DEFINING PRINCIPLES OF EXPERT PERFORMANCE DURING MEDICAL PROCEDURES: OPTIMIZING ASSESSMENT CRITERIA OF PROCEDURAL SKILLS

DEFINING PRINCIPLES OF EXPERT PERFORMANCE DURING MEDICAL PROCEDURES: OPTIMIZING ASSESSMENT CRITERIA OF PROCEDURAL SKILLS

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LAY ABSTRACT

An important aspect of being a pediatrician includes performing procedures. Currently, when medical learners are training to become pediatricians, procedural skills training and assessment mainly focus on the technical aspect of the procedure (e.g., psychomotor skills), which could mean that medical programs are missing key skills that are important to perform a procedure safely and effectively- at the expert level. In this thesis, we investigate the skills needed to become an expert in performing pediatric procedures through interviewing expert pediatricians and discussing the skills that they believe are crucial when performing procedures. Overall, we found that the skills needed for procedural expertise go beyond technical skills and encompasses non-technical skillsets such as decision-making, communication, and situational awareness. The findings of this study can be used to improve assessment criteria to ensure that assessment of learners include all of the skills important to perform a procedure.

ABSTRACT

Introduction: For pediatric residency programs, the Royal College of Physicians and Surgeons of Canada has outlined certain Entrustable Professional Activities that center around procedural skills that residents are assessed on for competency. Currently, procedural skill training and assessment focuses on the technical aspects of procedural performance such as psychomotor skills and knowledge, hindering our understanding of procedural expertise. Madani et al., (2017), have developed a universal framework that describes the core skill domains important for expert performance in the operating room; however, the framework may not be transferable to pediatrics and procedures performed outside of the operating room. This thesis aims to understand the core principles that guide expert performance during medical procedures.

Methods: In this study, we took a qualitative description approach and used Braun and Clarke's reflexive thematic analysis. We conducted semi-structured interviews with faculty from procedure-heavy specialties across Canada, and inquired about general steps in procedures, skills needed for procedural expertise, and procedural training programs.

Results: There were 18 participants in this study from six institutions across Canada. We identified five themes from our data: (1) Procedural Expertise Requires Skills that Go Beyond Psychomotor Skills, and Relies Heavily on Non-Technical Skills, (2) The Generalization of Procedural Expertise is Dependent on the Skills, Specialty, and Contextual and Patient Factors, (3) Approaching Expected/Unexpected Events in

Procedures and Deciding on Adaptations is a Crucial Part of Expertise, (4) Pediatric Training Programs Use a Variety of Approaches in Procedural Training, and (5) Decrease in Procedural Opportunities for Experts Lead to Skill Decay.

Conclusions: In conclusion, the findings of this thesis suggest that the core principles of procedural expertise are similar to the core principles of expert surgeons apart from communication with caregivers. The findings of this thesis can be used in developing holistic assessment plans for procedural performance and modifying Madani et al.'s framework for expertise in pediatric procedures.

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LIST OF ABBREVIATIONS AND SYMBOLS

BMV: Bag-Mask Ventilation

CBD: Competency By Design

CBME: Competency-Based Medical Education

CLV: Central-Line Placement

CPR: Cardiopulmonary Resuscitation

CVC: Central Venous Catheter

DOPS: Direct Observation of Procedural Skills

EPA: Entrustable Professional Activity

IO Insertion: Intraosseous Insertion

ITER: In-Training Evaluation Report

MIST: Minimally Invasive Surfactant Therapy

NICU: Neonatal Intensive Care Unit

NOTSS: Non-Technical Skills for Surgeons

OSCE: Objective Structured Clinical Examination

OR: Operating Room

OSANTS: Objective Structured Assessment of Non-Technical Skills

OSATS: Objective Structured Assessment of Technical Skills

RCPSC: Royal College of Physicians and Surgeons of Canada

WBA: Workplace Based Assessment

DECLARATION OF ACADEMIC ACHIEVEMENT

Jasmin Dhanoa primarily performed the work described in this thesis and was supervised by Dr. Elif Bilgic. Participant recruitment was done with assistance from Dr. Quang Ngo and Dr. Elif Bilgic from the Department of Pediatrics at McMaster University. Study preparation, data collection, analysis, and dissemination were completed with the support of Dr. Anita Acai and Dr. Quang Ngo.

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CHAPTER 1: INTRODUCTION

1.1 Procedural Skills in Pediatrics

1.1.1 Overview of Procedures

Procedures are a crucial part of patient care in pediatrics, yet it can be difficult for residents to gain competence in procedural skills due to patient safety concerns and limitations in clinical exposure. Clinical practice involving pediatrics procedures is continually evolving due to changes in pediatric illnesses, treatments, technology, and differences in procedural settings (e.g., emergency department versus endoscopy unit), amongst others.[1] Thus, it is becoming increasingly important for pediatric physicians to be competent in procedural skills to effectively practice medicine and meet the needs of the patients and their families. Procedures can be conducted in the operating room (OR), which is a controlled environment that is only accessible to certain individuals that are needed for the procedure, or outside of the OR (e.g., in the emergency department).[2] In pediatric medicine, most procedures are performed outside of the OR, where physicians are expected to perform procedures in smaller spaces, which can lead to overcrowding, or in spaces with fewer environmental controls (e.g., sterility, lighting, temperature of the room, individuals in the procedural space).[3] Therefore, outside of the skills needed to perform the procedures themselves, there are additional complexities depending on the procedural setting and context, which require additional skills to manage a procedure.

1.1.2 Procedural Skills Needs Assessments in Pediatrics

In simple terms, procedural skills can be defined as “the mental and motor activities required to execute a manual task. Procedural skill competence requires both safe technical performance and appropriate knowledge for decision-making in the preparation, performance and post-performance phases of the procedure."[4(p49)] Currently, the Royal College of Physicians and Surgeons of Canada (RCPSC) has outlined 26 procedural skills in the objectives for training for pediatrics which were determined through expert consensus.[5] Procedural skills in pediatrics can range from acute (e.g., wound care) to critical (e.g., emergent tracheal intubation), and residents must demonstrate competence in all skills.[5] Although procedures are an important part of pediatric medicine, gaining procedural skills has been difficult for trainees across pediatrics training programs, with one reason including less frequent procedural encounters in the clinical setting due to advancements in medicine and better preventative care.[1,6,7] With this lack of procedural encounters, trainees have fewer opportunities to develop their procedural skills and competence, and both trainees and practicing physicians can struggle with skill degradation, potentially leading to lower comfort levels when performing procedures.[6]

There have been various needs assessments done to explore the competency and comfort of trainees and pediatricians regarding procedures. For example, in a study conducted by White et al. (2021), researchers explored the need for procedural skills in general pediatrics during independent practice. The researchers found that there were procedures that were performed frequently (e.g., bag-valve-mask ventilation [BMV] of an neonate, lumbar puncture, and ear curettage), procedures that were performed rarely (e.g., chest compressions, BMV of a child, and intraosseous line insertion), and procedures that pediatricians had not performed in their career (e.g., peripherally inserted central catheter, central venous line insertion, and peripheral arterial line insertion).[1] Additionally, pediatricians stated that life-saving procedures such as defibrillation/cardioversion, laryngeal mask airway, and intraosseous insertion (IO) were crucial to practice but infrequently performed.[1] Lastly, pediatricians found it most difficult to maintain skills in intubation of a child, chest tube insertion, and arterial line insertion.[1]

Furthermore, in a study conducted by Cormier et al. (2019), researchers explored self-reported procedure experiences in the neonatal intensive care unit (NICU). Residents self-reported competence only in performing lumbar punctures.[8] In addition, only 17% of the residents in this study developed competence in resuscitation skills (e.g., BMV, intubation of an infant less than 28 weeks in NICU).[8] Cormier et al. (2019) found that there was generally a positive correlation between the number of rotations a resident completed and the development of resuscitation skills. Overall, pediatric residents are expected to be competent in NICU resuscitation skills; however, this study found that most residents do not feel competent in these skills.[8] Cormier et al. (2019) have suggested multiple reasons for why NICU resuscitation skills are lacking amongst residents. For example, currently, the RCPSC deems that three rotations are the minimum requirement for neonatal care; however, residents might need more training.[8] Additionally, there is the possibility that there are not enough opportunities for residents to view or perform resuscitation.[8]

Similarly, in a study conducted by Levy et al. (2014), researchers explored resident ratings of the significance of pediatric procedural skills outlined by the RCPSC and resident's ratings of their competence in these procedures; the difference of these ratings were stated as gap scores. Overall, residents perceived that they are competent in three procedural skills (i.e., BMV, lumbar puncture, and chest x-ray interpretation), while for 23, residents perceived themselves as being unprepared or only somewhat prepared to perform.[9] Additionally, there was a high correlation between perceived importance of a procedure and self-reported competence.[9] However, there were four skills with a large gap between mean importance and competence, which signals to these skills being highly important but residents having lower competence. These skills were evidence/documentation for child maltreatment (gap score = 1.67), IO insertion (gap score = 1.56), chest-tube insertion (gap score = 1.51), and defibrillation (gap score = 1.47).[9] In addition, the perceived importance of and competency in procedures were highly correlated when there was a curriculum in place to teach the specific procedural skills.[9] Also, the importance and competency of procedures was highly correlated when there was a requirement to provide evidence of learnt skills.[9] Overall, the researchers suggested that clinical practice may not provide enough exposure for trainees to develop competence, and formal procedural curricula could support residency education for procedures as well as opportunities for deliberate practice.[9]

To add on, Bismilla et al. explored the perceived importance of procedures and preparedness of residents performing procedures. On average, 12 skills were perceived to be very important (e.g., BMV, cardiopulmonary resuscitation (CPR), IO insertion, lumbar puncture), 17 skills were perceived as important (e.g., bladder catheterization, ear curettage, suturing), and three skills perceived as having little to no importance (e.g., indwelling catheter management, suprapubic aspiration, central venous line [CVL] placement).[10] Furthermore, residents felt increased preparedness to perform procedures that were a part of the final in-training evaluation report (ITER) compared to procedures that were not included in this assessment.[10] Overall, 10 procedures that were rated as having high importance also had similarly high rates of preparedness, with four of these procedures being on the ITER.[10] Lastly, there was a higher likelihood of a formal curriculum being in place for the procedures that were perceived to be very important and residents were more likely to perceive greater preparedness in the procedures with curricula.[10] A requirement of evidence of the learned skills was also highly correlated with the rated importance of procedures and somewhat correlated with the rated preparedness of residents.[10]

