores of the participating students were compared by a two-tailed student t-test. An analysis of variance was utilized to compare the baseline demographics of the traditional and simulator-based small group subjects. A two-tailed t-test was used to ensure the pre-test scores of the students in both intervention groups were similar. Reliability of the pre- and post- test was assessed by measuring internal consistency by the Cronbach alpha test.

To address the second research question, the examination scores were subdivided into declarative and procedural knowledge components, each consisting of ten questions. The change in declarative knowledge score was compared between the two teaching styles using a two-tailed t-test. Accordingly, the change in procedural knowledge score was assessed in a similar manner. To examine long term retention, the scores on the subset of final clerkship examination questions were explored using descriptive statistics and were compared between the two intervention groups using a two-tailed t-test with the mean scores.

Results of the questionnaire were analyzed using descriptive statistics, including measures of central tendency and percentages. The overall satisfaction score was calculated using the mean of the responses to the first seven items in the questionnaire. Due to the skewed distribution of the scores, the non-parametric Mann-Whitney U was used to compare the overall satisfaction scores between the two teaching groups. The single response confidence scores were compared in a similar nonparametric manner using the Mann-Whitney U statistic. Though the questionnaire results are ordinal data, the creation of an ad-hoc integer scale using the mean score was used. This is a widely accepted practice and has been demonstrated to possess adequate face validity. Internal consistency of the "satisfaction" questionnaire was measured with the Cronbach alpha calculation.

Differences in group dynamics between the two interventions were scored quantitatively with a tally-style observation form and were summarized in a descriptive fashion. The interview responses of students and facilitators were presented in a qualitative manner in the results.

D. Ethics

The proposal for this study was reviewed and approved by the Conjoint Health Research Ethics Board of the University of Calgary and the Calgary Health Region. Consent for this project was granted by the acting head of Pediatric Clerkship, Dr. Harish Amin. All students approached to participate in the study were given an informed consent form outlining the details of the experiment, the nature of data collected, and the questions being researched (Appendix K). In addition, subjects were given opportunities to meet with the author to discuss the study and ask questions. Participants were informed that they were free to withdraw from the project at any time, any information they provided would be anonymous, and the results of the examinations and questionnaires would not impact their final grade for the pediatric rotation. Written consents were obtained from the participants before entering the study.

CHAPTER FOUR: RESULTS

Thirty-eight out of fifty available students (76%) were enlisted for participation in the study. Nineteen subjects were enrolled in each of the traditional and simulator-based study arms. All 38 students performed the pre- and post-test; 32 out of 38 subjects (84%) completed the questionnaire. In general, the baseline proportions of age and gender in the two teaching groups were similar. The traditional small group had a slightly different gender proportion than the simulator-based group with more males and less females; however, chi-squared analysis demonstrated this difference was not significant.

Characteristics and scores from the six students who chose not to participate in the questionnaire were compared to the thirty-two students who completed the entire study. Among these six students, no significant differences were found with respect to age, gender or facilitator when compared to the group at large. No trend with respect to clerkship block could be identified. Of interest, five out of the six students who did not complete the questionnaire were participants in the traditional small group teaching session. The overall pre-test scores were similar between both groups, though the scores for the six students not participating in the questionnaire were slightly lower (65.83 versus 69.21 for the remainder of the subjects). The mean score improvement from pre- to post-test was lower for the six students not participating in the questionnaire than for those students that completed the study, however this did not reach statistical significance (7.50 versus 9.38 respectively, $p=0.48$).

A. Overall Knowledge Gain

The primary endpoint of the study compared the knowledge gain from pre- to post-test between the two intervention groups. Overall, students demonstrated a significant improvement in their score from pre- to post-test (paired t-test, $p<0.001$, 95% confidence interval of -12.18 to -5.98) (Figure 1). The baseline pre-test values were not significantly different between the two groups (t-test, $p= 0.88$). The mean score improvement was 9.74 percent for the traditional small group versus 8.42 percent for the simulator-based session (Figure 2). The standard deviations were similar between the two groups, 8.89 for the traditional group versus 10.15 for the simulator group. Both groups had a range of 35, however if the single outlier is removed, the range in the traditional small group is smaller (Figure 2). Both methods demonstrated a significant improvement from pre- to post-test as calculated using paired t-tests ($p= <0.01$ for both). A two-tailed t-test for two independent samples demonstrated no significant difference between the two groups with respect to magnitude of knowledge gain ($p= 0.67$, with 95% confidence intervals of the difference of -4.96 to 7.59). The internal consistency of the written examination improved from pre- to post-test, (alpha= 0.15, 0.5 respectively).

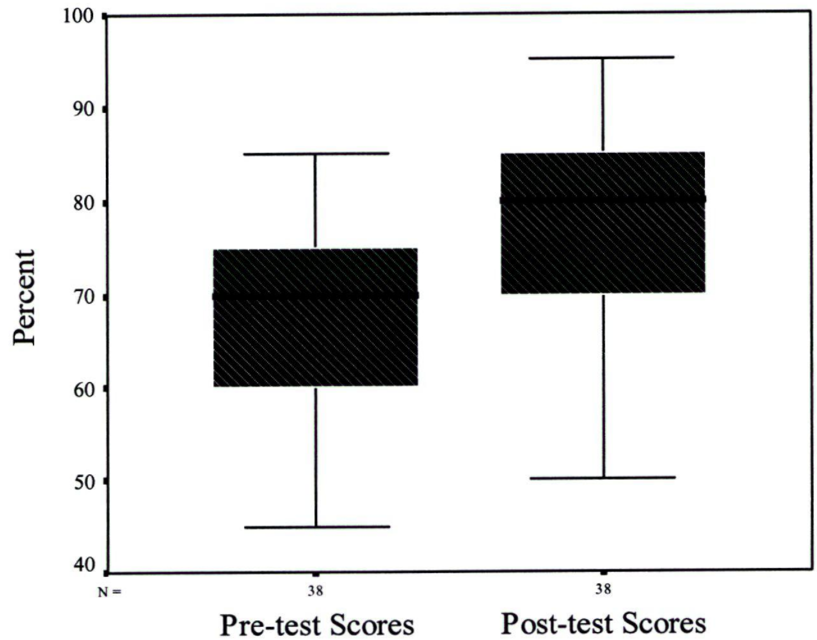

Figure 1: Percent Improvement from Pre-to Post-test Scores in All Subjects

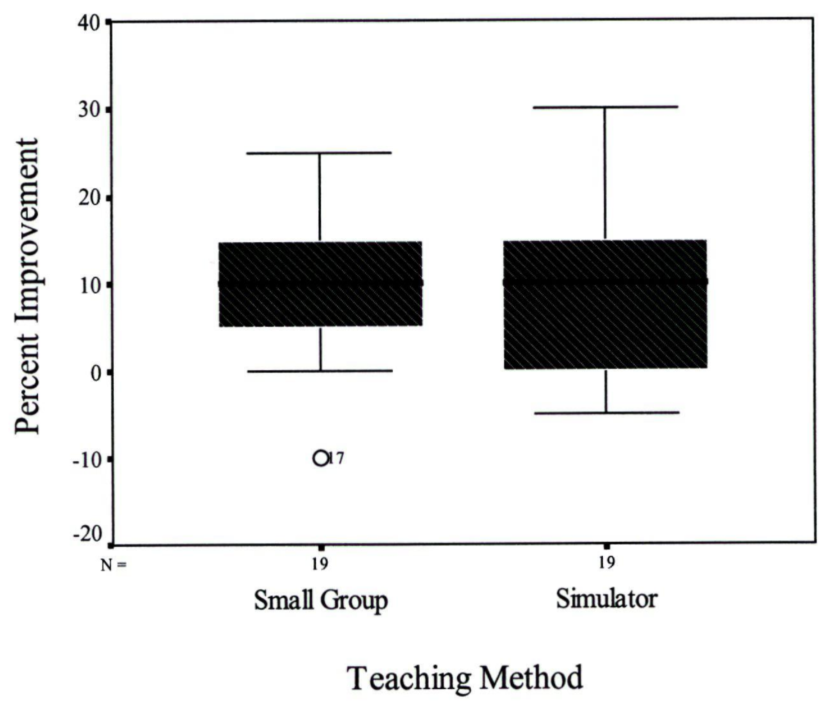

Figure 2: Percent Improvement from Pre- to Post-test for Each Teaching Method

B. Declarative and Procedural Knowledge Gain

No statistically significant difference was demonstrated between the two teaching styles with respect to score improvement in either the declarative or procedural subset of questions. The mean improvement in the declarative scores of both intervention groups was 10, with a standard deviation of 12.47 and 13.74, respectively, and a range of 50 for both. Both the traditional and simulator-based groups demonstrated a statistically significant improvement from pre- to post-test in the declarative knowledge scores (paired t-tests, $p<0.01$ for both). A two-tailed t-test comparing the difference in improvement between the two groups was not significant at $p=1.0$, with a 95% confidence interval of -8.64 to 8.64.

Comparison of the changes in procedural scores resulted in similar findings. The mean improvement of the procedure scores for traditional small group sessions was 9.47 versus 6.84 for the simulator intervention. The standard deviations were similar at 16.12 and 16.68, respectively, and the ranges were identical at 60. Again, both the traditional and simulator-based groups demonstrated an improvement from pre- to post-test in the procedural subset of questions, however the difference was only significant in the traditional small group (paired t-tests; $p=0.02$ for traditional, $p=0.09$ for simulator-based). A two-tailed t-test comparing the procedural score improvement between the two groups was not significant at the $p=0.05$ level ($p= 0.62$), with 95% confidence intervals of the difference -8.17 to 13.44.

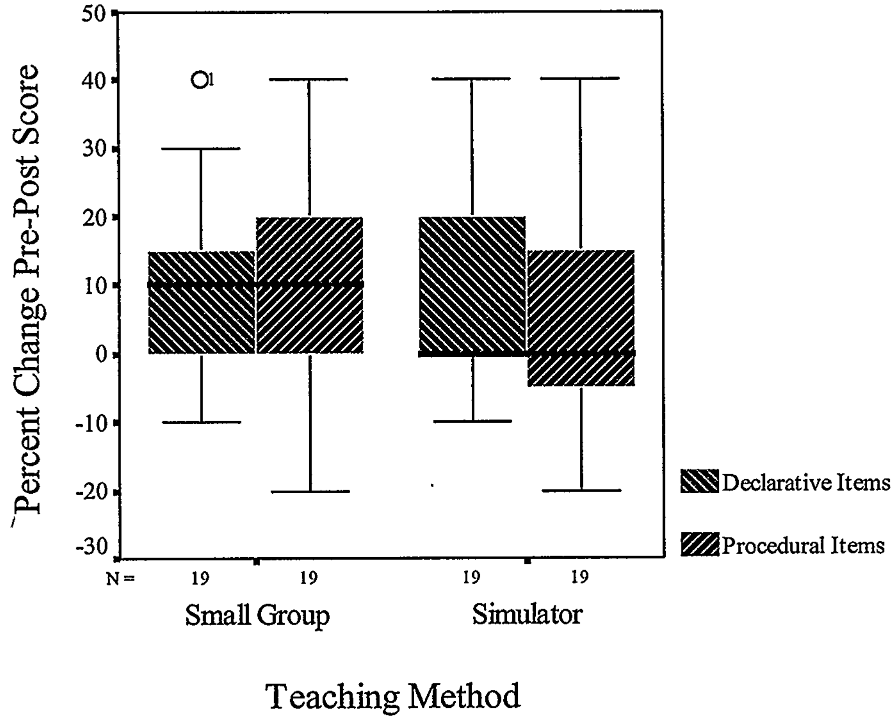

Figure 3: Percent Change from Pre-Post Score in Declarative and Procedural Items

C. Long- term Knowledge Retention

Using data from the final pediatric clerkship examination, the subset mean score of the students participating in traditional small group teaching was 0.89, compared to 0.85 in the simulator group. The range is larger in the simulator-based group compared to the traditional small group (0.43 vs. 0.30, respectively), as is the standard deviation (0.15 vs. 0.10, respectively). Using a two-tailed t-test, the difference between these scores is not found to be significant at the $p < 0.05$ level ($p=0.08$, 95% confidence intervals -0.04 to 0.13). Thus, this study did not demonstrate a significant difference in long term knowledge recall between the traditional versus simulator-based small groups.