Moreover, training can impact a physician's comfort level and confidence in performing procedures later on in clinical practice. For example, many studies have indicated that pediatricians often do not feel comfortable performing life-saving procedures (e.g., defibrillation, chest tube placement) due to limited exposure in training and during practice but are still competent in these procedures.[11,12] On the other hand, physicians have been shown to feel comfortable handling less emergent cases (e.g., fracture care) as physician's may have more exposure to these types of procedures.[11,12] To add on, procedures can also be difficult to perform in non-OR pediatric settings due to the aforementioned environmental factors as well as the presence of caregivers (e.g., family members). Caregiver presence can often be an important aspect of care and allows the patient to feel calm and caregivers secure. However, when caregivers are present during a procedure, it can be difficult for physicians to train residents on procedural skills,[13] and it can be anxiety-provoking for residents.[14] Some concerns cited from residents include feeling increased pressure when attempting to perform a procedure after a failed attempt,[14] increased procedural failures due to family presence and resident anxiety,[13] family perception of resident's knowledge and experience, concerns about legality,[13,14] and the supervisor being more likely to take over the procedure.[14] In addition, due to family member presence during the procedure, additional staff may be required to support the family,[13] such as Child Life Specialists. Therefore, in pediatrics, where procedures are done outside of the OR, there are additional factors that impact opportunities for procedural skill gain. With all these factors in mind, it is important to acknowledge that pediatricians are responsible for being competent in a diverse set of procedural skills that focus on both technical and non-technical skills. With respect to procedures performed outside the OR, there are many environmental factors that can impact the procedure, and in pediatrics, there may be additional considerations needed (e.g., patient and family related considerations). Regardless of the frequency of procedures, procedural skills are an important aspect of patient care in pediatrics, and it is still crucial for trainees to be competent in procedures and skills required.

1.2 Overview of Assessment in Medical Education

Assessment allows observers (e.g., faculty members) to use judgements to make decisions about learners' skill level for specific clinical tasks and progress within a medical program.[15] The goals of assessment in medical education can be broadly placed into three categories.[16] The first goal of assessment is to promote learning among trainees and physicians to maximize skill gain.[16] The second goal of assessment aims to ensure that all residents and practicing physicians are upholding professional standards; this goal also focuses on public protection from doctors who might not have achieved competence in certain skills.[16] The last goal of assessment is to be able to use assessment as a way to stratify applicants for selection (e.g., during residency or fellowship applications) .[16]

Moreover, in medical education, there are three key considerations that must be considered when making assessment judgements.[17] The first consideration is the construct that is being assessed.[17] In Competence by Design (CBD), these constructs can be illustrated by the various competencies (e.g., procedural skills, communication, etc.) that residents are expected to develop throughout training.[17] The second key consideration of assessment is the use of assessment data and assessment judgements.[17] Assessment data is gathered through various, exams throughout a learner's training (e.g., written test scores, observed assessments) and these pieces of data inform assessment decisions (e.g., passing or failing, developing competence).[17] The last consideration of assessment is the outcome after a judgement is made. Outcomes of the judgment vary depending on the assessment.[17] For example, based on the assessment data of a resident, if they have achieved competence in certain clinical activities in a specific stage of training, a decision would be made to promote them to the next stage of training. If a resident was not able to achieve competence, then they might be required to go through a remediation process before promotion. Additionally, within medical education, there are many types of assessments that a resident expected to receive to advance in their training and ultimately finish their residency training. Some types of assessments include written examinations (e.g., the Royal College written exams), observed assessments from supervising faculty through direct observation in the clinical and simulation settings, and multisource assessments (e.g., observed assessments from patients or non-physician healthcare providers).[16] Written examinations are usually presented in an open-ended or multiple-choice format,[16] used to assess the knowledge of a trainee and lead to a pass/fail decision. In addition, assessments from supervising faculty could occur at the end of a rotation where the faculty member provides an overall assessment of the resident's performance in patient care throughout the rotation.[16] Similarly, faculty (or senior trainees) could perform frequent direct observations in the clinical and/or simulations settings in order to assess trainee progress in a specific clinical activity.[16] Lastly, multisource assessments are completed by various individuals outside of the supervisor who observed the resident's performance during a clinical activity, and whose feedback regarding the trainee's performance would be valuable as a part of their competence gain and performance on the clinical activity.[16]

Procedural skills assessment has been widely focused on the technical aspects of a procedure, but it is important to consider the nontechnical skills that are also crucial in performing these procedures.[18] There are many moving parts to a procedure that occur in the preparation (e.g., communicating with patient and caregivers, obtaining consent, preparing equipment), performance (e.g., communicating with members of the care team, using clinical reasoning, using critical thinking), and post-performance (e.g., debriefing with patient and team) phases of the procedure.[18] Although all of the assessments mentioned above are used for procedural skills assessment, direct observation is a key method for performance-based assessment.[19] Performing assessments through direct observation allows the supervisor to directly observe the learner, providing a comprehensive view of the learner's skills and highlighting strengths and weaknesses.[18]

1.2.1 Summative and Formative Assessments

There are two categories of assessments that are commonly used in medical education: assessment of learning and assessment for learning. Assessment of learning is usually associated with summative assessments where residents are assessed on knowledge and skills acquired at a specific point in time, which then may have high-stakes decisions around promotion and readiness to graduate.[17,20,21] Assessment of learning can be beneficial in early medical training when learners are being assessed on core knowledge.[15] Summative assessments also promote self-regulation and accountability in learners but can deter them from pursuing more practice and training[16] due to a greater focus on passing summative assessments instead of gaining skills to develop competence.[22]

On the other hand, assessment for learning is usually associated with formative assessments, which are regular and low-stakes assessments of residents.[17,20,21] Assessment for learning was developed based on Miller's Pyramid, a framework used to assess clinical competencies. Miller's Pyramid is divided into four stages that all connect to one another to help drive learning and inform assessment.[20,23] The bottom of the pyramid starts with the 'knows' stage, which focuses on the declarative knowledge of a trainee and is assessed by factual recall through traditional tests (e.g. multiple choice tests, short answer tests, etc.).[20,23] The next level is the 'knows how' stage, which emphasizes the interpretation and application of knowledge and is assessed through essays, case studies, and problem-solving assessments.[20,23] The third stage is the 'shows how' level where trainees are to apply their knowledge into practice which can be assessed in the simulation setting through the Objective Structured Clinical Examination (OSCE).[20,23] The apex of the pyramid is the 'does' stage where trainees perform in the clinical setting under direct observation and assessment usually occurs in the workplace.[15,20,23]

A key component of formative assessment is providing learners regular feedback to support learning, thus requiring additional resources such as faculty time to provide frequent feedback.[15] In the past, the focus of assessment was 'of learning.'[20] Now, the primary goal of assessment is to promote learning, which is why assessment for learning is emphasized further through frequent observations and assessments with a considerable focus on feedback.[20] Additionally, assessment for learning connects with overarching values in medical education such as learner-centeredness.[20]

However, it is important to note that currently, low-stakes, formative assessments are often summarized and reviewed to make high-stakes, summative decisions as a part of competence committees.[17] Therefore, some educators believe that although the goal of frequent assessments are for learning, these are combined to make decisions of learning, which blurs the purpose of the assessment for both residents and faculty, potentially having an impact on how the assessments are perceived and used for learning. As Van der Vleuten says: "Whenever assessment becomes a goal in itself, it is trivialized and will ultimately be abandoned. Assessment has utility insofar as it succeeds in driving learning, is integrated in a routine and ultimately comes to be regarded as indispensable to the learning practice."[20(p609)] Therefore, when using assessments for dual purposes, as is the case currently, it is always essential to remember the ultimate goal of assessment, which is for learning. Thus, programs need to ensure that there are structures in place to keep the focus on learning.[20]

1.2.2 Assessment Settings for Observed Assessments

Observed assessments are used to help close the knowing-doing gap, ensuring that residents possess the key skills of their specialty, by tracking progress, and informing program decisions about trainees' skills. Aligned with higher order components of assessment, which focus on doing as opposed to just knowing, observed assessments done in the workplace and simulation settings are examples of these higher-order assessments.[24] Since the focus of observed assessments in the simulation and clinical settings are mostly for formative purposes, we will focus on the formative piece in this thesis, acknowledging that in each setting, summative assessments are also performed.

1.2.3 Workplace-Based Assessments

Currently, workplace-based assessments (WBAs) are the most common type of assessment done in the settings of patient care.[25] Unlike other assessment settings such as simulation, a clinical setting demands more from a resident as patient management is much more complex, requiring the incorporation of multiple skills and knowledge.[25,26] For example, when learning to perform a procedure such as intubation in a simulation setting, the resident may only need to focus on the technical aspects of the procedure, but in the workplace, the resident may need to lead the room, communicate with the patient, and use technical skills to perform the procedure.[27,28] In medical education, WBAs are conducted frequently through direct observation by a faculty, senior learner, or other individuals such as patients and nurses to assess trainee progress, and areas of strength and weaknesses, allowing residents to determine skills to focus on for further progress.[28,29] Longitudinal assessment of a learner can also help better integrate feedback into future assessment as there is continuous observation of the resident over time.[29] Specifically, clinical activities can be used for longitudinal assessments as residents can progress through activities at differing rates to develop competence.[30] Assessments in the clinical setting can also offer the chance to assess skills that would be difficult to assess in other settings such as professional behavior, communication with healthcare team, and organization.[26]

WBAs also have some drawbacks such as established evidence for its usage for assessment of trainee performance. Assessor variables such as health profession, experience in the field, and psychological factors can all impact the assessment and associated feedback.[28] For example, as a part of multisource assessment, a nurse assessor may believe that a resident has achieved certain competencies, which may differ when compared to a faculty physician performing the assessment. However, these two assessors are likely assessing different aspects of performance, hence both of their perspectives would be of great value for a holistic understanding of resident's performance and competence. Experience in the field may also influence assessment as research has shown that generally senior healthcare providers can be stricter with assessments.[28] Lastly, the psychological factors such as cognitive load[28] and halo effects of raters can sometimes be attributed to a lack of training to assess residents and a lack of a framework to guide assessment.[31] Furthermore, when considering procedural skills, some procedures are rare and thus residents may not gain experience or competence that would be reflected in their WBAs. For example, bag-mask ventilation (BMV) and cardiopulmonary resuscitation (CPR) are considered to be very important procedures,[9,10] but these procedures may not be encountered in the clinical setting for residents to perform and develop. Therefore, when performing WBAs, there needs to be consideration of how WBAs are implemented, especially regarding factors that may contribute to the success or failure of implementation, which would then impact the educational and decision-making value of the WBAs.[28]

1.2.4 Simulation-Based Assessments

Simulation is a commonly-used system to allow residents to learn and be assessed on both technical and non-technical skills in a realistic, low-risk setting.[25] In the simulation setting, residents can acquire skills and show competence without putting patients at risk, which can be advantageous when trainees are learning procedural skills.[32] Simulation platforms can be used to assess trainees through direct observation both formatively and summatively, using the feedback from simulation learning to inform assessment of the resident's skills and clinical practices.[8] Since one of the focuses of medical education is related to providing trainees with optimized and enhanced opportunities for feedback through formative assessments, and since there are no concerns over patient safety in simulation, formative assessments tend to be an important component of simulation sessions. Specifically, through formative assessment, feedback is provided to learners by a more senior learner or faculty.[33] Although the assessment forms have space for written feedback, the act of assessment creates opportunities for verbal feedback as well. One effective way of providing feedback is through debriefing, which is done at the end of a simulation scenario and can follow a variety of strategies.[8] Simulation can also be used for summative assessments where trainees are assessed on competence.[33] Overall, the simulation setting can be used for both summative and formative assessments, for example by allowing[33] trainees to use the formative feedback they receive during procedural simulation training to help prepare for an OSCEs, which is a summative assessment.

A common way in which simulation is used for procedural skills training is by first having residents practice procedures in the simulation setting where there are no threats to patient safety before performing in the clinical setting.[25,34] As mentioned in prior sections, simulation allows for training and assessment of multiple procedural skills but it also allows for skill maintenance.[32,34,35] For example, certain procedures are uncommonly seen in the clinical setting; thus, trainees may not get the opportunity to learn these and receive assessments as a part of their training. Hence, simulation allows for competence development through deliberate practice and mastery learning, and assessment of what was learnt – simulation allows for trainees to build, improve, and maintain the skills acquired from these settings.[35,36] In addition, simulation can allow learners to get comfortable with working in interdisciplinary teams, and gain and show competence in skills such as communication and teamwork.[34,35] From an educator perspective, simulation is advantageous because it allows for objectives of simulation sessions to be planned beforehand so that trainees can focus on specific skills for training and assessment, whereas in the clinical setting, clinical activities can be unpredictable.[34] In the simulation setting, educators can also perform ongoing assessments and pause the simulation to provide feedback, allow trainees to ask questions, and then re-start the simulation session, allowing educators the opportunity to observe whether trainees were able to implement the feedback to improve performance.[34]

Research has shown that simulation settings are effective for learning procedural skills and conducting assessments. For example, in a study by Sawyer et al., researchers explored how neonatal resuscitation performance can be improved by using simulation. After assessing the pre- and post-performance of participants, it was found that there was generally a significant improvement in resuscitation skills.[37] Similarly, in another study by Velmahos et al., researchers found that trainees who practiced central venous catheterization (CVC) placement in a simulation setting outperformed those who learned by observing educators in the clinical setting.[33,38] Residents were also assessed on attempts on placing the CVC, locating anatomical benchmarks, and there was a multiple-choice test to assess knowledge gained; the simulation group outperformed the traditional learning group in all areas.[33,38] Assessment of procedural skills in the simulation setting is also useful because supervisors are not always available to observe trainees in the clinical setting due to the demands of the environment, and both the trainee and educator can focus on the individual steps of the procedure.[39] Although assessment in the simulation setting can provide many benefits to both trainees and educators, it is crucial to note that simulation is not a substitute for clinical practice as these settings provide their own advantages for trainees.[35]

When educators are incorporating simulation for training and assessment, there are some limiting factors to consider. Firstly, simulation is not always an adequate resemblance of human behavior and what is learned in the simulation setting cannot always translate to performance in the clinical setting.[32,34] Human behavior is very complex, and thus more can be learned outside of the simulation setting.[34] Next, the design of the simulation can also impact learning. If a simulation is not properly designed, there are defective pieces, or it does not mimic reality to a certain extent, then learning can be impacted as trainees may find shortcuts or gloss over important factors of patient care.[34] This can also extend to assessment in a simulation setting. If the assessment is not designed properly to consider factors of simulation, then it can be challenging to assess trainees. For example, if part of a clinical activity is to assess trainees' communication skills with the healthcare team, but the simulation does not account for team members being present, then this assessment might not work correctly. Furthermore, a trainee's mindset going into a simulation assessment may differ from a clinical based assessment because trainees may be already aware of the task at hand. For example, if trainees were aware that the simulation case is to assess communication skills, then there could be over-exertion of the skill that is being assessed. Lastly, feasibility issues can also arise in simulation such as high costs, time restraints, and resources available.[34]

1.3 Evolving Training Paradigm in Medical Education

1.3.1 Competence by Design (CBD): Competency-Based Medical Education in Canada

Medical education has been undergoing major changes. Traditionally, medical education focused on a time-based approach with the education philosophy of assessment of learning.[40,41] However, in 1960s to 1970s, there was a push to change the approach in which physicians were trained due to gaps in the curriculum, a diminishment in basic skills,[40] and a lack of skill in surgical management, medical management, and non-technical skills.[42] While the mentioned issues within medical education was prompting change, other stakeholders, such as patients and public health leaders, were also urging for evolution in medical education to help meet the societal needs of healthcare.[40] Today, Competency-Based Medical Education (CBME) is the international framework that is being implemented in medical education, and is described as "an outcomes-based approach to the design, implementation, assessment, and evaluation of a medical education program using an organizing framework of competencies".[43(p589)] With the CBME model, trainees are expected to meet certain competency criteria in order to progress through their training and be deemed competent in their specialty.[44]

Although CBME is the international framework in medical education, Competence by Design (CBD) is the Canadian form of the CBME model introduced in 2017 by the Royal College of Physicians and Surgeons of Canada (RCPSC).[45] CBD divides training of specialty programs into four stages; transition into the specialty, foundations of the specialty, core of the specialty, and transition into practice.[45] Within each stage, trainees are expected to achieve learning objectives that are highlighted by

Entrustable Professional Activities (EPAs), which are key tasks of a discipline and are centered around the CanMEDS 2015.[45] Ultimately, throughout each stage, trainee progress in EPAs and other program requirements are discussed in competence committees to determine progress and needs.[45]

1.3.2 Entrustable Professional Activities

The important components of CBD that connect the theoretical and practical aspects are Milestones and Entrustable Professional Activities (EPAs), which are used to help assess trainees and ensure progress and competence. Milestones are described as the expected skills of a resident at specific stages in the CBD framework, which are general across all specialties.[42] Each Milestone includes observable markers of a residents' skill along a developmental continuum, and are used for planning, teaching and assessment.[46] Hence, Milestones are also used by educators to determine if residents are progressing at the appropriate pace.[44] EPAs on the other hand can be defined as "key tasks of a discipline that an individual can be trusted to perform without direct supervision in a given health care context, once sufficient competence has been demonstrated".[46(p2)] In CBD, EPAs are the framework for assessment, and each EPA includes multiple milestones.[46] When performing EPAs, trainees must be observed by a senior physician (e.g., faculty, a trainee more senior than the trainee being observed) in order to receive mentoring, feedback, and assessment in the EPAs.[45]

The RCPSC has designed EPAs to be developmental so trainees will begin training with smaller responsibilities and then progress to larger responsibilities.[47] EPAs are also designed to allow both the resident and supervisor to have a thorough understanding of the competencies and expectations that a resident should achieve at specific stages of training.[47] The crucial aspect of EPAs is entrustment of decision-making, which signals to the trainee that they have the knowledge and skills to practice specific clinical activities unsupervised, which is the ultimate goal of CBD.[44] Once the trainee is successful in performing a specific EPA unsupervised, they have gained competence in that activity.[44] Entrustment also acknowledges that a trainee will not be able to learn all clinical tasks at once, but as competency is gained, trust and autonomy is given to the trainee to practice and make judgements of the situation at hand.[44] It is important to recognize that EPAs differ among specialties, and trainees are required to understand the skills that align with their specialty. For example, EPAs in General Surgery require residents to be competent in many more procedures compared to residents in Pediatrics or Emergency Medicine.

Focusing on pediatric procedural skills as a part of the core pediatrics residency program, the EPAs that are associated with these skills include Foundations EPA #7 Performing basic pediatric procedures (e.g. bag valve mask ventilation; cardiopulmonary resuscitation, lumbar punctures), Core EPA #1 Resuscitating and stabilizing neonates following delivery (e.g. neonatal resuscitations), Core EPA #9 Performing core pediatric procedures (e.g. chest tube; ear curettage, chest tube insertion, intubation), and Core EPA #14 Providing teaching and feedback (e.g. teaching procedural skills).[48] These EPAs focus on technical skills such as safety and procedural performance, but also non-technical skills such as communication, decision-making, management of complications, and self-awareness.[48] Therefore, as evident from the EPAs, procedural competence is an important part of the core pediatrics program, and most of the procedures are focused on further in pediatric sub-specialties,[12] including emergency medicine, critical care, neonatology, and gastroenterology.