D. Satisfaction Scores

The subjects' mean satisfaction scores in the traditional and simulator-based small groups were compared. In general, the results were very favourable for both types of teaching. The simulator group demonstrated a slightly higher mean than the traditional group (4.71 vs. 4.53 out of a possible 5, respectively) (Figure 4). The standard deviation was smaller for the simulator group, 0.31 versus 0.45 for the traditional group; similarly, the range was 1.0 for the simulator group versus 1.71 for the traditional group. A clear "ceiling" effect was demonstrated in the questionnaire results, with most individuals rating the questionnaire items four or five out of a possible five. An outlier was present in the small group who assigned scores much lower than the means; however this did not appreciably affect the data.

No significant difference was noted in the overall satisfaction scores of the subjects in the small group versus the simulator teaching session. Due to the skewed distribution of the data, a nonparametric test was used to compare the two mean scores. Using the Mann-Whitney U test, the p value was calculated at 0.18, suggesting no significant difference between the mean satisfaction scores of the two groups. The internal consistency of the questionnaire was 0.75, calculated using Cronbach alpha for reliability.

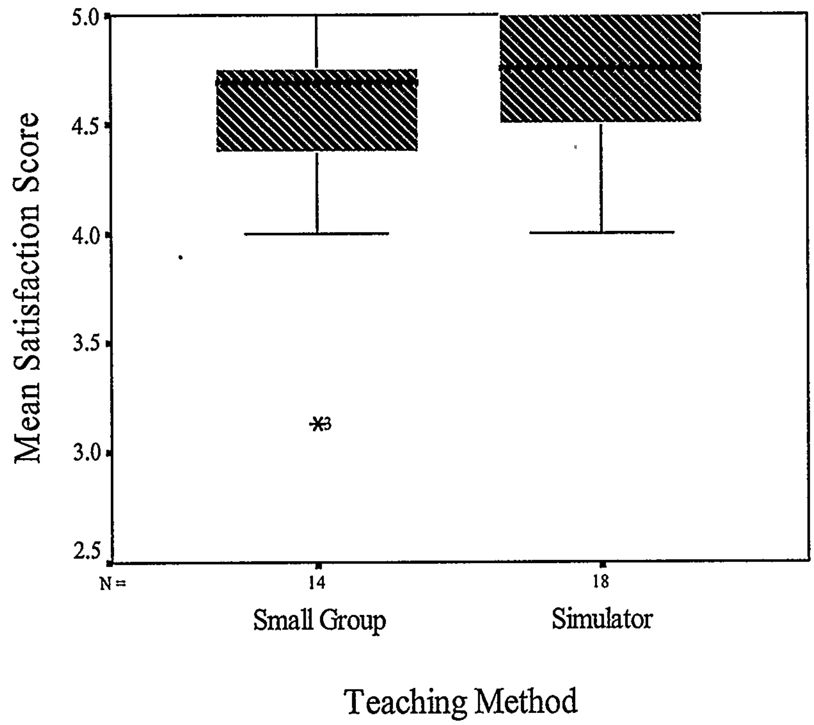

Figure 4: Mean Satisfaction Score of Students based on Teaching Method

Of interest, 97% of all subjects gave a mean summated satisfaction score of 4/5 or higher. Eight individuals, including six in the simulator group, gave it a perfect score of 5/5, representing 25% of the subjects. Upon reviewing each item separately, examination of the data revealed a discrepancy between the two intervention groups' response for item number three: "this session was exciting and held my attention". The mean score of the small group was 4.14 versus 4.78 for the simulator group. This difference was significant at $p < 0.01$, suggesting that in general, students found the simulator session more exciting than the small group. No significant differences were present with respect to the level of satisfaction by facilitator, age, or gender when these factors were examined with the Kruskal-Wallis nonparametric analysis of variance.

E. Confidence Scores

Self-report of confidence was a further endpoint for examination in this study. Item number eight on the questionnaire pertains directly to students' confidence levels after having participated in the teaching session. In general, students reported feeling more confident in managing pediatric shock and dehydration after either type of teaching session, with 97% rating the statement at least 4/5 (agree, or strongly agree). Sixteen out of thirty-two subjects (50%) strongly agreed with this statement; eight (50%) of these subjects had attended a traditional small group session, whereas eight (50%) had attended a simulator-based session.

The mean confidence score of subjects participating in small groups was 4.43, almost identical to that in the simulator group (4.44) (Figure 5). Because of one outlier present in the traditional small group, the range was much larger than in the simulator group (3.00 versus 1.00, respectively). Similarly, the standard deviation was 0.85 in the small group versus 0.51 in the simulator group. Comparing these means using the nonparametric Mann Whitney U test, these small differences in the confidence scores are clearly not significant ($p = 0.64$).

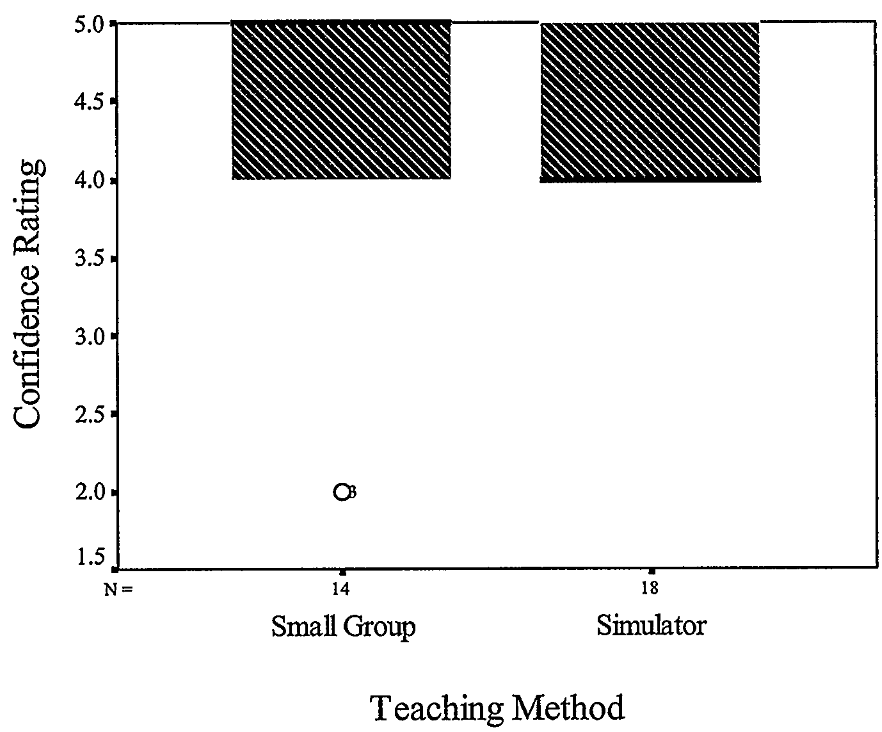

Figure 5: Mean Confidence Score by Teaching Method

F. Group Dynamics

Due to technical difficulties, three of the four simulator sessions were not adequately taped to allow assessment of student-facilitator interaction, and therefore comparison can be made only between the one simulator session versus the four traditional small group sessions. The mean scores of each item were calculated from the four traditional small group teaching sessions and compared with the single scores from the simulator-based teaching. These results are summarized in Figure 6.

The number of student-initiated questions to the facilitator was lower in the simulator-based than the traditional small groups, with a mean of 10 vs. 22.25 questions. However, the number of student initiated questions to other students was much higher in the simulator group (15 versus 2.25 questions, respectively). The amount of facilitator lecturing was lower in the simulator group (5 versus 9.75 times, respectively), and accordingly, the number of student-only conversations lasting over 60 seconds was clearly higher in the simulator group (10 versus 0, respectively). The amount of facilitator-initiated questions to students also appeared lower in the simulator group (66 versus 102.5 questions, respectively). Last, the number of facilitator comments regarding management decisions was lower in the simulator group compared to the traditional small group (10 versus 14.5 comments, respectively), but the number of student comments to other students was much higher (17 in the simulator group, 1.25 in the traditional small group).

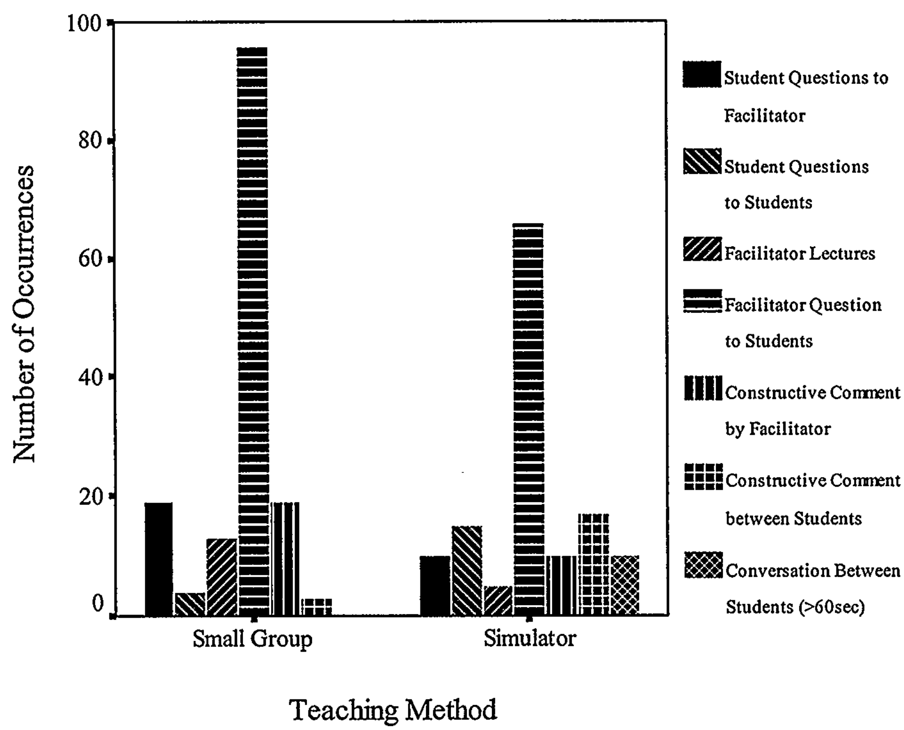

Figure 6: Differences in Group Dynamics between the Two Teaching Methods

G. Student and Facilitator Comments

1. Traditional Small Group Teaching

Students in the traditional small group session stated that the sessions were well directed and focused on relevant and practical topics of significance for their level of training. The ability to ask specific questions and therefore direct the session to their learning needs was referred to as one of the greatest advantages of the traditional small group teaching style. Others cited that interaction with both colleagues and mentors enhanced the interest of this teaching style.

A common disadvantage of small group teaching session mentioned by students was the intensive nature of the style often led to an overload of information, long sessions, and ultimately, disinterest from the students. Though many students stated the high level of interaction was beneficial, some commented that the sessions frequently became sub-optimal when the teacher spoke too much, offered too little input, or when a student dominated the agenda. The subjects offered that the two hour session led to a significant increase in their knowledge, however two commented on feeling as though they reached the point of "information overload". Though the students felt the portrayal of reality was poor in the small group setting, they nonetheless much preferred it to didactic teaching.