1.3.3 Benefits and Limitations of CBD

The CBD model has shown many promises to improve medical training so physicians can be effective in clinical practice. One of the most important aspects of the competency framework is that it is an outcomes-based model that takes a learner-centered approach, where there is a greater focus on trainee skills and less importance on how long a trainee spends in their training.[49] Hence, with a focus on outcomes, programs can ensure that their learners have the necessary skills to prepare them for independent practice and address societal needs.[49] Additionally, an emphasis on trainee competencies and skill attainment allows trainees to be exposed to a variety of educational and clinical experiences that build upon each other to promote constant learning, and create a holistic physician.[42,49] Hence, the lessened importance of time-based outcomes and a learner-centered approach has cultivated a flexible training environment where each trainee can understand their own skill levels and areas of weakness (competence not achieved) to work towards strengthening and achieving competence.[49] With the traditional medical education framework, there was the issue of ‘failure to fail’ where generally, all trainees would be able to progress through training after a specified period due to the emphasis of the time-based model.[50] However, with CBD, trainees can only progress through training after competence is gained.[50] Additionally, the CBD model has created an overall positive learning environment where residents are given the opportunity to gain formal feedback from their educators, and CBD has cultivated a supportive environment where residents, supervisors, educators, and other stakeholders all work together to help learners gain competency for each EPA.[42] Although CBD has achieved some of the goals of the framework, there have been some disadvantages and criticisms. The literature suggests that one of the most prominent criticism of the competency framework is that the model takes a reductionist approach where assessments focus on very detailed measurable competencies that remove space for self-discovery and training beyond competency levels.[51] Although the purpose of CBD is to allow trainees to gain a variety of experiences in their training, many have argued that the assessments serve more as a checklist for trainees to complete.[42,44,49,51] There have also been arguments made that specific skills and behaviours (e.g. patient-physician relationships, situational awareness, metacognition) among physicians cannot be measured using the competency framework because human behavior is too complex to be assessed through discrete activities.[44] Another challenge with the competency-based framework is reported as the lack of psychometric evidence supporting the framework. In the CBD framework, one method of assessment is through direct observation of skills, including workplace-based assessments (WBAs); however, WBAs have low validity evidence within the context of medical training.[51] The reason for validity concerns with WBAs is because of the unpredictability of everyday practice, thus making it difficult to gauge whether the assessment truly represents patient care across different contexts.[52] Nonetheless, even with further research investigating CBD and psychometric measures, medicine is becoming more and more complex with interdisciplinary teams and technologically-advanced care to allow for the metrics to consider all factors at play.[51] Also, CBD has many challenges in implementation.[43,51] Firstly, faculty are often not trained to teach within the CBD model which causes a variety of difficulties in the assessment and feedback practices EPAs were created nationally with the hope of standardizing the clinical activities that are essential for each specialty, ensuring that residents gain competence in those pre-determined activities.[42] However, there seems to be a misalignment between the standard set of EPAs versus when residents get exposed to those EPAs and other activities not currently covered that could also be important for a specialty.[42,54] Other issues with the EPAs include receiving consistent and high quality feedback from supervisors, worries about supervisor-trainee relationship due to continuous requests of completing EPA assessments, and lack of transparency of the evidence needed to be deemed competent in an EPA.[3,11,12] Secondly, with the advancements in medical education, there are more stakeholders involved in the processes of implementing CBD (e.g., government stakeholders, program directors, leads in postgraduate medical education, educational assistants, faculty, trainees), causing greater problems in coordinating the needs of the public.[43] Also, with all the different stakeholders, there is the issue of inter-agency data sharing as there are not many systems put in place to share data between parties.[43] Furthermore, residents have criticized the CBD model for its false claims of focusing on competency of residents instead of time-based outcomes.[42] Theoretically, residents should be able to complete their training once competence in all EPAs have been achieve per stage of training, but logistically this cannot work.[42,49] CBD is still influenced by the time-based model where residents will generally progress forward within the estimated graduation date.[42] Some residents have expressed their lack of confidence in the CBD framework due to the excessive amount of administrative stress (i.e. paperwork), greater time commitment, negative impact on mental health, and challenges with technology associated with the EPA assessments.[3,11,12] Residents have also mentioned that light-procedural specialties, such as internal medicine, might not have needed CBD as the previous framework was very successful.[42] CBD is still evolving within Canada; thus, it is important to acknowledge that these frameworks still need to be adapted by educators and learners.

1.3.4 Pediatrics and CBD

Pediatrics covers a wide variety of specialties and patient population including children and youth, and pediatrics trainees are expected to be competent in various procedural and non-procedural skills.[55] CBD was introduced across the Canadian Pediatrics programs starting in July 2021 with the core pediatrics program, and some programs are still undergoing transition.[56] Similar to the other specialties, the core pediatrics residency training is divided into 4 stages, each including EPAs relevant to each stage. Specifically, there are 2 EPAs in Transition to discipline, 11 EPAs in Foundations, 14 EPAs in Core, and 5 EPAs in transition to practice.[57] These EPAs focus on a variety of competencies such as patient management, procedural skills, interpersonal skills, and communication, among others.[57]

1.4 Overview of Expertise in Procedural Skills

Within CBD, although the goal is for residents to reach a 'competent' level rather than an 'expert' level, once a learner becomes an independent physician, they are expected to perform at an expert level to enhance patient safety. Therefore, understanding expertise would allow for the optimization of training and assessment strategies within residency programs to ensure that there is an alignment between skills required in training and practice.

An expert can be defined as an individual who "devotes most of their lives to attaining the highest levels of performance in a highly constrained activity".[58(p274)] There are numerous frameworks of expertise that have been used in medical education, one being the Dreyfus and Dreyfus model of expertise that maps out a learner's professional progression through five different stages.[59] The first stage is the novice stage where the learner is responsible for adhering to rules without context.[59] In the second stage, advanced beginner, the learner starts to understand context and gains experience.[59] The third stage is the competent stage where the learner has gained enough experience to develop competency (i.e. target of CBD).[59] The next stage is the proficient stage where the learner has developed automaticity with certain tasks as past experience has helped shape patterns of recognition.[59] The last stage is the expert, where the learner can intuitively solve problems instead of strictly following the rules and principles which were the focus of the earlier stages.[59] Using intuition is an important quality of an expert, as it allows performance through the usage of tacit knowledge which cannot always be communicated because it is not entirely available in the conscious mind.[59] In fact, the Dreyfus and Dreyfus model and other research argue that expert performance is automatic and performed subconsciously where it can be difficult for the expert to outline the steps or skills required for performance.[59,60] This is why many skills can be taught through demonstration of performance instead of description.[60,61] For example, an expert physician may choose to demonstrate how to intubate a patient instead of describing how to intubate, as it can be difficult to communicate all the different steps in the procedure. Another quality of an expert is the ability to adapt to changes quickly and efficiently.[62] An expert performer can identify and break down the current clinical situation while also thinking about the next series of steps needed to perform a task.[62] Experts who have had ample experience at a task are able to automatically adapt to shifting situations and react to the unfamiliarity.[62] Similarly, expert performers exhibit cognitive skills where they use monitoring, planning, reasoning, and anticipating for performance.[58] For example, when performing a high stakes procedure, an expert physician will not only prepare for the procedure itself but also prepare for any complications by preparing equipment and gathering personnel ahead of time. Furthermore, extensive knowledge of the field and task is another quality of an expert.[58] Specifically, in medicine, expert physicians have greater advanced clinical reasoning and knowledge of diagnostic options compared to trainees who may rely on biomedical reasoning to make diagnostic decisions.[58]

1.4.1 Deliberate Practice

Generally, in a given field, all learners start in a similar stage where they must practice and gain experience in order to become proficient in a given task and perform independently.[63] Once these skills and tasks have been performed regularly, the individual will reach a point of arrested development where the task is performed automatically, without conscious effort.[63,64] Some learners will strive to pursue further improvements and learning in the given task to develop more skills; these learners are usually deemed experts.[63] These learners likely use deliberate practice to improve skills. Deliberate practice can be defined as “the individualized training activities especially designed by a coach or teacher to improve specific aspects of an individual’s performance through repetition and successive refinement.”[58(p278-279)] From an educator perspective, using deliberate practice in teaching has been broken down into 5 stages. Firstly, motivating the learners to improve performance.[63,65] Secondly, having clear objectives for a specific task; the objective of the task is to improve in a part of the performance.[63,65] Third, having measurable parameters in place for performance.[63,65,66] Fourth, repeated practice of the specific skills.[63,65,66] Lastly, giving constructive feedback in a timely manner.[63,65,66] These five stages can be repeated in a cycle to allow for skill development and performance improvement.[63,65,66] Learners should be given multiple opportunities to practice the task repetitively in order to improve.[63,65,66] Additionally, in medicine, deliberate practice can be done in both the clinical and simulation settings. In the clinical setting, a learner can focus on specific aspects of training in order to improve skill. For example, a learner may choose to focus on tying the end of the suture correctly and with the guidance of a supervisor, they can receive feedback and practice repeatedly. In some cases, deliberate practice cannot be accomplished in the clinical setting, thus simulation can be used.[67] In simulation, deliberate practice can be feasible and possible due to less concerns regarding patient safety.[67] Also, more learners can use simulation for deliberate practice because the simulation can be repeated compared to waiting for a specific case in the clinical setting.[67] Lastly, simulation is especially advantageous because it can mitigate the ‘failure to fail’ phenomenon as simulation can allow learners to learn from mistakes and learn complex cases in a low risk setting.[67] However, as mentioned at the beginning of this section, though the goal of training programs is to strive for competence rather than expertise (while still using deliberate practice techniques), unless we have a deeper understanding of knowledge and skills that are crucial to perform a procedure at the expert level, educators might be missing to train and assess residents on those crucial skills, which might lead to programs inaccurately deeming residents as competent when in fact they might be missing important knowledge and skills.

1.4.2 Expertise in Procedural Skills

Currently, expertise in procedural skills is not well understood, which is also reflective of the definition of procedural skills provided by the RC (definition in section 1.1.2 of the thesis), which focuses on technical skills. Based on the medical education literature and expertise literature, the closest understanding of procedural skills and expertise is the framework that was defined by Madani et al.,[68] (2017) where researchers investigated the domains of intraoperative decision-making and behaviors of expert surgeons. The study found five themes that reflect the domains of expert performance in the Operating Room (OR); psychomotor skills, declarative knowledge, interpersonal skills, personal resourcefulness, and advanced cognitive skills.[68] First, psychomotor skills are defined as motor functions that work together to form a chain of events that results in procedural performance.[68] In the assessment of psychomotor skills, there is a heavy emphasis on technical skills such as motion, instrument handling, hand-to-eye coordination, and precision.[68] Second, declarative knowledge is split into three sections; knowledge of the human body, knowledge of surgical practices, and knowledge of literature.[68] Knowledge of the human body comprises of information pertaining to anatomy, physiology, and pathology.[68] Secondly, knowledge of surgical practice includes the chain of events in surgery, planned and unplanned events, and knowledge of instruments and equipment.[68] Thirdly, knowledge of literature pertains to the knowledge regarding the specific case.[68] Third, interpersonal skills refers to the harmony of the healthcare team working together.[68] Teamwork, communication, and cooperation are used so team members can work together to complete the surgery.[68] Additionally, leadership and management skills are used to ensure that the team is productive and effective in completing the surgeries in a timely manner.[68] Fourth, personal resourcefulness domain includes individual factors (i.e. physical factors, psychological factors, and social factors) that could impact performance during surgery.[68] Finally, advanced cognitive skills are described as higher order thinking skills that are exhibited through the performance and behaviors in the OR.[68] Overall, although this study by Madani et al.[68] outlines features of expertise in procedural skills, this study focused on intraoperative performance in surgery, hence the findings might not be transferable to pediatrics, or procedures performed outside of the operative setting. Hence, it will be very important to clearly understand the knowledge and skills that are important when performing pediatric procedures successfully at an expert level, so that better assessment criteria could be established that go beyond technical skills.

1.4.3 Research Objectives

The purpose of this thesis study is to understand the core principles (e.g., knowledge and skills) that are essential for expert performance during pediatric procedures, going beyond technical skills. Our research question is what are the core principles that guide expert performance during a medical procedure?

CHAPTER 2: METHODOLOGY

2.1 Overview of Study Design

This is a qualitative descriptive study whereby reflective thematic analysis was performed to address our research objectives. Specifically, we conducted semi-structured interviews with pediatrics faculty who practice in procedure-heavy specialities such as pediatric emergency medicine, pediatric gastroenterology, neonatology, and pediatric critical care. Our work was guided by the Domains of Intraoperative Performance Framework developed by Madani et al.[68] (framework described in section 1.4.2 of the thesis). Specifically, the framework was used to guide the development of our interview guide and the interpretation/summary of our data.

2.2 Recruitment and Participants

Through the support of education leaders and faculty colleagues, participants were recruited nationally through email. Those who were interested in participating in the study were asked to either fill out a recruitment form or directly email the principal investigator or graduate student for more information. Since this study was focused on procedure-heavy specialties in pediatrics and is about expertise, our inclusion criteria required participants to be faculty members and from pediatric emergency medicine, pediatric gastroenterology, neonatology, or pediatric critical care.

Once participants were recruited, they were asked to read and sign the consent form, complete a demographics form, and participate in an interview. The demographics form asked basic questions regarding the participant's personal and professional background, types of procedures performed, number of years in practice, number of procedures performed monthly, experience with EPAs.

2.3 Interviews

An interview guide (Appendix A) was created in collaboration with an expert clinician and education scientists, using what is known about EPA assessments, expertise, and training and assessment in medical education. Since this study focused on procedural expertise in general and is not specific to a certain procedure, we formulated our interview questions to be broad yet distinctive to different types of procedures. The interview guide went through several iterations to optimize the depth of data to be captured and to clarify the questions. For example, the first iteration of the interview questions focused on the general steps of a procedure and skills of an expert proceduralist. Then, we added questions that focused on unexpected events during procedures and adaptations needed to mitigate these events; these questions were added to help understand the skills experts develop when procedures do not go as planned. Furthermore, in the next iteration of the interview guide, we added questions that highlighted types of procedures. Specifically, we decided to ask about the frequency of procedures and challenging procedures. We made these modifications to the interview guide based on the research team discussions, along with the information we found in the literature surrounding assessment needs in procedural skills. Lastly, two pilot interviews were conducted to help modify the interview guide to better address the research objectives. After these interviews, further modifications were made, including grouping procedures into three categories: high stakes versus low stakes, easy versus difficult, and common versus rare. These categories were developed to help us explore the types of skills needed to perform a variety of procedures and whether certain skills are more important over others, depending on the procedure group. Additionally, some procedures can overlap in these categories (e.g., an intubation may be described as high stakes, difficult, and rare), so participants may describe expertise based on their perceptions of the procedures or versions of the procedures that would be in different categories. Also, participants explored whether there are any similarities or differences in skills needed between and across the categories (e.g., high-stakes versus low-stakes procedures; high-stakes versus rare procedures).

Interviews were conducted online via Zoom and took between 40 to 60 minutes each. The audio was recorded using the recording function on Zoom and transcribed using an external transcription service whom we had a confidentiality agreement with. We continued to recruit participants until we believed that thematic sufficiency was reached. We determined thematic sufficiency based upon the depth of data collected; for example, we stopped data collection when we stopped hearing new information from the participants.[69] Additionally, we used Guiding Questions When Evaluating Evidentiary Value of Qualitative Interviewing Findings developed by LaDonna et al.,[69] (2021) as a guiding tool for thematic sufficiency. Upon completion of the interview, participants received an electronic gift card valued at $20.

2.4 Analysis of Interview Data

For the analysis of our interview data, Braun and Clarke's reflexive thematic analysis was used.[70]

There are 6 steps in the analysis:

(1) Familiarization with the Data: The data were transcribed and reviewed.

(2) Systematic Data Coding: Initial codes were developed across the data by reading the transcripts line by line and coding specific ideas, which were combined according to the data set.

(3) Generating Initial Themes: Themes were created based on similar codes from the previous step by grouping similar concepts together, with the guidance of our interview guide (e.g., grouping ideas together based on the different sections/groups of questions from the interview guide).

(4) Developing/Reviewing Themes: Both codes and themes were reviewed against the datasets to ensure that they represented the data and that no important ideas were missing. Both codes and themes were analyzed carefully to ensure that there was no repetition of ideas, to merge ideas together or separate ideas that needed their own theme, and to ensure themes were authentic.

(5) Theme Naming/Refining/Defining: Themes were named and defined to reflect the data. Individuals external to facilitating the interviews helped review the themes and provided feedback on any changes that were necessary.

(6) Report writing: Themes were established and linked back to address the research objectives. Specific quotes were selected from the transcripts to help support the findings of the data.

To ensure the trustworthiness and authenticity of our results, we: (1) maintained an audit trail, to keep a record of all decisions and their rationale, (2) built a robust research team to help consider multiple perspectives in our findings, (3) involved health professions and education scientists from different backgrounds in data collection and analysis, (4) involved additional personnel external to the research to support in pilot interviews, review data, and refine the themes, and (5) conducted field observations in procedure-heavy specialities in both clinical and simulation settings. A field observation guide was developed based on the interview guide to connect what is reported in the interviews to what is seen in practice. The graduate student used the field observation guide to take notes and capture the expert's thoughts, decisions, and skills.

2.5 Ethics Approval

This study received ethics approval from the Hamilton Integrated Research Ethics Board (HiREB) #16524.

2.6 Reflexivity Statement

Currently, I, Jasmin Dhanoa, am pursuing a Master of Science in the field Health Science Education. In my undergraduate studies, I have had some experience in qualitative research within the broader field of education. Specifically, I have helped facilitate focus groups, analyze qualitative data, and supported manuscript writing. Additionally, in the 1st year of my masters, I have taken a qualitative research course, all of which have informed different stages of my thesis project. It is also important for me to acknowledge my identity as part of this research and how it may influence the research. Coming into this thesis, I am a non-clinician, with very little clinical experience. During my undergraduate training, I had the opportunity to volunteer and work in a family physician clinic where I would help interview patients and complete administrative work. I would also shadow or assist in small procedures in the clinic such as skin biopsies, mole removal, or joint injections. This experience has allowed me to work closely with an expert health professional and understand some of the skills required to perform procedures. Lastly, although I do not have lived experiences related to CBD, I have been actively reading the literature related to our topic of interest and have been holding conversations with physicians, learners, and education scientists involved in CBD to gain a deeper understanding of their experiences.

CHAPTER 3: RESULTS

Overall, there were five main themes identified from our data: (1) Procedural Expertise Requires Skills that Go Beyond Psychomotor Skills, and Relies Heavily on Non-Technical Skills, (2) The Generalization of Procedural Expertise is Dependent on the Skills, Specialty, and Contextual and Patient Factors, (3) Approaching Expected/Unexpected Events in Procedures and Deciding on Adaptations is a Crucial Part of Expertise, (4) Pediatric Training Programs Use a Variety of Approaches in Procedural Training, and (5) Decrease in Procedural Opportunities for Experts Lead to Skill Decay.

We interviewed 18 participants from six institutions: McMaster University, Western University, McGill University, University of Alberta, University of Montreal, and University of Toronto from March to November 2024. Of the 18 participants, nine were pediatric emergency physicians, four were in pediatric critical care, three were neonatologists, and two were pediatric gastroenterologists. Participants had a wide variety of experience in practice ranging from zero to five years and over 16 years. Moreover, participants' monthly procedure count ranged from one to five procedures to over 51 procedures.

3.1 Theme 1: Procedural Expertise Requires Skills that Go Beyond Psychomotor Skills, and Relies Heavily on Non-Technical Skills

Most participants expressed that technical skills such as hand-eye coordination, moving hands in synergy, and fine and gross motor skills are important for performing procedures, independent of the type of procedure. However, in low-stakes, common, and easy procedures, there is a certain level of automaticity with technical skills as these procedures are performed frequently. On the other hand, participants shared that in rare procedures, there is less automaticity, thus rehearsing the steps of the procedure and following protocols and guidelines were suggested as important.

> *"I think that as time goes on [low-stakes procedures] almost becomes a little bit more automatic for us, once you've practiced [for] a longer period of time. I still have [to] often [think] things through, but I don't think I'm probably as deliberate about it."*

Non-technical skills, on the other hand, determine expertise, as these skills require the proceduralist to think beyond the technical aspects of the procedure and include all other events that are also occurring. For example, before performing the procedure, the expert must prepare for the procedure and any complications and communicate with their team, the patient and their caregivers, while also paying attention to incoming patients and their needs.

> *"For the junior [trainees], [who are] doing it for [the] first time, it's just more the psychomotor skills that become the main objective [...] not as much how are you preparing the intubation medications? What's your backup plan when you do something? [Or] What are you expecting to see?"*

3.1.1 Theme 1A: Experts Use Knowledge, Anticipatory Guidance, And Problem Solving in Order to Make Decisions.

For all procedures, the importance of knowledge was discussed the most during the interviews by participants, as they believed knowledge helped them make informed decisions. Participants believed that knowledge of indications, contraindications, anatomy, physiology, procedure optimization, the steps of the procedure, the equipment, troubleshooting, and complications were all important.