Facilitators also gave positive reviews to the traditional small group sessions. Main advantages of this type of teaching from a facilitator's point of view included the ability to assess the needs of each student, thereby allowing specific changes to be made to the teaching. In addition, two facilitators stated they felt that it served as a non-threatening environment which enabled them to “draw out” shy students.

A disadvantage of small group learning cited by facilitators is the poor simulation of reality. Though a student may be able to verbalize the steps required to manage a patient with a medical condition, the practical knowledge and skills to do so may be lacking. One facilitator stated that some topics were simply easier to teach with visual aids or models. A further disadvantage discussed was the time intensity for teachers. All students and teachers alike stated they would participate in this format of teaching again, and felt that it was primarily effective in teaching knowledge and attitudes.

2. Simulator-based Small Group Teaching

The simulator sessions were equally well received. In general, students stated that the sessions were enjoyable, fun, and "way better than small group". Students noted that the “hands-on” learning is very different from discussion, and many felt "on the spot" when asked to lead the scenarios. Initially, students felt awkward and insecure in role-playing with the simulator; however management became progressively easier once they became familiar with the mannequin and the scenarios. Students commented that the realistic nature of the simulator, with its breath sounds, voice, and physiologic changes, was helpful in developing the "adrenalin rush" commonly experienced in actual resuscitations. Over time, students became immersed at the task at hand, and felt their nervousness dissipated.

Students cited the main advantages of simulator-based learning included the development of team management skills, the identification of management difficulties (for example, difficulty in establishing intravenous access), and the utility of learning in a safe environment at this stage of their training. In general, they felt the sessions were relevant, practical, and enjoyable. Students commented on the value of repeated rehearsal of the scenarios to solidify the learning, as well as the importance of the debriefing discussions after the management scenario.

A main disadvantage of simulator-based teaching mentioned by many students was the initial stress associated with performing a management scenario. However, subjects felt that this feeling was transient, and the process enabled the identification of knowledge deficiencies very quickly. One student stated that the sessions were simply too short and they would have preferred to have spent more time on the simulator. One student also would have preferred the discussion to occur at the very end of the session to prevent disruption of the natural flow, and enable more time on the simulator.

Facilitators felt much the same as the students. Three facilitators reported feeling somewhat unconfident and not "in control" at the beginning of the session, but all became much more comfortable after observing the students enact a management scenario. One facilitator commented that it was a completely different atmosphere and teaching experience, and once accustomed to it, felt it was very enjoyable. Major advantages noted by the teachers included the ability to teach in a more realistic and pressured environment, as well as enhanced opportunities for learning management, leadership qualities, and technical procedures. Two facilitators felt that students would be more apt to remember the principles and management taught when facing a similar scenario in the hospital. Disadvantages of the simulator session cited by the facilitators included less time for "cognitive" teaching, the high resource intensity, and difficulties with following their guidelines. In addition, the success of simulator training seemed to be more dependent on student personality; with very shy students, it was sometimes difficult to build the "momentum" necessary for an effective session.

3. Comparing Traditional with Simulator-based Small Group Teaching

When comparing the traditional and simulator-based small group sessions, a number of differences were apparent. Group dynamics were felt to be significantly different between the two styles, with the simulator-based teaching encouraging a higher level of student interaction and leadership. All facilitators commented that simulator-based teaching allowed greater assessment of students' skill, knowledge and management capabilities; deficits in knowledge were easily detected with this teaching style. A steep learning curve in using the simulator as a teaching aid was experienced by the three facilitators who had not previously used this technology; however this was overcome with increased familiarity. All four teachers felt the students were either equally or more engaged in the simulator session compared to the traditional small groups.

Not surprisingly, in spite of the content being controlled, the teaching strategies were also felt to be different between the two styles. When teaching on the simulator, some facilitators experienced a tendency to focus on management and skills at the expense of pathophysiology and differential diagnoses. Furthermore, two teachers felt simulator-based teaching prevented in-depth coverage of a topic, however the other two facilitators completely disagreed and felt it enabled to cover concepts more comprehensively. Accordingly, one facilitator stated that though the expectation was to teach identical subject matter in the two teaching styles, the agenda seemed nonetheless different in the two groups.

Overall, all four facilitators felt that that simulator-based teaching was effective in enhancing the development of knowledge, skills, and attitudes. All commented on the ability of simulator-based teaching to optimize students' preparation of common clinical problems at the clerkship stage of training. Last, one facilitator commented that simulator-based training may be especially useful in helping junior physicians integrate the knowledge, skills and attitudes required to solve and manage a clinical problem.

CHAPTER FIVE: DISCUSSION

Simulators are increasingly being refined, purchased and utilized to educate medical personnel, despite few existing studies demonstrating superiority over pre-existing teaching methods.[19,20,22] This study compared the declarative and procedural knowledge gains of third year undergraduate medical students resulting from participation in either a traditional or simulator-based small group teaching session. In addition, the two teaching methods were compared with respect to promotion of long-term knowledge retention, student satisfaction, student confidence and group dynamics.

There are three unique aspects to this study. First, the direct comparison of simulator-based teaching with a "standard" teaching method -in this case, traditional small group- represents a further contribution to the emerging body of literature exploring the efficacy of simulator-based teaching compared to conventional teaching methods. Second, the primary outcome measured, knowledge acquisition, was specifically chosen as an endpoint to allow for direct comparison between the two teaching methods, and to ensure that the learning objectives and study outcomes were appropriate for the undergraduate level. A third aspect of this study worthy of particular attention was the study population; very few studies have explored the use of simulators in the undergraduate population.[20,22,24] In general, medical students have strong theoretical basic science knowledge, but minimal clinical experience in managing patients. With the growing problems of large class sizes and a paucity of teaching clinical opportunities, simulator technology may be of exceptional value in the undergraduate population by enabling safe practice before actual patient encounters.

A. Student Knowledge Gains

The primary outcome of the study compared the knowledge gains resulting from traditional versus simulator-based small group teaching in a cohort of third year undergraduate medical students. Though students from both groups demonstrated a significant improvement from pre- to post-test scores, the simulator-based teaching method did not yield superior results to the current standard, traditional small group teaching. However, the simulator-based group did perform as well as traditional small group with respect to student knowledge gain. Previous studies comparing traditional teaching with other forms of technology enhanced teaching (for example, computer-based or simulator-based) have demonstrated comparable results: similar degrees of knowledge gain despite the use of different mediums.[20,22]

Though the two different methods of teaching may be equally effective at enhancing declarative and procedural knowledge acquisition, it is possible that simulator-based learning enhances other types of learning not directly measured in this study, such as the integration of knowledge, skills and leadership activities. According to Kneebone in a 2003 review article on simulation technology, simulator-based teaching may have a significant effect on developing skills and attitudes in addition to promoting knowledge gain.[46] Thus, its value in the undergraduate population may actually be much greater than suggested by the results of a multiple-choice examination. This is an area of further research.

However, multiple extraneous variables may have also impacted on the findings of this study. These include issues related to the evaluation tool, as well as differences between the two teaching groups with respect to environment, students, and facilitators. Each of these factors will be discussed in turn.

1. The Evaluation Tool

a. Instrument Sensitivity

The primary evaluation tool used in this study was a twenty question, single-answer written multiple choice examination specifically devised from the learning objectives for the session. A written assessment tool was selected to measure the primary outcome variable: student knowledge gain. It was surmised that since the subjects were in their first year of clinical encounters, the simulator may enhance knowledge gain through relevant and exciting student-driven practice. Increased student motivation, encoding specificity and the addition of a kinaesthetic element were factors imparted by the simulator that could theoretically promote "deep learning" and enhance the acquisition and recall of knowledge. Students at the clerkship level of training are expected to be able to integrate clinical information and exhibit problem solving through patient management. To assess this theory, the written examination included two styles of questions: lower-level declarative or recall type items, and vignette-style management or procedural type items.

The finding of similar declarative and procedural knowledge scores between the two groups was surprising, considering the general impression of both students and facilitators that simulator-based sessions encouraged more focus on procedural than declarative knowledge. Nonetheless, the facilitators were advised to teach identical content in the two sessions, and therefore this may have accounted for the findings of no significant difference between the two groups.

A second possibility is that simulator-based teaching encouraged a higher level of cognitive processing than traditional small group teaching, and this aspect of learning was not specifically measured in the examination. In 1956, Bloom created a taxonomy of cognitive learning by identifying performance levels of increasing complexity.[47] According to this model, lower level processes such as the acquisition of knowledge and comprehension must be first established before an individual can master more complex tasks such as application, synthesis and evaluation.

Participation in traditional small group teaching may promote knowledge and comprehension of a subject, but may not enable the student to apply the learned material. In contrast, simulator-based teaching requires students to learn, comprehend, apply and analyze concepts through patient management in simulated scenarios. Thus, the evaluation tool used in this study may not have adequately tested the higher taxonomic levels of cognitive learning that were imparted by the simulator-based session. While the sensitivity of the evaluation tool warrants consideration in interpreting the study results, further factors such as the psychometric properties of the measuring instrument must also be examined.

b. Psychometric Qualities of the Instrument

To assess the quality of the written examination as an evaluation tool, validity and reliability were considered. The examination was tested for both face and content validity before administration. Undergraduates and staff pediatricians confirmed face validity. Given that the items were drawn directly from the learner objectives and significant improvement of scores from pre- to post- test were demonstrated, content validity was supported. For reliability, the Cronbach alpha was used to measure internal consistency. The reliability estimate of the written examination was calculated to be 0.50.

Many explanations could account for this lower than expected reliability score. First, the test was somewhat heterogeneous with respect to content tested. The pathophysiology and management of pediatric shock and dehydration is a subject diverse in content and theory, and thus it is difficult to achieve high internal consistency between the questions. The test, consisting of only twenty questions, was brief considering the breadth of concepts tested. Further, two styles of questions were used, measuring both procedural and declarative knowledge. Other factors that may have affected the reliability include student differences and environmental effects.

2. Environmental Effects

Earlier studies have indicated that the environment may have a positive or negative impact on learning.[8,28] While all efforts were made to keep the teaching setting similar, the environments were necessarily somewhat different due to the presence of the simulator and associated hardware. All teaching sessions occurred outside of the hospital environment, with the small group sessions occurring in conference rooms and the simulator sessions taking place in the STARS hanger. While the small group environment was a standard learning milieu, the environment for the simulator sessions was unfamiliar to most students. The simulators, aircraft, and PA system may have been a distraction for the students or conversely, made the teaching more exciting to some individuals. Further, the added noise and novel surroundings of the simulator may have affected the performance of some students.

3. Student Differences

According to Newble, differences in student characteristics may also impact on the effectiveness of a teaching session.[8] In this study, student differences between the two study groups may have affected the knowledge gains resulting from the teaching sessions. No statistically significant differences were noted between the groups with respect to age, gender and pre-test marks. However, the proportion of males to females in the traditional small group sessions was slightly higher than in the simulator-based classes, and this may exert a subtle influence. Furthermore, it is possible that certain clerkship blocks had a higher number of students who were more interested in pediatrics, leading to increased motivation to perform well. Last, with each progressive clerkship block, the students had acquired more clinical experience, and therefore it was possible that students performing early in the study would have demonstrated lower pre-test scores. However, comparison of the mean scores demonstrates no such trend.