> *"When you're actually in it you've got to take that knowledge you learn in the classroom and determine whether or not it's safe to proceed."*

Moreover, three skills that were highly discussed in the interviews by participants were situational awareness, problem solving, and decision making. Participants expressed that situational awareness is key to becoming an expert, as experts must use anticipatory guidance in order to detect problems quickly and solve them. Also, experts must be aware of their surroundings (e.g., Emergency Medical Services alerts, patient management), and their own personal strengths and limitations (e.g., skill-based constraints, emotional management). For example, an expert needs to reflect on their current strengths and consider if they are the ideal person to be performing the procedure and whether there is someone else who should perform (e.g., with higher procedural log for the specific procedure).

> *"So typically, in high stake procedures either I'm doing it [or] [...] I would delegate to the senior fellow with me or [...] call a backup neonatologist. [I would say] I need you to cover for that [...] [or] I'll be your back up and then I'm taking care of other things because in the NICU it's not unusual to have two or three patients in crisis at the same time. You need to figure out which one to delegate, which one to do and how you do it, how to be efficient. Then you're intentional and focused in the moment at the same time, so now it happens automatically, but*

in my early career, like I had to be systematic about it to get to that level that's like [automatic].”

Participants mentioned that other considerations include any personal limitations such as tiredness, stress, or certain emotions (e.g., anxiety) that may impact their performance, so the expert needs to manage their emotions to perform the procedure safely. Additionally, for low-stakes and easy procedures, participants shared that situational awareness is still needed; however, since these cases are usually less urgent, troubleshooting can be addressed using more resources such as imaging, consulting other professionals, or trying alternative treatment options.

“There are different techniques that you can use to try [to] still do the procedure. But there are definitely times where you say, okay, I'm just going to have to stop here and look at an alternative way to achieve the stability that you seek.”

Similarly, problem solving was stated to be crucial amongst experts, as high-stakes and difficult cases can be urgent, and complications need to be corrected in a timely manner. Additionally, participants mentioned that an expert understands that problem solving does not always require a big change in what is currently being done. Usually, problem solving will entail a simple change such as changing the positioning of the patient or changing equipment. Problem solving can also entail abandoning the procedure or calling for help; however, most participants understood that they are usually the last line of help as they are the expert. Hence, calling for help could mean consulting with other specialties (i.e., surgery) that may be more equipped in problem solving in areas relevant to the case.

> *"But I think that really there's minor adaptations that we always do in a procedure [...] Sometimes they happen automatically. [If] I can't see, am I even thinking about what I am doing to reposition myself? I may not. It may just happen almost subconsciously. So, I think that there are adaptations that happen without us necessarily deliberately thinking about it, once you have achieved a certain level of competence [...] [If] you're struggling and you're not successful and you've done the usual things that you would do to be successful, and then you have to say okay, no, I need to move on to either a different procedure or I need to do this in a different manner. I think those larger adaptations that probably happen after you've done the small things [...] With regards to do you abort the procedure and move to a different procedure? I think that depends a little bit on the high stakes level of it [and] the patient status? Do you have time?"*

Lastly, participants stated efficient and effective decision making sets apart experts from novices. Decision making will occur during all phases of a procedure, including the pre-procedure (preparation), intra-procedure (performance), and post-procedure phases of the procedure. In the preparation phase, participants shared that experts will make decisions regarding the necessity of the procedure, the personnel needed, the equipment needed, the treatment plan, backup plans, approaches for troubleshooting regarding anticipated complications, and procedural optimization (e.g., positioning the bed or patient). During the procedure, if there is an unanticipated complication, the healthcare team may not be aware of the next steps, so the expert needs to decide on the next steps and then communicate with everyone. In the post-procedural phases, the expert will make decisions regarding monitoring/testing the patient to ensure that the procedure was successful.

> "*So, the way I look at it is the situation overall because I think also about what else is going on because you're not dealing with that patient in isolation. You're still responsible for 70 other babies in the NICU, not necessarily in other settings. So, one is the situational awareness of what else going on. Two is the patient [and] the patient stability needs [and] different needs – the procedure, the difficulty of the procedure, what I need for the procedure, equipment so on. [Three] the support that I need, so reflection on my own and then the team that I have.*"

3.1.2 Theme 1B: Communication and Emotion Management are Fundamental During the Procedure for the Healthcare Team, the Caregivers, and Patients

Communication was another non-technical skill that most participants discussed in the interview. Participants stated communication plays a key role in all phases of the procedure, as it allows everyone to have a shared mental model of the procedural plan and decisions that are made throughout. Participants shared that in preparation, the expert will communicate the mental model of the procedure with the healthcare team through a procedural pause prior to beginning the procedure. This entails discussing the course of treatment, the steps of the procedure, any anticipated complications, troubleshooting steps, and backup plans. During the procedure, experts will continuously communicate with the team by directing the room, explaining the next steps of the procedure, and communicating any changes in the procedural plan. In the post-procedural phase, the expert will communicate the success of the procedure to the team and the next steps in care. Specifically in difficult and rare procedures, participants mentioned that communication will be more deliberate, particularly in the preparation and performance phases, as the expert and team may not be as familiar with the steps or procedural plan.

> *"I think [in] the rare procedures, I just don't have as much subconscious [thinking] to rely on, [so] I would spend more of my mental energy, cognitive load, thinking about and planning for complications because it is rare. I know I just can't rely on quick responsiveness of myself or the team because we just don't do [rare procedures] as often."*

Communication with the patient and caregivers was also stated by participants to be important at the expert level. The participants stated that the expert will take time to communicate the need of the procedure, the risk and benefits, and they will answer any questions the caregivers have before obtaining consent. The expert may also communicate with the patient during the procedure and use the appropriate language based on the patient's age to ensure they feel comfortable. Many participants shared that they collaborate with other healthcare professionals (i.e., nurses, child life specialists) to support communication and emotion management of the caregivers and patients to allow for the expert to focus on the procedure. Sometimes the expert team cannot communicate in the moment due to the urgency of the procedure, so they will communicate with the family after the procedure is complete. However, in low-stakes or easy procedures, participants shared that they can usually take time to explain the procedure and obtain consent and communicate with the family while performing the procedure.

> *"During these procedures, [...] if I am leading a resuscitation or something, I am in constant contact with the family and summarizing things out loud for the entire team and making sure everyone is fully aware of what we are doing now, what are the next steps, and if this is not successful, what do we do next? And also asking for input – is there anything else that we need to do? Is there anything that I missed?"*

Additionally, emotion management of their own emotions and the teams' emotions were deemed important by most participants. Participants expressed that they try to acknowledge and control their own and teams' anxieties about the procedure if it is a difficult or high-stakes procedure, and although many participants mentioned that they do not always have time to reflect on their emotions, they allow their team to have a break. In extremely stressful situations (e.g., death of a patient, intensive resuscitation), the whole unit will have an emotional debrief to discuss their emotions. Overall, the expert and team rely on each other for emotional support, and during the procedure, they try to remain calm and professional, so they can debrief later.

> *"In critical situations, it's extremely important to be open to input and to be able [to], in the moment, despite all the stress, to filter what's important [...] If you*

> *have ego and a big barrier that's up it's very hard for you to filter that because everything becomes unknown, and it makes people uncomfortable to speak up. It creates a psychologically unsafe situation and also puts you in a vulnerable position because you pretend you know something, and you don't know."*

3.1.3 Theme 1C: Experience with Performing Procedures is not a Driving Force in Developing Expertise but can be Helpful in Skill Development

Experience related to skill development was mentioned the least by participants. Experience (case exposure) was considered important because it allows for a certain level of automaticity when performing procedures, which allows the expert to focus on other skills such as adaptability and habit building. Moreover, participants shared that experience allows them to have more breadth of knowledge due to being exposed to more procedures and cases. The main reason that experience was not deemed of the utmost importance was because even if a physician has many years of experience, that does not automatically make them an expert; the skills required to be an expert proceduralist does not equal the number of years in practice.

> *"I think something about procedural expertise [is that] [...] being senior doesn't automatically mean that you are the most expert on the task. So even if you have years of exposure and years of doing said procedure, there are some people who are experts and some who can do it but are not experts."*

3.2 Theme 2: The Generalization of Procedural Expertise is Dependent on the Skills, Specialty, and Contextual and Patient Factors

Almost all participants agreed that the skills required for procedural expertise could be generalized across the three procedural categories: high stakes versus low stakes procedures, easy versus difficult procedures, and common versus rare procedures. Participants shared that skills and tasks such as preparation, knowledge, obtaining consent, decision making, communication, and documentation were common factors of all procedures while skills such as situational awareness, troubleshooting, and identification of personal limitation were still deemed important but weighed differently depending on the procedure.

> *"I think the general principles are really what we talked about in terms of that communication, preparation and the preparation applying to location, equipment and personnel, the information gathering that you need to have with the indications and contraindications and the reason why you are doing the procedure in that situation."*

For example, in a low-stakes procedure, such as a lumbar puncture, if an expert has already attempted the procedure a couple of times without success, then they may choose to try again later, as the expert needs to consider the patient's tolerance for the procedure, and the lack of urgency for the procedure. In contrast, if an expert is performing an intubation, they know it is a high-stakes procedure, it needs to be performed, and they may need to call for help in the case of failed attempts. Another example includes the greater focus on planning and communication in high-stakes and rare procedures as these procedures are urgent and can be infrequent, thus more emphasis is placed in the preparation phase. However, in low-stakes procedures there is less emphasis in planning and communication as the healthcare team encounters these procedures often enough to understand the shared mental model. Additional factors such as specialty and contextual and patient factors are also taken into consideration in the generalization of procedural expertise.

> *"For the Royal College of Emergency Medicine exam [...] each station will almost always have a procedure built in and what we tell our residents is you should have the same approach for every procedure. I would don my PPE, I would prepare the necessary equipment, I would landmark the site, I would prep and then drape, then I would do the task, [...] and then I would do my confirmatory testing. Like that is what we drill into them. So those basic principles of sort of pre-and post-like that is absolutely [similar], but I would not want to lose sight of in that generality is the importance of patient factors and context factors. How you approach this when you are working in Timmins, Ontario is going to be very different to how you approach it when you are working in Hamilton General or McMaster Children's or Sick Kids or Toronto General. Like those context- and patient-specific factors are just so important when you are thinking about how you apply your technical expertise."*

Specialties operate in different ways, so the importance of procedural skills can be weighed differently. For example, in pediatric gastroenterology, caregivers cannot be in the procedural room; thus, there is less emphasis on communicating with the family during the procedure compared to other specialties, such as pediatric emergency care, where caregivers are usually in the room, so communication is weighed with more importance. Also, throughout the interviews, some participants had a difficult time with categorizing procedures, as they believed that patient and contextual elements play a key role in determining the procedural category.

> *"That is actually what makes procedures more challenging. It is not the steps to doing the skill, it is what is happening with the patient because every patient is different. Usually, it is like a patient-related thing that is making the procedure difficult, it is not because the procedure itself is technically difficult to do, it is that there is something wrong with the patient that is making it hard."*

3.3 Theme 3: Approaching Expected/Unexpected Events in Procedures and Deciding on Adaptations is a Crucial Part of Expertise

All participants believed that an important aspect of being an expert is adaptability in the case of unexpected or expected events such as complications. Ideally, an expert would have anticipated any complications in the preparation phase of the procedure and communicated them with the team, but this is not always the case. Participants shared that the expert needs to have situational awareness and grasp the context quickly so that they can inform the team of the change of procedural plan. In order to decide the next steps, the expert must consider the patient holistically (e.g., patient history, patient characteristics, impact of procedure on daily living). In high-stakes and difficult procedures, the expert and team will discuss the backup plan(s); therefore, in these procedures, they are prepared to adapt based on the plan they have created. A couple of participants also mentioned that they follow relevant guidelines or protocols that may be available. Essentially, in approaching unexpected or expected events, participants mentioned having the choice of additional attempts through trying different approaches, calling for help, or abandoning the procedure. As mentioned before, with each additional attempt in a procedure, there needs to be a change made. The change can be small such as changing equipment, or the change can be large, such as changing personnel. Furthermore, participants stated they may decide to ask for help from other experts. In high-stakes, difficult, and rare procedures, the other experts may already be in the room, as these procedures are urgent and thus the procedure can quickly be passed on to the other expert or can be completed in collaboration. Lastly, abandoning the procedure is usually only an option if the procedure is not lifesaving (i.e., low-stakes procedures). In abandoning the procedure, the expert can reassess the patient and context before deciding on the next steps.

> *"[During a procedure], let's say this line is not going in, then what other lines should [the physician] put in? How to position the baby? Maybe try to do this, try to do that, I would expect that. And if they know when to stop. I think something of a non-expert would be I am going to try again [...] But an expert would be it is futile to try again, I am going to give this a break, and we are going to look at other options. There is also some experts that are maybe junior who think they can do it still [...] They are the ones who are like let it go, I know I am not going to be able [to] because sometimes it is just you are not able to do it."*

3.4 Theme 4: Pediatric Training Programs Use a Variety of Approaches in Procedural Training

Participants shared that there are a multitude of methods in which trainees are trained for procedural skills. Most participants explained that simulation plays an important role in developing skills for procedures, as learning outcomes in simulation can help trainees focus on individual skills (e.g., technical skills) or multiple skills simultaneously (e.g., collaboration, situational awareness). Participants stated other techniques such as deliberate training and debriefing are also used in simulation for training procedural skills. Using deliberate practice for developing procedural skills was highly encouraged by some participants, as they shared that there are fewer opportunities to practice skills after training is complete. Moreover, some participants mentioned that a couple of times a year, there are procedure simulation days dedicated for specific procedural skills or categories. For example, some procedural skill days may focus on common procedures while others focus on rare procedures. Lastly, most participants expressed that giving trainees the opportunity to observe and perform procedures in the clinical setting with direct and indirect supervision allows development of procedural skills. Direct and indirect supervision of trainees depended on the specialty, procedural category, and comfort of the expert and trainee. Some specialties (i.e., pediatric gastroenterology) require the expert to be directly supervising the trainee at all times during the procedure, so the expert can easily intervene if needed. Additionally, participants stated in high-stakes and difficult cases, the expert is usually directly supervising the trainee. It is uncommon to allow a trainee to perform a rare procedure as they may not have the skills to perform it. Lastly, the expert and trainee comfort can help determine if direct or indirect supervision is needed. If both the expert and trainee are comfortable with the trainee performing the procedure, then the expert may opt for indirect supervision. However, if there is a lack of comfort in performance or the trainee would like feedback on their performance, then direct supervision is usually needed.

> *"If something does go wrong or the student or the learner struggles a little bit, then we may need to take over, and then we will explain what we are doing as we are doing it. Then, give them another opportunity to try on the next suture for example."*

> *"Most residents, when it is an unfamiliar situation, they will be like 'oh, I think I could do it because I've read about it, and I am ready to go, but I would appreciate the observation or like the help,' and that is usually a sign that they are not overly comfortable"*

3.4.1 Theme 4A: Lack of Consensus Regarding Procedural Skills that Trainees Struggle With

Although there was no consensus, overall, participants stated that trainees struggle with non-technical skills (e.g., communication, situational awareness, sequence of events), as trainees usually direct their attention entirely on the technical aspect of the procedure. Non-technical skills are also difficult to teach due to lack of focus on non-technical skills and challenges in assessing non-technical skills, so trainees usually have to learn through observation. Participants mentioned one potential reason for the lack of consensus is that trainees come from diverse backgrounds where some trainees may have more experience in procedures while others may not. For example, some participants mentioned that international trainees often have developed some procedural skills, as they have more procedural experience. Other times, trainees may use skills they learned in their past rotations and apply the skills to their current rotations.

> *"Well everybody struggles at certain times with every procedure, whether you're junior, senior, and expert. [...] For example, we have trainees who come from Pediatrics, and we have trainees come from Anesthesia. So, if they come from Pediatrics, they will struggle with intubations, arterial lines, central lines, but Anesthesia trainees do not because they do those so much more commonly in their base training."*

3.5 Theme 5: Decrease in Procedural Opportunities for Experts Lead to Skill Decay

A common concern among participants was the lack of opportunities to perform procedures, especially for experts in academic centers, as trainees need to perform procedures to develop competence. Also, each trainee needs to complete their EPA assessments, so when there is an opportunity to complete a procedure, it is usually offered to a trainee. Participants stated that a major consequence of the limited procedure exposure is the procedural skill decay among experts. Experts are usually directly or indirectly supervising trainees in procedures and even in direct supervision, the expert is not leading the procedure. Some participants have mentioned maintaining their procedural skills through simulation; however, experts rarely have the time for simulation and participants expressed a lack of professional development opportunities.

> *"So, the challenge once people become faculty is that unless they are doing a skill frequently, their skills decay. So, we identify either through needs assessments or through critical incidents or other events the skills that are infrequent and require training."*

A small number of participants were also concerned that for trainees and opportunities for developing procedural skills is also decreasing due to specialties exploring less invasive methods of care. For example, in the Neonatal Intensive Care Unit, instead of performing intubations, physicians perform Minimally Invasive Surfactant Therapy (MIST). Although less invasive procedures may be beneficial for patients, it makes developing procedural expertise difficult.

> *"[With] chest tubes, we are trying to find the gentlest way to ventilate so we have less pneumothoraces, but that means doing less chest tubes. So, we are trying [...] to put in lines less. We are trying to minimize the procedures for the sake of the babies but that means less [procedure] opportunities for that [is] the biggest problem that we have."*

CHAPTER 4: DISCUSSION

4.1 Overview of Results

This study explored the core principles that guide procedural expertise in performing medical procedures in pediatrics. We conducted semi-structured interviews with faculty from procedural heavy specialties, including pediatric emergency care, pediatric gastroenterology, pediatric critical care, and neonatology. We identified five themes from the data: (1) Procedural Expertise Requires Skills that Go Beyond Psychomotor Skills, and Relies Heavily on Non-Technical Skills, (2) The Generalization of Procedural Expertise is Dependent on the Skills, Specialty, and Contextual and Patient Factors, (3) Approaching Expected/Unexpected Events in Procedures and Deciding on Adaptations is a Crucial Part of Expertise, (4) Pediatric Training Programs Use a Variety of Approaches in Procedural Training, and (5) Decrease in Procedural Opportunities for Experts Lead to Skill Decay.

In medicine, the literature groups non-technical skills into three categories: cognitive skills, social skills, and personal resource skills.[71,72] In the present study, we found that some of the skills across these categories can overlap one another; for example, problem solving and situational awareness worked interconnectedly where experts needed to grasp the context of the situation quickly and then use problem-solving techniques to decide on a solution. Personal resource skills could also encompass cognitive skills, as emotion management requires experts to use cognitive processes to be aware of their personal limitations. In the next sections, we will begin by further exploring non-technical skill domains, followed by understanding current assessment practices and their strengths and weaknesses, and comparison of our findings to the

Madani et al.[68] framework and what makes pediatric procedural expertise unique compared to other procedural expertise.

4.2 Cognitive Skills – Decision Making and Situational Awareness

Clinical decision making is a core competency in medical education that requires physicians to constantly have situational awareness to engage in cognitive processing with the cues from the environment.[73] As we heard from participants, in the preparation phase, the expert will take relevant information about the patient (e.g., indication, contraindication, patient history) and make decision to set up for the procedure – gather equipment, personnel, and set up the procedural environment.[74,75] Then, more deliberate cognitive processes will be used to understand the context of the situation, the necessity of the procedure, interpret the information that is given, and start anticipating any expected/unexpected events that may occur.[74,75] During medical procedures, the environment is constantly changing with different cues competing for the attention of the physician; thus, effective and efficient decision-making is a skill needed in procedural expertise.[73] Additionally, situational awareness, taking cues from the environment (e.g., department, patients, personal needs), analyzing the cues, and anticipating changes in the current situation, is also considered in making decisions.[74] In the current study, participants described situational awareness as needing to focus on personal limitations, the workflow of the department, and individual patient needs. It is also crucial to be aware of team members and their role in patient care in order to delegate tasks and understand scheduling of the team (e.g. who is available and at what time).[74] In dynamic departments such as the Intensive Care Unit or the Emergency Department, it is even more important to be aware of the updates within the department as patients are consistently entering and leaving the unit;[74] similar comments were heard from pediatric emergency physicians and pediatric critical care physicians from the current study.