Though the baseline characteristics of the students were similar, differences in personality types and learning styles may have affected the primary outcome. [8,28,48] Students with little interest in the teaching session may have altered the group dynamics and inhibited active participation and discussion. If the simulator group had a higher number of introverted individuals, it is possible that participation and learning may have been suboptimal. Students in the simulator-based group may have found the technology or performance aspect threatening, and fear of making mistakes may have impeded learning. Educational psychologists have identified many types of learners, ranging from visual to auditory learners.[49] Some students, described as kinaesthetic learners, may benefit more from a "hands-on" teaching style, as opposed to others who learn better by listening to discussion. There is no reason, however, to believe that the proportions of these types of learners would be different in the two groups, and therefore this factor is unlikely to have significantly affected the results.

4. Facilitator Differences

The primary purpose of a facilitator in a small group session is to ensure the learning objectives are discussed with full participation from a well- functioning team. As noted by Trigwell et al in 1999, differences in facilitator teaching style and personality may affect the effectiveness of the teaching session.[50] Although most teachers are comfortable delivering lectures, the small group format is highly dependent on other facilitator skills such as questioning, discussion, and observation. These techniques are developed and refined over years by medical educators, and inter-facilitator differences in leading small group sessions almost certainly exist. Nonetheless, since each facilitator participated in both teaching sessions, the effect of differences in facilitator teaching styles on the final outcome should be minimized. Variability in the degree of facilitator preparedness may have also impacted on the students' final performance; however, educator training of the teaching sessions was an essential aspect of this study to control for this effect.

The incorporation of simulator technology into small group teaching is likely to have affected each facilitator's teaching style in a different manner. For teachers unfamiliar with the patient simulator, this "teaching aid" may have acted as an obstruction to the natural flow of teaching, hindering their ability to fully discuss all the required objectives. Many of the teachers also commented on the "learning curve" experienced when teaching with the simulator. Further, some facilitators commented on the natural tendency to teach slightly different agendas with the two teaching styles. Most commented on the tendency to discuss pathophysiology during traditional small groups, versus the propensity to focus on management during the simulator-based sessions. Nonetheless, similar results were demonstrated between the two groups, suggesting that regardless of the teaching method, comparable information was assimilated by the students.

B. Long- term Knowledge Retention

A secondary outcome of the study evaluated the student scores on a subset of questions from the final clerkship examination as a measure of long term knowledge retention on the concepts of pediatric shock and dehydration. Analysis revealed no significant difference between the performances of the subjects in the two intervention groups, though the scores of the traditional teaching group were slightly higher. This result may be unexpected, considering that some literature would suggest that simulator-based teaching sessions might enhance long term memory recall by allowing repeated practice which enhances "deep learning". [29]

While there may be no difference between the two teaching methods with respect to promoting long term knowledge retention, other explanations for the findings exist. Arguably, the evaluation tool to measure long term knowledge retention was suboptimal. The multiple choice questions used to measure long term knowledge retention were extracted from the final pediatric clerkship examination and therefore were previously created based on different objectives. Thus, the measuring instrument for long term knowledge retention may not have had a high degree of content validity.

C. Student Satisfaction

The high student satisfaction with simulator-based teaching demonstrated in this study reflects the sentiment found in previous studies.[19,21,23,38] Students rated both simulator and small group sessions very highly in general, and accordingly, the scores demonstrated a "ceiling" effect. Previous literature has demonstrated the ceiling effect to be found frequently in educational questionnaires.[51] This effect may account for the finding of no significant difference between the satisfaction scores of the students participating in the simulator group versus the traditional small group.

Bias and psychometric properties of the questionnaire must also be considered when reviewing the questionnaire findings. The novelty effect of the simulator may have led to an elevation in this group's satisfaction scores; this effect is difficult to quantify with a single questionnaire. Social desirability bias may have caused students to rate the experience more positively than otherwise.[45] However, since the researcher was present at all the sessions, this effect would be present in both groups and therefore should have minimal impact on the difference between the two sessions. The six students who chose not participate in the questionnaire may be a further source of bias. Five of the six students had participated in a traditional small group session, and these students demonstrated a lower overall knowledge gain than the study mean. This may suggest that these six students were less interested in the teaching session, and failure to participate in the questionnaire may have led to an overestimation of student satisfaction with the traditional small group teaching sessions.

In general, the psychometrics of the satisfaction questionnaire was demonstrated to be adequate. Reliability of the satisfaction questionnaire was high, with a Cronbach alpha value of 0.75, suggesting internal consistency. The questionnaires were also tested for face validity, and necessary revisions were made before administration.

D. Confidence Scores

Overall, students rated their confidence in managing pediatric shock and dehydration as improved as a result of either type of teaching session. Most students agreed with the statement that their confidence increased with the training session, however a ceiling effect again occurred which made it difficult to detect differences between the two groups. This lack of significant difference between the confidence scores of the two groups warrants consideration. Since the simulator provides a more realistic "hands-on" training experience, one might expect this learning technique to enhance confidence in patient management. However, the material covered or the time spent in the session may not have been adequate to facilitate this effect. An alternate explanation may be that practice with the simulator uncovered shortcomings and gaps in the students' knowledge base. As one student stated, "it is a totally different type of learning when you have to do it". With some students, this "reality check" may have actually decreased their confidence in management skills.

E. Group Dynamics

Group dynamics were assessed by videotape review, and differences were noted between the traditional small groups and the simulator-based sessions. Unfortunately, due to a technical mistake with the video recording, only one of the simulator sessions was adequately taped for observation. Having observed all of the sessions, the researcher felt that the sole recorded simulator session was representative of the other simulator-based sessions in terms of group dynamics. During the videotape review performed by the researcher, observations were recorded which highlight the differences between the two session types.

The traditional small group sessions were characterised by very little interaction between students, however frequent "rapid fire" questions and answers between student and facilitator were common. The amount of lecturing performed varied by teacher, and the content focused more on pathophysiology, less on management. Initially, the majority of student-led contribution was from a few individuals; however as the sessions progressed, other students started to ask questions and increase their participation.

The simulator-based session had a very different style of interaction. Students appeared visibly nervous at the onset of the session; this dissipated and turned to enthusiasm as the lesson progressed. Often, multiple students spoke simultaneously, commenting to each other about management decisions. Student activity dominated in the case scenarios, with no facilitator "mini-lectures" interrupting the flow of management. Over the course of the teaching session, students became notably faster and more assured with the management of the cases. Similarly, the facilitator seemed to become more comfortable taking a secondary role and observing student management. Interestingly, the debriefing session after each case scenario resembled the traditional small group format, with the students offering little input other than occasionally answering facilitator-driven questions.

This study supported the use of a simulator as a teaching aid to promote student-centered learning, and is the first study to methodically detect differences in group dynamics between traditional and simulator-based small group teaching. The observations made in this study suggest that the simulator-based session offered more student interaction and less teacher-driven lecturing than the traditional small group method. Though this study did not show improved knowledge gain or retention in the simulator-based group as compared to the traditional small group, it is possible that students learning in a "richer" environment with more student discussion will function superiorly in a clinical scenario when problem solving and performance are the most required skills. These factors were not examined in this study, and are a subject for further research.

F. Advantages and Obstacles to Simulator Implementation in Medical Education

In accordance with previous studies discussed in the literature review,[3,7,22,24,40,44,46] numerous advantages of using a simulator as a teaching aid were apparent to both students and facilitators. The enhanced realism of the scenarios added both emotional appeal and opportunity for “hands-on” patient management. The opportunity for practice in a safe environment, the development of peer relations and leadership skills, and the ability to learn through the physiologic changes demonstrated by the mannequin were all cited as advantages not offered by conventional small group teaching.

This study demonstrated a high element of student participation in the simulator-based groups; qualitatively, examination of the group dynamics suggested increased student discussion and critique in the groups using the simulator. This may be of benefit for a number of reasons. First, active student participation enhances attention and interest in the topic. Accordingly, satisfaction scores for the simulator-based session were excellent. Second, the relevant and practical nature of simulator teaching appears to be a strong motivator for undergraduate students; motivation has been shown to be a potent factor in successful self-directed learning.[52] Third, it is likely that student-driven learning may encourage enhanced independent problem-solving behaviour, a desired attribute of residents and attending physicians.

However, incorporating a simulator as a teaching aid into the undergraduate medical education curriculum is not without difficulties. This study encountered many obstacles to simulator use that were previously discussed in the literature review. The limited availability of the simulator, technical expertise required for operation, travel time, and resource intensity were barriers that demanded intensive planning for this study. Centers that do not have an established simulation center face a significant cost and time investment in developing such a center, in addition to the recruitment and training of specialized technicians. Finally, both students and particularly physician-educators must be willing to embrace this new technology, which requires a considerable amount of training and education to optimize its utility as a teaching tool.

Since there are few studies demonstrating an improvement in medical performance after simulator training, many centres are understandably slow to adopt this technology with its high price.[3,7] While this study did not demonstrate an improvement in student knowledge gain over traditional small group teaching, the simulator-based sessions were rated extremely highly by the students, knowledge gain was demonstrated, and interviews with both facilitators and students were very positive about the new style of teaching. Previous studies have also demonstrated overwhelmingly positive reactions from both learners and educators in response to simulator-based teaching, and regardless of hard data, it appears that the number of simulators in Canada will continue to increase, particularly in academic and training centres.

G. Limitations of the Study

1. Randomization and Bias

Due to the constraints of the clerkship schedule and availability of the simulator, the subjects could not be randomized with respect to traditional or simulator-based small group session, and therefore unintentional selection bias may threaten internal validity. However, randomization between the two facilitator groups did occur, and the clerk blocks were alternated with respect to session type. Subjects were enlisted on a volunteer basis causing a potential source of selection bias, however this effect is diminished since both groups were composed entirely of volunteers. Though the sample size recruited was not large, thirty-eight participating subjects was a sufficient number to meet the sample size criteria, and no subjects were lost to attrition with respect to the primary outcome measured.

All facilitators taught the small group session before the simulator session, a factor which possibly affected the results. Sessions were at least one month apart for all facilitators, and it is possible that the second (simulator) teaching session may have been more successful due to the repetition of the content. However, facilitators received the majority of their training before their first session, and a brief refresher was given before the second session. Thus, it is possible that the facilitators may have been less prepared for the second session due to a lapse in time without training. These factors may have played some role in the final results; however their absolute effects are not easily quantified.

Experimenter bias in marking the pre- and post-test was not a consideration since single answer multiple choice examinations were used. The "novelty" factor of the simulator may have affected the satisfaction questionnaire results, causing the students to rate the teaching technique higher than expected. The researcher administered both the questionnaires and the interviews, and though social desirability bias may have occurred, its effect would be present in both groups. Review of the videotaped sessions for group dynamics was performed by the experimenter. The accuracy and consistency of the recordings were ensured by using a tally system and stopwatch; the use of a sole observer eliminated the possibility of inter-observer variability.

2. Threats to Internal Validity

As with most educational research, potential threats to internal validity exist within this study. The experimental treatment in this study occurred over a discrete period of time, and therefore pre- and post-test marks are unlikely to be affected by other learning events beyond the treatment. Differences in content taught or facilitator effectiveness with a teaching style may have affected the final results, though attempts were made to minimize any variability. Furthermore, the marks obtained on the final clerkship examination may be affected by a number of different variables, such as individual studying, recent teaching sessions and student interest in pediatric medicine.

Further possible extraneous variables must also be considered. Theoretically, it is possible that the written examination post-test scores increased simply because of prior experience with the pre-test; however improvement in scores is more likely due to the intervention. No pre-measures of attitudes were administered before the teaching, and therefore it is not possible to determine whether students had unusually positive or negative attitudes towards small group teaching. However, by not administering a pre-test questionnaire, any pre-test sensitisation effect is eliminated, and thus the external validity of the study is strengthened.

3. The Measurement Instruments

Despite the efforts made to produce a reliable and valid measurement tool, the written examination may not have been sufficiently sensitive to identify learning points derived from the more management-driven simulator-based session. Almost certainly, all subjects learned more than was tested on the examination and these differences may be most pronounced in procedural management, skills and leadership ability. Arguably, a combination of multiple choice and observed individual testing scenarios may be a more valid source of evaluation. Long-term knowledge retention would have been better assessed by an examination derived directly from the specified learning objectives. The qualitative questionnaire may have been improved by using a seven-point scale, which may decrease the ceiling effect.[51]

H. Questions for Further Studies

The limitations of this study highlight the need for further research into simulator use in undergraduate medical education. Further studies could enlist a larger sample size which would increase the ability to detect small differences between the groups. The optimal evaluation instrument to test student knowledge gain, both declarative and procedural, could be multi-dimensional and include not only a written examination, but a more "hands on" approach, such as management of a standardized or simulated patient, in an Observed Standardized Clinical Examination (OSCE) format. It is possible that in this environment, the students who attended simulator-based teaching may demonstrate superior knowledge gains over those who attended the traditional small group format. Further longitudinal studies might incorporate the assessment resident performance in actual patient encounters.

Many recent studies have demonstrated high student satisfaction with simulator-based education.[19,21,23,38] This study not only reviewed student satisfaction with simulator teaching, but also compared it to the responses of those students receiving traditional small group teaching. By keeping the content as similar as possible, the two teaching methodologies were compared directly, and were found to be very similar in student evaluation. Further studies should aim to develop a more sensitive instrument which is able to identify smaller and more specific differences in student attitudes towards the teaching methods.

The evaluation of group dynamics was not assessed as thoroughly as anticipated due to technical difficulties. This portion of the study could be replicated, and it is likely that a difference in group dynamics in the two session styles would be demonstrated.

This study did demonstrate positive findings such as increased student discussion and decreased facilitator lecturing, and further studies in this area would add to the debate on whether or not student- dominated discussion actually enhances learning.[8,28,53]

I. Conclusion

This study compared two teaching strategies, traditional and simulator-based small group teaching, to generate insight into patient simulator application into undergraduate medical education. Both teaching styles were demonstrated to be equally efficacious at promoting declarative and procedural knowledge gain. A clear advantage of simulator-based teaching was not demonstrated over traditional small group teaching in the augmentation of student knowledge. Further, no significant differences were observed in long term knowledge retention between the two groups, using marks from a subset of questions from the final clerkship exam. In general, subjects rated high satisfaction with both methods of teaching. The simulator-based sessions were rated slightly higher in student satisfaction, however the difference between the two sessions was not statistically significant. Interviews provided an abundance of student and facilitator opinion regarding the perceived efficacy, characteristics and ease of use of the two teaching styles. Differences in group dynamics were noted between the two groups, with the simulator-based session demonstrating higher student interaction and less facilitator "mini-lecturing". Advantages and obstacles to the implementation of simulator-based education in the undergraduate medical curriculum were discussed.

The practice of medicine has changed dramatically over the last twenty years, and accordingly, medical education is responding to new challenges by incorporating novel teaching aids.[2,4,7] Currently, the use of simulators is in its infancy. Although there is growing interest in the use of simulators for teaching, assessment, certification and research, obvious barriers exist. Obstacles include the cost of purchase and maintenance, the paucity of available simulators, the required small student to facilitator ratio, and the expertise required to maintain the simulator.[3,7,22,37,44,46] Opponents cite concerns over the "game-like" quality of simulator teaching and the possibility of dehumanizing patient care.[7] Nonetheless, the most resounding supporters of simulators to date are the actual students, who feel that this technology is unique in offering a realistic experience and the ability to practice safely.[19,21,23,38]

Further studies in the area of simulation research are necessary to develop valid and reliable measurement tools, assess learning at different levels of education, experiment with alternative teaching styles, examine the optimal length of teaching sessions, and explore further areas of medicine where the simulator may be used for research or teaching. Educational research into the utility of high-fidelity patient simulators will continue to lag behind the development of increasingly realistic, user-friendly, and sophisticated simulators. Given the widespread enthusiasm of educators and students to this versatile new tool, it is almost inevitable that the new generation of simulators will gain widespread distribution and firmly establish a place in medical education.

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APPENDIX A: Teaching Session Objectives

THE PRINCIPLES AND MANAGEMENT OF PEDIATRIC DEHYDRATION AND SHOCK SECONDARAY TO GASTROINTESTINAL ILLNESS

A. OBJECTIVES FOR CLINICAL VIGNETTE #1 (SHOCK)

Given a real or simulated scenario of a pediatric patient presenting with shock, the student will:

1. Generate a differential diagnosis for the clinical problem of acute upper GI bleeding in a pediatric patient;
2. Identify the physical signs and symptoms of acute hypovolemic shock in a pediatric patient;
3. Apply principles of the circulatory system to explain the physical signs of shock in a pediatric patient;
4. Using available information, evaluate a patient as to the possible type of shock;
5. Distinguish between the different types of shock, namely hypovolemic, septic, cardiogenic, dissociative;
6. Formulate a plan for the initial resuscitative management of hypovolemic shock in a pediatric patient;
7. Formulate a plan for ongoing management of a child with shock.

B. OBJECTIVES FOR CLINICAL VIGNETTE #2 (DEHYDRATION)

Given a real or simulated scenario of a pediatric patient presenting with dehydration due to gastrointestinal illness, the student will:

1. Generate a differential diagnosis for the clinical problem of acute vomiting and diarrhea in a pediatric patient;
2. Identify the physical signs and symptoms of acute dehydration in a pediatric patient;
3. Assess the degree of dehydration in a pediatric patient: mild, moderate or severe;
4. Calculate the estimated fluid deficit, maintenance and ongoing losses;
5. Choose the optimal route of rehydration for a patient's condition (oral, IV);
6. Identify the appropriate steps in the acute management of dehydration, including the principles of fluid resuscitation;
7. Formulate a plan to manage a pediatric patient with dehydration, including fluid type, rate and volume to be administered;
8. Compose a plan for the refeeding of the patient.

APPENDIX B: General Instructions for Teachers

Purpose of study:
This study aims to compare two styles of small group teaching; traditional versus simulator-based teaching.

The subject to be taught to the third year clinical clerks is the management of pediatric dehydration and shock due to gastrointestinal illness, however some aspects of pathophysiology, differential diagnosis etc. will also be included.

Schedule for Teaching Sessions:

13:15- 13:30- Students arrive for teaching session
13:30- 13:45- Students oriented and receive pre-test (written)
13:45- 14:30- Case #1
14:30- 15:15- Case #2
15:15- 15:30- Post- test and survey
15:30 – Most students leave; a few will undergo a brief interview

Methods of Evaluation:

Students will undergo a 10-15 minute written test at the beginning and end of the session
The students will write a perform a short attitudinal survey at the end of the session
The sessions will be videotaped to explore interaction
Certain students and staff will be interviewed after the sessions

Content of the Sessions:

- The goals of the teaching sessions are to discuss SIMILAR CONTENT in both types of teaching.
- However, the content will be PRESENTED AND LEARNED in a DIFFERENT MANNER between the two sessions
- The objectives for the session are listed on the sheet entitled "objectives"
- The "Guidelines" handout is a reference for facilitators and outlines material which may be covered in the teaching session. The most important concepts are denoted with an asterisk*- these concepts should be covered.
- To supplement facilitator knowledge, a short chapter on Shock from the APLS text is provided for a reference
- In general, sessions should commence and focus around the 2 clinical vignettes (dehydration and shock)
- Discussion may center around history, physical, differential diagnosis, laboratory investigations, acute and chronic treatment
- Please remember the aim is to be a facilitator, asking questions and challenging errors. This is very different from the lecture format

Format of the Teaching Sessions:

- Small group sessions consist primarily of discussion with members sitting in a circle
    - After the vignette is read, the facilitator may then ask a member how they would assess and manage the patient acutely, ask what further pieces of history are needed, etc.

- In contrast, simulator sessions should be focused around the child (mannequin)
    - The same discussion re: history, physical may be made but the students should be prompted to act as in a "real life" scenario (i.e. if the child was presenting in the emergency department).
    - The students should be instructed to work as a team in the management of the case and to "think out loud"
    - For example, during the physical examination, a student should auscultate the heart, assess vitals, pulses etc.
    - Similarly, as the students run through the management of the case, they should be asked to reassess the patient after a bolus is given, etc.
    - I will be available at these sessions to act as a "nurse", for instance to supply blood work results
    - Facilitators may want to use a "time out" approach to discuss aspects aside from acute management which may have been overlooked (i.e. Important points of history, physical, differential diagnosis)

APPENDIX C: Clinical Vignettes

Clinical Vignette #1

HISTORY

Kevin is a six-year-old boy who is transferred to the emergency department of your hospital from a rural clinic. Over the past 12 hours, Kevin has developed vague abdominal pain and has proceeded to have hematemesis for the last six hours. The rural physician estimates he has vomited approximately four times over the last six hours. The emesis is primarily fresh blood, approximately one cup in volume each emesis. He has had no fever, rash, arthritis, or headache. This is the first episode of hematemesis.

Kevin has been healthy in the past, with no hospitalisations or surgeries. He is currently on no medications and immunisations are up to date. Functional inquiry reveals he has had one episode of bloody diarrhea four months ago, thought secondary to infection, which spontaneously resolved after two weeks. There is no family history of bleeding disorders or coagulopathy.

PHYSICAL EXAMINATION

General Assessment:
Frightened, alert, pale child

Vital signs
HR 140 BP 85/40 RR 26 O2Sat 95% on R/A Weight 20 kg

Head and Neck
Pallor with dried blood around mouth
Tympanic membranes and oropharynx normal
No adenopathy

Chest
Clear to auscultation

CVS
Tachycardia, normal heart sounds
Grade 2/6 systolic ejection murmur at left sternal border
Cool pale extremities
Capillary refill time 3 seconds
Pulses full centrally, weak peripherally

Abdomen
Soft, no specific tenderness or rigidity
Bowel sounds diminished
Liver 1 cm below costal margin at mid clavicular line and firm; span 8 cm
Firm mass in the epigastrium extending down 6 cm
No spleen tip felt; no other masses

Genitourinary
Normal male genitalia

Musculoskeletal/Skin
1 spider angioma on face, 2 on chest
No birthmarks
Normal weight and muscle tone

Neurologic
Frightened, but consolable
Cranial nerves intact
No tremor, asterixis, normal cerebellar testing
Normal reflexes, tone, muscle bulk

TOPICS FOR DISCUSSION

1. What are your initial steps in managing this patient?
2. What is your assessment of the patient's current clinical condition?
3. What is your differential diagnosis of an upper GI bleed? What do you suspect is likely in this case?
4. What physical signs and symptoms are concerning? What are reassuring?
5. Is this patient in "shock"? What does "shock" mean?
6. What are the different categories of shock? What kind might this patient have?
7. Discuss further management, including investigations, ongoing care, and definitive treatment

Clinical Vignette #2

HISTORY

You are a family physician working in the emergency department in a small rural hospital. Mrs. McMillan has brought in her five-year-old son, Tim, who has developed fever, vomiting and diarrhea over the last four and a half days. Initially, Tim became noticeably sleepy, anorexic, and developed vomiting and diarrhea. Yesterday, a fever developed and has been recorded as high as 39 degrees Celsius.

For the past 4 days, he has vomited approximately 5- 12 times/ day. The diarrhea is watery, non-bloody, foul smelling, and associated with abdominal cramping. Tim has had approximately seven to fifteen stools/ day over the last 4 days; it has decreased somewhat over the last 24 hours. Mrs. McMillan has tried to administer Tim ginger ale and soup, but he is unable to keep anything down. She is worried he is dehydrated.

Tim's medical history is unremarkable. He has had no hospitalisations or surgeries. Immunisations are up to date and he is on no medications. He has not had symptoms such as these in the past. Other members of the family are well, and there are no known sick contacts.

PHYSICAL EXAMINATION

General Assessment:
Miserable and pale
Lethargic and passive during the examination.

Vitals:
HR 135, RR 30, BP 85/50, T 38.0., Weight 22kg

Head and neck:
Tacky mucous membranes
Tympanic membranes, oropharynx normal
No evidence of adenopathy, meningismus

Chest:
Clear
No significant increased work of breathing

CVS:
Mildly hyperdynamic circulation.
Warm centrally but cool hands and feet.
Pulses palpable.
Heart sounds normal.
Grade 2/6 systolic ejection murmur at left sternal border.

Abdominal:
Mildly distended, tympanitic to percussion
Mild diffuse tenderness
No rebound or peritoneal signs
No hepatosplenomegaly/masses

Genitourinary:
Negative

Musculoskeletal and Skin:
Negative

Neurologic:
Lethargic and variably responsive
No focal signs on screening exam

TOPICS FOR DISCUSSION

1. What are your initial steps in the acute management of this patient?
2. What further pieces of history would help you assess Tim's degree of dehydration?
3. What physical signs are concerning? What are reassuring?
4. How do you estimate degrees of dehydration? What is the estimate for Tim?
5. What is the differential diagnosis of this patient's illness?
6. What investigations would you order?
7. Describe the ongoing management of this patient, including the specifics of fluid resuscitation (type, rate, delivery), and refeeding plans for this patient.

APPENDIX D: Facilitator Teaching Guidelines

Facilitator Guidelines for Vignette #1 (Shock)

DEFINITION

- Circulatory dysfunction resulting in the failure to provide sufficient blood nutrients and oxygen to satisfy tissue needs
- *i.e. Inadequate tissue perfusion*

A. CLASSIFICATION OF SHOCK

COMPENSATED SHOCK

- Vital organ perfusion is maintained
- Compensatory measures

UNCOMPENSATED SHOCK

- Compensatory adjustments have failed
- Hypotension and poor tissue perfusion

IRREVERSIBILE SHOCK

- End organ failure resulting in death

B. PATHOPHYSIOLOGY OF SHOCK

COMPENSATORY MEASUREMENTS

- maintain arterial blood pressure at the cost of exacerbating tissue perfusion

TISSUE HYPOXIA DUE TO:

- Failure to oxygenate the blood due to airway or breathing problems
- Shunting of deoxygenated venous blood so it bypasses the lungs and remains deoxygenated in the systemic circulation (cardiogenic)
- Presence of a low concentration of normal hemoglobin

C. TYPES OF SHOCK

This teaching session focuses on hypovolemic shock, however the two points about septic shock should be covered

1. HYPOVOLEMIC
* Most common, focus of today's teaching session
Problem: decreased circulating blood volume
Causes: Dehydration, Hemorrhage

2. DISTRIBUTIVE
Problem: Vasodilation
Causes: Sepsis, Anaphylaxis, Drug Intoxication, Spinal Cord Injury

- **Stress that the child may appear warm and well perfused (and febrile) until late in the course of septic shock**
- **Septic shock is treated with fluid boluses (up to 40mg/kg) and IV antibiotics. Often requires ICU for support of hypotension with further fluid or inotropes**

3. OBSTRUCTIVE
Problem: Obstruction of cardiac filling
Causes: Cardiac Tamponade, Tension Pneumothorax, Pulmonary Embolism

4. CARDIOGENIC
Problem: Decreased Contractility
Causes: Congenital Heart Disease, Myocarditis, Dysrhythmias

5. DISSOCIATIVE
Problem: Oxygen not released from hemoglobin
Causes: Carbon Monoxide, Methemoglobinemia

D. HYPOVOLEMIC SHOCK DUE TO HEMORRHAGE

Total Blood Volume of a Child: 80 cc/kg

*Stress the progression of shock from tachycardia and decreased urine output (early) to poor perfusion and hypotension (late)

STAGE 1 (< 15% EBV loss)

- all parameters normal

STAGE 2 (15- 20% EBV loss)
CRT> 2 sec

- Increased HR
- Irritable mental status
- Urine output Normal or decreased
- BP normal

STAGE 3 (25-40% EBV loss)
CRT > 5 sec

- Increased HR
- Lethargic
- U/O decreased
- BP widened/ decreased

STAGE 4 (40% EBV loss)

- CRT > 5sec
- Unresponsive
- HR increased/ decreased
- U/O absent
- BP decreased

E. DIFFERENTIAL DIAGNOSIS OF ACUTE UPPER GI BLEEDING

* Indicates that typical presentation should be discussed

1. UPPER INTESTINAL BLEEDING

- *Esophageal varices
- *Peptic Ulcer disease
- *Gastritis
- Mallory Weiss tear

2. ACUTE SMALL INTESTINAL BLEEDING

- *Intussusception
- Infectious enteritis
- *Meckel' s diverticulum
- Vasculitis: HUS/HSP
- Vascular: Hemangioma, AV malformation

3. NON GI RELATED BLEEDING
- Nosebleed
- Tonsillar bleed
- Trauma to oropharynx
- Hemoptysis
- Ingested blood (newborn)
- Factitious bleeding
- +/- Coagulopathy/ Platelet insufficiency/dysfunction

F. PHYSICAL EXAMINATION

APPEARANCE
- Reflects adequacy of perfusion
- Mental Status (alert vs. altered)

WORK OF BREATHING
- Tachypnea, hyperpnea, bradypnea

CIRCULATION
- Heart Rate (tachycardia, bradycardia)
- Pulses (decreased, bounding absent)
- Capillary Refill (delayed, cool skin)
- Urine output (decreased)
- Blood Pressure (increased, normal or decreased)

G. MANAGEMENT OF HEMODYNAMICALLY UNSTABLE PATIENT

**ALWAYS STRESS ABC'S: AIRWAY, BREATHING, CIRCULATION

A/B. AIRWAY AND BREATHING
- Assess for obstruction, decreased LOC, respirations (rate, effort, colour)
- Apply oxygen via face mask (if breathing) or via bag and mask ventilation (if respiratory effort insufficient)
- Indications for intubation: Insufficient respiratory effort, decreased level of consciousness, unable to maintain airway, respiratory arrest, pulmonary toilet
- Attach to cardio respiratory monitors: hr, RR, BP, O2sat

CIRCULATION
- Monitoring equipment (C-R monitor, SaO2)
- IV access, as large as possible (possible central line)
- IO access if IV not available
- Fluids:

- Rapid administration of 20 cc/kg Normal Saline IV/IO
- Assess response; ensure hypovolemic shock
- Second administration of 20cc/kg Normal Saline IV/IO
- Strongly consider Packed Red Blood Cells 15 cc/kg if bleeding
- Consider Albumin 5% or Pentaspan 10 cc/kg after first or second bolus
- *After 40cc/kg of fluid, consult ICU*
- NG tube to suction, especially if vomiting
- Lab work: CBC, Lytes, BUN, Creatinine, glucose, Liver enzymes, PTT/INR, Cross Match, Blood gas, Blood cultures, etc.

DISABILITY

- ETT necessary if GCS <8

SECONDARY SURVEY

- Reassess ABC's
- Full physical examination
- Short History
- Notify ICU of admission
- Definitive management:
- Notify GI service for control of hemorrhage (possibly start octreotide, PPI) after non-GI causes excluded
- Start broad spectrum IV antibiotics if any possibility of septic shock

Facilitator Guidelines for Vignette #2 (Dehydration)

IMPORTANCE:

- Dehydration caused by infectious gastroenteritis is the primary cause of infant morbidity worldwide
- Untreated dehydration may lead to shock and death

A. CAUSES OF DEHYDRATION SECONDARY TO VOMITING AND DIARRHEA IN THE PEDIATRIC POPULATION

INFECTIOUS

- Bacterial: Shigella, Campylobacter, Yersinia, Salmonella, E coli, C. Diff
- Viral: Rotavirus* (most common), adenovirus, Norwalk virus
- Parasitic: Giardia, Cryptosporidium
- Extraintestinal infections: Sepsis, UTI

INFLAMMATORY

- IBD: Crohn's disease, Ulcerative colitis
- Celiac disease
- Systemic disease: JRA, Lupus, etc.

METABOLIC/ ENDOCRINE

- Inborn error of metabolism
- Cystic Fibrosis
- Hyperthyroidism
- Congenital Adrenal Hyperplasia

TOXIC INGESTION/ MEDICATION

- Antibiotic associated

NEOPLASTIC

- Neuroblastoma
- Lymphoma
- VIP/Ganglioneuroma

TYPES OF DIARRHEA

ACUTE VS. CHRONIC

- Acute :< 2 weeks duration
- Chronic: > 2 weeks duration

B. ASSESSMENT OF DEGREE OF DEHYDRATION

1. HISTORY

2. PHYSICAL EXAMINATION
    - General appearance and Mentation
    - Heart rate
    - Pulses
    - Capillary Refill
    - Mucous Membranes
    - Respirations
    - Fontanelle
    - Skin Turgor
    - Urine Output
    - Blood Pressure

1. LABORATORY INVESTIGATIONS
- CBC, Lytes, BUN, Creatinine, Glucose, Osmolality, Urinalysis

2. CLINICAL ASSESSMENT OF DEHYDRATION
- Infant (<1-2 years): Mild (5%), Moderate (10%), Severe (15%)
- Child (>2years): Mild (3%), Moderate (6%), Severe (9%)

Mild Dehydration:

- All vital signs normal except thirst and irritability

Moderate Dehydration

- Tachycardia, dry mucous membranes, oliguria, mild tachypnea, orthostatic hypotension

Severe Dehydration

- Symptoms as with moderate dehydration, plus:
- Drowsy to comatose, tachycardic, pulses decreased, hypotension, mottled skin with decreased turgor

C. PATHOPHYSIOLOGIC TYPES OF DEHYDRATION

1. HYPONATREMIC DEHYDRATION (Na<130 mEq/L)
- Relatively more sodium than water is lost from the ECF, or excess water is provided
- Seizures may occur if Na drops below 120 mEq/L

2. ISONATREMIC DEHYDRATION (Na130-150 mEq/L)
- Sodium and water lost from ECF in approximately equal amounts

3. HYPERNATREMIC DEHYDRATION (Na >150mEq/L)
- More water than sodium is lost from extra cellular space or excess sodium is provided

This teaching session will focus on isonatremic dehydration, which most commonly results from a gastrointestinal illness.

HYPONATREMIC AND HYPERNATREMIC DEHYDRATION MUST BE CORRECTED MORE SLOWLY (well over 24 hours).

D. *MANAGEMENT OF DEHYDRATION*

1. ORAL REHYDRATION THERAPY VS. IV?

a. Oral Rehydration Therapy (ORT) indications:

- Mild to moderate dehydration
- Able to drink small amounts frequently
- No evidence of shock
- Adequate supervision

b. Intravenous Therapy indications:

- Shock
- Severe Dehydration
- Intractable vomiting
- Severe diarrhea exceeding 100 cc/kg/hour
- Altered mental status
- Severe electrolyte abnormalities

2. INITIAL MANAGEMENT OF DEHYDRATION
   - Immediately:
     - **Always ABC's**: Airway, Breathing and Circulation

A/B: AIRWAY/BREATHING:
- Assess for obstruction, decreased LOC, respirations (rate, effort, colour)
- Apply oxygen via face mask (if breathing) or via bag and mask ventilation (if resp. effort insufficient)
- Indications for intubation: Insufficient respiratory effort, decreased level of consciousness, unable to maintain airway, respiratory arrest, pulmonary toilet
- Attach to cardio respiratory monitors: hr, RR, BP, O2sat

C. CIRCULATION
- Prevent/ treat evidence of shock – no electrolytes required
- Establish IV
- Initial bolus: 20 cc/kg of NS given rapidly IV
- Reassess for further signs of shock and treat as necessary
- See "guidelines for shock"

D. SUBSEQUENT MANAGEMENT OF DEHYDRATION

Fluid therapy = deficit + maintenance + ongoing losses

1. Calculating the Fluid Deficit:

1. Body weight x Estimated % dehydrated/100 = Deficit in Litres
   - (i.e.) 22 kg infant x 3% dehydrated/100= 0.660 L or 660 cc deficit
2. Subtract the volume of fluid already given as boluses from the deficit
   - (i.e.) 660 cc – 220 cc given as bolus= 440 cc deficit
3. The deficit should be replaced over approximately 24 hours

50% of the deficit should be replaced in the first 8 hours
   - (i.e.) 440/2 = 220/ 8hours= 28 cc/hr x 8 hours

The next 50% should be replaced over the next 16 hours
   - (i.e.) 220 cc/ 16 hours = 14 cc/hr x 16 hours

Hyponatremia and hypernatremia must be corrected more slowly!

2. *Calculating the Maintenance Fluids*

Using the 4, 2, 1 Rule (cc/hr)

- 4 cc/kg for the first 10 kg
- 2 cc/kg for the second 10 kg
- 1 cc/kg for the remaining kg

(i.e.) A 22kg child would have a maintenance fluid requirement of:

4 x first 10 kg= 40 cc/hr

2 x second 10 kg= 20 cc/hr

1 x 2 remaining kg= 2cc/hr

Adding up to 62 cc/hr

3. *Ongoing Losses*
   - Diarrheal losses should be replaced every 4-8 hours, depending on severity
   - If stool output mixed with urine, 50% of the total volume should be replaced

4. Choosing the correct intravenous fluid

   a. Initial fluid bolus for prevention/treatment of shock:

   - ALWAYS Normal Saline, or Ringer's Lactate

   b. Correcting the deficit:

   - D5/ .45 most appropriate for isonatremic dehydration
   - Add 20 mEq/L KCl when patient has started voiding

   c. Maintenance fluids

   - Use D5/.45 (+ 20 mEq KCl/L when voiding) when deficit is being replaced
   - Once patient has improved and is eating, a more physiologic solution is D5/.2 with 20 mEq KCl/L

5. Replacing ongoing losses
   - Large variation in electrolyte composition of diarrhea
   - 0.45 NS with 20 mEq KCl/L is an appropriate starting solution
   - May require higher concentrations of sodium and potassium
   - Difficulties managing blood electrolytes may be aided by stool electrolytes

F. ONGOING CARE OF A PATIENT WITH DEHYDRATION

1. FREQUENT REASSESSMENT
    - Clinical assessment q 4h to start
    - Check electrolytes q 4-8 hours, depending on initial values
    - Stool should be sent for viral studies, culture and sensitivity, ova and parasites and C. Diff toxin
    - Stools may also be sent for WBC, Reducing substances, fat, and electrolytes
    - Reassess fluids with response to therapy
    - Look for other complications: infection, fluid overload

2. REFEEDING THE PATIENT
    - Feeding may be reintroduced when vomiting and diarrhea are decreasing
    - A strict BRAT (bananas, rice, apples, toast) diet does not hasten recovery
    - The implementation of a regular diet is recommended, starting slowly at first
    - Transient lactose intolerance may occur after a gastrointestinal illness- this usually resolves by 4- 6 weeks post illness

APPENDIX E: Pre/Post Assessment Tool

UNIVERSITY OF
CALGARY

The objective of this short quiz is to assess your knowledge gain on the topics presented in today's teaching session. This is an important part of the study, and your participation is greatly appreciated. The results of this quiz are for study purposes only; this will have no impact on your clerkship evaluation.

AGE _____ GENDER _____ STUDENT ID:

For each question, choose the **SINGLE BEST ANSWER** by filling out the corresponding letter on the scanner sheets.

PLEASE ENTER YOUR STUDENT ID ON THE SCANNER SHEET.

1. A seven-year-old patient presents to the emergency department with painless, black, tarry melena stools with streaks of bright red blood. He has been healthy in the past with no significant medical problems. Assessment of the patient demonstrates moderate hypovolemic shock. What is the most likely cause of GI bleeding in this patient?

    a. Esophageal varices
    b. Meckel's diverticulum
    c. Peptic ulcer disease
    d. Rectal polyp
    e. A-V malformation

2. A four-year-old boy had surgery to remove a ruptured appendix 12 hours ago. You have been asked to assess the patient for on the ward for tachycardia. On arrival, you note that the child's vitals are as follows: HR 150, RR 24, BP 90/45, O2 sat 90% on R/A, T 39. The child is arousable but lethargic, pulses are full and extremities are warm. The rest of the examination is non-contributory; an IV is in place. After administration of oxygen via face mask, the O2 sat increases to 99%. What is your NEXT course of action?

a. Cross- match and transfuse 10cc/kg of packed red blood cells
b. Immediate transfer to ICU
c. Perform CBC and blood cultures; withhold antibiotics unless a positive blood culture is obtained
d. Administer 20 cc/kg IV crystalloid bolus; draw blood work; give broad- spectrum IV antibiotics
e. Administer 40cc/kg normal saline bolus; reassess fluid status

3. What is the estimated circulating blood volume of a 10-kg child?

a. 1600 cc
b. 800 cc
c. 1200 cc
d. 600 cc
e. 1400 cc

4. What is the first physical sign of dehydration to manifest in a pediatric patient?

a. Delayed capillary refill
b. Decreased diastolic pressure
c. Tachycardia
d. Cool extremities
e. Decreased urine output

5. What is the most common type of shock seen in the pediatric population?

a. Hypovolemic
b. Septic/ Distributive
c. Cardiogenic
d. Obstructive
e. Dissociative

6. Which of the following definitions best explains the concept of shock?

a. Inadequate tissue perfusion
b. Decreased cardiac contractility
c. Insufficient systolic and/or diastolic pressure
d. Significant tachycardia
e. Insufficient preload available for perfusion

7. A seven-month-old infant is brought to the emergency room unconscious. The boy had three days of vomiting and profuse watery diarrhea before presenting. HR 220, BP 60/25, RR 60/min and shallow, O2sat 89% on room air. What is your FIRST STEP in management?

    a. Immediately establish 2 large bore IV's and fluid bolus 20 cc/kg Normal Saline
    b. Administer O2 by facial mask, IV fluid bolus, IV antibiotics
    c. O2 by bag-valve mask and prepare to intubate
    d. Take thorough history, complete physical examination, and send off blood work
    e. Immediately establish 2 large bore IV's and fluid bolus 40 cc/kg Normal Saline

8. An 8-year-old patient on the ward is being treated for hypotension (BP 70/25). After 40 cc/kg of normal saline, there is no appreciable rise in the blood pressure. What is your NEXT STEP in management?

    a. Administer subcutaneous epinephrine 0.1 ml of 1: 10,000
    b. Administer a further fluid bolus of 20 cc/kg Normal Saline
    c. Consult the ICU for colloid administration and/or inotropic support
    d. Administer 15 cc/kg cross- matched PRBC's, regardless of the hemoglobin
    e. Perform blood work (CBC, blood cultures) and start on IV antibiotics; reassess in 1 hour

9. What is the most common pathogen causing diarrhea in childhood?
    a. Salmonella
    b. Campylobacter
    c. E coli
    d. Adenovirus
    e. Rotavirus

10. Which of the following characteristics about osmotic diarrhea is TRUE?

    a. It is a rare type of diarrhea
    b. Salmonella, Campylobacter and Rotavirus all cause this type of diarrhea
    c. It is diagnosed by a 72 hour fecal fat collection
    d. It persists while fasting
    e. It is characterised by a high stool Na and small osmolar gap

11. Which of the following statements about shock in a pediatric patient is TRUE?

    a. Decreased level of consciousness is a common sequelae of mild shock
    b. The presence of warm extremities and full peripheral pulses in a patient help exclude the possibility of shock
    c. The development of shock is an uncommon event in a tertiary care hospital
    d. Hypotension occurs late in shock and heralds the onset of decompensation
    e. Tachycardia occurs only when the child has progressed to moderate shock

12. You have been asked to assess the degree of dehydration for a 10-month-old boy. He is drowsy and irritable, with dry mucous membranes and a slightly sunken fontanelle. His HR is 160, RR 40 and BP is 80/60. Urine output is 0.4 cc/kg/hour. What is his estimated deficit of total body water?

    a. 6%
    b. 3%
    c. 9%
    d. 10%
    e. 15%

13. A 2-year-old girl is seen in the emergency department with vomiting and diarrhea. Which of the following historical points most strongly suggests the need for IV rehydration rather than oral?

    a. Lethargy and confusion
    b. Vomiting 8 times over the last 24 hours
    c. Fever up to 39 degrees C
    d. Bloody diarrhea
    e. History of febrile seizures with previous gastrointestinal illnesses

14. A twelve-year-old girl is suffering from heat exhaustion and moderate dehydration. On exam, she is irritable with vitals of T39 HR 130, RR 30, and BP 100/60. What is your FIRST STEP in management?
    a. Fluid bolus 20 cc/kg 0.9% Normal Saline
    b. Fluid bolus 10 cc/kg 0.9% Normal Saline
    c. D5/ .45 at twice maintenance until deficit is replaced, adding potassium once voiding
    d. 10 cc/kg of 5% albumin
    e. Oral rehydration therapy 10 cc q 15 min

15. How long should it take to replace the fluid deficit in moderate to severe isotonic dehydration?

    a. 12 hours or less
    b. 12- 18 hours
    c. 24-36 hours
    d. 36- 48 hours
    e. Over 48 hours

16. You are admitting a 32-kg child pre-operatively and must write orders for maintenance fluids. What is the most appropriate fluid order?

    a. 0.9% NS with 20 mEq KCl/L at 64 cc/hr
    b. D5/.2 with 20 mEq KCl/L at 64 cc/hr
    c. 0.9% NS with 20 mEq KCl/L at 72 cc/hr
    d. D5/.2 with 20 mEq KCl/L at 72 cc/hr
    e. D5 with 20 mEq KCl/L at 62 cc/hr

17. A two-year-old boy is recovering from an acute diarrheal illness and is now complaining of hunger. What is the most appropriate response to the father's question regarding starting feeds?

    a. Start with fluids and gradually progress to a full diet
    b. Start with fluids and add a bland diet of rice, apples, toast and bananas for approximately 1 week
    c. Start with fluids and progress diet accordingly, however avoid dairy products for 2- 3 months
    d. Keep on minimal oral feeds until bowel movements are formed and back to normal frequency
    e. Start on a gluten-free diet until villous atrophy recovers

18. A seven-year-old girl is seen in the emergency department with three episodes of hematemesis over the past five hours. Her mother describes her as suffering from vague abdominal pain, followed by hematemesis with clots. She has had no stools yet. On initial examination, the patient is alert but pale, with a heart rate of 140 beats/min, RR 20, BP 90/50 O2sat 98% on room air. Pulses are full and she is well perfused; she is in no acute distress. What is your INITIAL STEP in management?

    a. Blood work including CBC, PTT, INR, Liver enzymes and cross match for 2 units of packed red blood cells

b. Obtain IV, STAT cross match, and transfuse with 15cc/kg of packed red blood cells
c. Administer oxygen, prepare to intubate to protect the airway
d. Obtain two IVs, fluid bolus with 20cc/kg 0.9% NS, then reassess
e. Start IV omeprazole and consult GI to guide management

19. You are asked to assess a 3-year-old child who presents to the emergency room unconscious. The child demonstrates a GCS of 5 and vital signs are as follows: HR 160, RR 46, T 35.9, and BP 60/30. Capillary refill time is delayed with cool extremities and pulses are weak. The child had been healthy until yesterday when she developed nausea, vomiting, fever and a rash. What is the most probable type of shock demonstrated by this patient?

a. Septic shock
b. Hypovolemic shock
c. Obstructive shock
d. Cardiogenic shock
e. Dissociative shock

20. Which of the following statements regarding pediatric dehydration is TRUE?

a. Initial electrolytes should be obtained before administering any IV fluids to a moderately dehydrated child
b. Acute vomiting and diarrhea most commonly leads to hypernatremic dehydration
c. Oral rehydration is often adequate for diarrheal illnesses in pediatric patients
d. All types of dehydration, (isonatremic, hyponatremic, and hypernatremic) may be fully corrected over 24-36 hours
e. Electrolyte monitoring is not required if no abnormalities were present on admission to hospital

APPENDIX F: Examination Key

Key: K= Knowledge, P = Problem-Solving

QUESTION #	ANSWER	TYPE	OBJECTIVE
1	B	K	B1
2	D	P	B6
3	B	K	B3
4	C	K	A2
5	A	K	B5
6	A	K	B3
7	C	P	B6
8	C	P	B7
9	E	K	A1
10	B	K	A1
11	D	K	B2
12	D	K	A3
13	A	P	A5
14	A	P	A6
15	E	P	A7
16	D	P	A4
17	A	K	A8
18	D	P	B6
19	A	P	B4
20	C	P	A7

Procedural Questions: 2,7,8,13,14,15,16,18,19,20
Knowledge Questions: 1,3,4,5,6,9,10,11,12,17

APPENDIX G: Evaluation Tool for Long Term Knowledge Retention

SIX QUESTIONS RELATED TO SHOCK AND DEHYDRATION EXTRACTED FROM FINAL PEDIATRIC CLERKSHIP EXAMINATION

FOR ALL QUESTIONS, MARK ONE OR MORE CORRECT ANSWERS

USE THE FOLLOWING TO ANSWER QUESTIONS 39&40

A five-year-old boy is brought to the emergency department with second and third degree burns affecting the trunk and legs. The ambulance paramedical crew had initiated an infusion of normal saline at a rate of 20 ml/kg/hour intravenously in the left arm

39. Following arrival at the emergency department, which of the following should be of IMMEDIATE concern?

    a. evaluation and maintenance of the airway
    b. evaluation of cardiac status for signs of hypovolemia/shock
    c. maintenance of the intravenous line
    d. rectal acetaminophen
    e. evaluation of fluid requirements

    MPL: 0.87
    Choice weights: a= 0.25, b= 0.25, c= 0.25, d= -0.13, e= 0.25

40. Subsequent important measures include which of the following?

    a. bladder catheterization
    b. insertion of nasogastric tube
    c. search for other unrecognized injuries
    d. oral administration of acetaminophen every 8 hours
    e. calculation of fluid requirements for the first 48 hours

    MPL: 0.72
    Choice weights: a= 0.29, b= 0.14, c= 0.29, d= -0.14, e= 0.28

45. A 7-year-old boy presents to the emergency department with hives (urticaria), difficulty swallowing, difficulty breathing, a change of voice, and dizziness. Life-saving measures the management of this child include which of the following?

    a. airway management

b. cardiovascular support
c. inhaled ipratropium bromide (Atrovent)
d. intravenous aminophylline
e. intramuscular epinephrine

MPL:0.67
Choice weights: a= 0.33, b= 0.33, c= - 0.16, d= -0.17, e= 0.34

52. A 15-month-old child has had diarrhea for three days. An 8% weight loss has occurred since a community health check visit six days ago. The serum sodium level is 155 mmol/L. You decide to use oral rehydration therapy for the management of this patient. Which of the following are correct statements related to the use of oral rehydration therapy in this patient?

a. An appropriate rehydration solution is one containing 5% glucose
b. An appropriate rehydration solution is one with a sodium concentration of 45 mmol/L
c. Oral rehydration therapy can be used if you find absence of bowel sounds
d. Oral rehydration therapy can decrease complications associated with intravenous therapy
e. This child should be hospitalized to enable close monitoring and ensure rehydration is proceeding at a reasonable rate.

MPL: 0.60
Choice weights: a= -0.20, b= 0.20, c= -0.40, d= 0.40, e= 0.40

53. A nine-month-old infant presents with a three day history of vomiting and diarrhea. What physical signs would suggest this infant has volume depletion?

a. heart rate of 180/min
b. mottled skin
c. decreased skin turgor
d. irritability
e. bulging anterior fontanelle
f. cool skin

MPL: 0.75
Choice weights: a = 0.25, b= 0.13, c= 0.25, d= 0.12, e= -0.25, f= 0.25

54. Which of the following are correct statements related to home management of gastroenteritis in infants?

a. cranberry juice reduces diarrhea
b. careful handwashing is important to prevent spread of gastroenteritis from person to person
c. breast-feeding mothers should continue to breast-feed when their infants have gastroenteritis
d. loperamide is of proven benefit in gastroenteritis
e. antibiotics should be prescribed early in the management of infants with gastroenteritis

MPL: 0.75
Choice weights: a= -0.50, b= 0.50, c= 0.50, d= -0.25, e= -0.50

APPENDIX H: Questionnaire

UNIVERSITY OF
CALGARY

The objective of this short 3-minute questionnaire is to assess the degree of satisfaction with the teaching received on the subjects of pediatric dehydration and shock. Please rate your responses on a scale of 1 to 5, 1 representing STRONGLY DISAGREE, to 5 representing STRONGLY AGREE.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Age_____ Gender____ ID #_______________

1. This teaching session was worth the time invested _____

2. This teaching session contributed to my knowledge on pediatric dehydration and shock _____

3. This teaching session was interesting and held my attention _____

4. The session was interactive and allowed me to participate _____

5. I have a greater understanding of the topic due to this session _____

6. I would like to participate in a teaching session like this again _____

7. This style of teaching is practical and will help me manage patients on the ward _____

8. I feel more confident in managing shock and dehydration in a pediatric patient due to this session _____

APPENDIX I: Interview Questions

Student or Facilitator
Traditional or Simulator-based

Date:

How do you feel the session went?

What are the main advantages to this type of teaching?

What are the main disadvantages to this type of teaching?

How was the interaction level with this style of teaching?

For what aspects of teaching do you feel this style is most effective? (i.e. Knowledge, skills, attitudes)

Would you want to use this teaching style again?
Why or why not?

(Teachers only)- Once both groups are completed
Please comment on the simulator-based small group teaching session versus the traditional small group teaching session with respect to efficacy, advantages, drawbacks, and student interaction

APPENDIX J: Group Dynamics Observation Form

Observed Behaviour	Count
1. Number of student- initiated questions to facilitator	
2. Number of student- initiated questions to other students	
3. Number of facilitator lectures over 60 seconds in length	
4. Number of facilitator- initiated questions to students	
5. Number of constructive comments by facilitator regarding management decisions	
6. Number of constructive comments by students regarding management decisions	
7. Number of conversations between students for over 60 seconds with no facilitator comments	

APPENDIX K: Consent Form

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CONSENT FORM
University of Calgary

Research Project Title: A comparison of high-fidelity patient simulator based teaching versus traditional small group teaching in the knowledge gains of third year undergraduate medical students learning the principles and management of pediatric dehydration and shock

Investigators: Dr. Penny Jennett
Dr. Leanna McKenzie
Dr. J.G. Descoteaux
Dr. Brent Scott

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Purpose of the Research
The purpose of this research study is to assess the impact on knowledge gain when patient simulators are incorporated into small group teaching sessions. Patient simulators are computerized mannequins that are capable of demonstrating interactive physical signs and physiologic reactions to interventions.

Experimental Procedures
Subjects in this study will either attend a traditional small group teaching session or a small group session incorporating a pediatric patient simulator. This 2.5- hour teaching session focuses on the principles and management of pediatric dehydration and shock.

Research Design
Participants are third year medical students at the University of Calgary who have enrolled for the study on a volunteer basis. The subjects participate in one of two types of teaching sessions.

Discomforts and Inconveniences
There should be no discomfort associated with the study. Students are asked to volunteer for one 2.5 hour teaching session on a Wednesday afternoon of their pediatric rotation. Subjects will be asked to travel to the Health Sciences Center or the STARS center (Aviation Boulevard, NE, Calgary).

Description of Participation
Students will be notified in advance on the time and place of the teaching session. On arrival, the subjects will undergo a short written examination testing concepts regarding pediatric dehydration and shock. This is followed by a 1.25 hour teaching session on the principles and management of pediatric dehydration and shock. Depending on the group, the teaching will either be performed in small group format or using a patient simulator in small groups. The session will be videotaped in order to assess group dynamics.

At the end of the session, subjects will be asked to partake in a post-test written examination. In addition, subjects will be asked to participate in a short survey measuring attitudes surrounding the teaching session. A subset of students will also undergo a short interview regarding their reactions to the teaching session. Finally, a subset of marks from the exit clerkship examination of those participating in the study will be analysed to assess long-term knowledge retention. Student's ID number will be required only to link marks from the clerkship examination to teaching intervention group, and will not be used to identify students. All examination marks and comments from the study will in no way impact on student evaluation and will be kept strictly confidential.

Direct and Indirect Benefits to Subjects
Subjects participating in the study will have an opportunity to be involved in a new and novel approach to learning. It is expected that both types of teaching sessions will allow learning and consolidation of principles surrounding a very common yet extremely important aspect of pediatric care.

Alternatives to Enrolment
Students not participating in the study may choose to remain a participant in the teaching session without undergoing the pre- and post-test evaluation and attitudinal survey. The student must understand that the session will still be video taped, however this will not impact on student evaluation in any way. Alternately, they may choose to not participate in the teaching session altogether and instead receive informal teaching on the ward for the three hours. However, this study provides a unique opportunity to participate in simulator-based teaching, which is currently not offered in the undergraduate medical curriculum.

Access to Information
All information obtained from the study, including the survey, pre-test, post-test, interviews, videotapes and exit clerkship examination marks will be held strictly confidential and be used only for research purposes. The marks will not in any way affect the evaluation of students' clerkship performance.

Study Information Updates
All subjects involved in the study will have access to updated and completed research results through communication with Dr. McKenzie

Financial Costs to the Subjects
No financial costs to the subjects are expected. Transportation to and from the simulator will be arranged beforehand with other students.

In the event that you suffer injury as a result in participating in this research, no compensation will be provided for you by the University of Calgary, the Calgary Health Region, or the Researchers. You still have all of your legal rights. Nothing said here about treatment or compensation in any way alters your right to recover damages.
Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the investigators or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time without jeopardising your health care. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact:

Dr. Leanna McKenzie
943-7211 pager 1319

If you have any questions concerning your rights as a possible participant in this research, please contact Pat Evans, Associate Director, Internal Awards, Research Services, University of Calgary, at 220-3782.

____

Participant's Signature **Date**

____

Investigator and/or Delegate's Signature **Date**

____

Witness' Signature **Date**

A copy of this consent form has been given to you to keep for your records and reference.