Clinical decision making is researched in a variety of different ways, one common area being subconscious and conscious decision making.[72] Subconscious decision making occurs when a physician can map out the plan, steps, and expectations of the procedure and perform without using deliberate cognitive efforts to focus on each step of the procedure.[72] Conscious decision making usually occurs during transforming situations that forces the physician to navigate and anticipate the unforeseen change and adapt to accomplish overarching goals.[75] Participants in the current study shared the subconscious performance of technical skills that can occur in low-stakes, easy, and common procedures as these procedures are performed frequently enough to map out the procedural process. The intake of similar information from past clinical encounters allows the decision making in these cases to be quicker and more efficient compared to other scenarios.[75] On the other hand, rare procedures require more deliberate use of skills, such as situational awareness or decision making, as these procedures require more conscious effort of the use of both technical and non-technical skills. Experience with procedures and high case logs can also support more subconscious decision making, as experienced physicians can have more pattern recognition with a greater breadth of procedures compared to a novice.[72] Overall, clinical cases may be common or rare so an expert can use both subconscious and conscious processes to make decisions, where both processes can be used chronologically (e.g., with subconscious being used first) or alternately (e.g., subconscious and conscious both being used based on the situation), depending on factors such as pattern recognition and conscious and subconscious efforts being used.[75]

4.3 Social Skills – Communication Skills

Communication skills are a fundamental aspect of procedural performance. In the present study, participants described various ways in which they communicate, and all experts shared positive experiences with communicating with the healthcare team; however, it is important to highlight the barriers to communication in medical settings. There can be many barriers in communication amongst the team, such as isolated training programs among interdisciplinary teams, diversity in communication styles and problem-solving techniques, and differences within healthcare settings and healthcare teams.[74] These barriers to communication can impact patient care, as team members may refrain from sharing patient information with one another, the team may feel less comfortable sharing ideas and discussing the treatment plan or backup plans, and there may be power imbalances.[74] Ultimately, lack of communication skills can prevent the healthcare team from having a shared mental model of the treatment plan, which can harm the patient.[74,76] As mentioned in the present study, communication in the preparation phase to create a shared mental model of the procedural plan is key so all professionals can understand their role. Communication is especially important in high-stakes procedures such as intubation where the proceduralist and leader of the room need to be in constant communication with one another in order to describe the next step of the procedure, read the monitor, and to ensure procedure success. Some studies have cited that poor communication during intubation can be one of the top reasons for bad outcomes in intubation and injury caused to the patient.[74,77] In these high-stakes procedures, closed-loop communication is important to ensure deliberate communication between the expert and the team.[74]

4.4 Personal Resource Skills – Emotion Management

Medical settings can be stressful environments where emotions run high for both healthcare professionals and patients.[76] In the literature, emotion management and situational awareness, specifically self-awareness, were coupled together.[74,76] With self-awareness, experts can understand their own emotions and feelings, they can understand how their colleagues and patients perceive them, and they can understand how to integrate into the healthcare setting.[76] Self-awareness is especially important among healthcare professionals due to the high demands on the workforce including long hours, high-pressure environments, higher risk of burnout, professional or personal distractions, task overload, stress, and cognitive overload, which can all impact decision-making abilities as well.[75,76]

Personal resource skills, or self-awareness, begins at the preparation phase during the procedural pause where the team can discuss the case and form a shared mental model which leaves little room for assumptions or ambiguity in the procedural plan.[74] Collaboration is especially important in personal resource skills as using the team's cognitive capacity together rather than focusing on individual capacity allows for better situational awareness, management of crisis, improves the work environment, and allows for increased focus on monitoring the patient.[74] Furthermore, in medical procedures, especially in pediatric settings, there are additional factors that need to be considered such as patient tolerance of procedure, caregiver questions and concerns, and a lack of a controlled environment as these procedures are usually performed outside of the operating room. Without proper management of personal resource factors, technical and non-technical skills can be impacted.[7272] For example, in the current study, many experts shared that if the emotions of the caregivers are not controlled during the procedure, it can be difficult for the expert to focus on performing the procedure. Overall, the benefit of self-awareness allows healthcare professionals to have better confidence, decision-making skills, and stress management—all essential aspects of expertise within medicine.[76]

4.5 Assessing Non-Technical Skills in Didactive and Simulation Environments

Although technical skills have been the primary focus of training and assessment, non-technical skills training and assessment is gaining momentum, and have primarily been taught in the classroom and in simulation centers in medical education.[71] In the classroom, non-technical skills are taught through didactic methods in workshops, e-learning modules, and video-based learning of effective and ineffective portrayal of non-technical skills.[71] One example of didactic teaching of non-technical skills is from Flin et al.,[78] where researchers created a non-technical skills course to inform surgeons about the importance of these skills for clinical outcomes. Surgeons watched videos of surgeries and rated the physician's non-technical skills using the Non-Technical Skills for Surgeons (NOTSS) and engaged in didactic learning methods to learn more about non-technical skills.[78] Surgeons agreed that non-technical skills assessment allowed them to consider how non-technical skills, such as cognitive and interpersonal skills, were crucial for patient safety, and most surgeons began focusing more on skills such as communication, decision-making, and situational awareness.[78]

In a similar study by Dedy et al.,[79] researchers performed a randomized control trial with junior trainees who were assessed on their non-technical skills with and without formal teaching of these skills. For the intervention group, participants received didactic teaching on non-technical skills such as situational awareness, decision-making strategies, leadership styles, and crisis management, and participants practiced these skills in the OR or simulation center.[79] Through assessments using the NOTSS and Objective Structured Assessment of Non-Technical Skills (OSANTS), the study found that the intervention group had significant improvement between its baseline and post-training, while the control group showed no significant improvements.[79] Additionally, in the post-training scores, the intervention group had higher scores than the control group; however, these scores were not significant.[79]

In another study conducted by Brunckhorst et al.,[80] researchers explored the link between technical (assessed using the Rigid-Ureteroscopy Assessment Sheet) and non-technical (assessed using NOTSS) skills performance in ureteroscopy in the simulation setting. Participants underwent formal learning with a technical and non-technical skill curriculum of simulation-based ureteroscopy while the other half learned using basic didactic methods.[80] Overall, the results showed that the curriculum is educationally valuable at improving technical and non-technical skills, which could signify the relationship and interplay between technical and non-technical skills for improved procedural performance.[80]

Overall, both technical and non-technical skills play an important role in procedural performance. However, majority of the current focus of procedural training and assessment is on technical skills, using assessment tools such as the Objective Structured Assessment of Technical Skill (OSATS) and the Direct Observation of Procedural Skills (DOPS). However, as uncovered in the present study, there are multiple skill domains that go beyond the technical aspects of procedural performance that assessments should focus on to create a holistic understanding of procedural performance, centered around both technical and non-technical skill domains. A holistic assessment should encompass multiple assessments that span the technical and non-technical skill domains, to target all of the skills important for procedural performance. By integrating technical and non-technical skills within procedural performance training and assessment, educators can ensure that our future pediatricians embody the skills needed for not only competence, but also procedural expertise and are equipped with these skills once they are practicing physicians.

4.6 The Core Principles that Define Procedural Expertise and its Comparison to Domains of Intraoperative Performance Framework

This study used Madani et al.'s[68] "What Are the Principles That Guide Behaviors in the Operating Room? Creating a Framework to Define and Measure Performance" to outline potential core principles that guide expert performance of medical procedures outside of the OR. When we compared our findings to the Domains of Intraoperative

Performance,[68] we found that the core principles of expert performance in medical procedures outside of the operating room were similar. Madani et al.[68] sought to capture intraoperative expertise by interviewing surgeons from multiple specialties regarding the procedures they routinely perform, the cognitive processes that are needed to perform these procedures, as well as describe their cognitive processes during procedural performance through video analysis of performance of the participants.[68] Five themes were identified that reflect expert intraoperative performance: psychomotor skills, declarative knowledge, interpersonal skills, personal resourcefulness, and advanced cognitive skills.[68] First, the Domains of Intraoperative Performance reflect psychomotor skills as being a crucial step in the performance phase of the procedure where most focus is on the technical aspects of performance.[68] Similarly, in the current study, psychomotor skills were identified to be an important aspect of the technical skills of procedural performance, highlighting skills such as hand-eye coordination and moving hands in synergy as being needed during the procedure. Additionally, declarative knowledge was highlighted by the Madani et al.[68] framework as part of expertise in intraoperative performance. Similar to Madani et al.,[68] we highlighted different types of knowledge that are crucial to being an expert in medical procedures. Namely, experts need to apply the knowledge they learned in the classroom (e.g., anatomy and physiology) to procedures, but they also need to be knowledgeable about the indications, contraindications, procedure optimization, the steps of the procedure, the equipment, troubleshooting, and complications. Madani et al.[68] also mention knowledge of literature and evidence-based practices;[68] however, only a small number of participants in the present study mentioned this type of knowledge being a priority.

Next, the Domains of Intraoperative Performance Framework divides interpersonal skills into two sections: teamwork and leadership.[68] In the present study, participants shared the importance of working in small and large teams depending on the procedural category. For example, in a low-stakes procedure, there may not be as many healthcare professionals involved in care as in a high-stakes procedure. Participants also shared the importance of having an effective team that can rely on each other on multiple levels. Participants expressed that they rely on their team during the procedural pause to generate ideas and discuss the procedure plan. During the procedure, the expert relies on the team to remind them of certain steps of the procedure that they are likely to miss, and in post-procedural tasks, the expert relies on the team to help ensure procedure success through testing and monitoring the patient. Also, experts rely on the healthcare team for emotional support, reducing cognitive load, and for feedback to improve performance. Moreover, leadership in the intraoperative framework describes the importance of productivity with resource management.[68] Similarly, in the current study, experts shared that when approaching expected and unexpected events, there can be a few approaches an expert can take such as additional attempts at the procedure, abandoning the procedure, or asking for help from other experts or specialties. Similar to the framework, we had experts share that during these times of high stress or complication, there is not time to debate the next steps and the expert needs to take lead and direct the team to the next step and then discussion can happen after the procedure.

Furthermore, the framework identified personal resourcefulness as a crucial aspect of intraoperative performance.[68] Personal resourcefulness encompassed physical (e.g., fatigue) psychological (e.g., confidence, fear of making errors, motivation, ego), and social factors (e.g., reputation, time pressure, personal and professional distractions) that could impact performance.[68] In the present study, we only had some experts identify self-awareness as an important aspect of procedural expertise and the conversations would usually revolve around physical or physiological factors such as fatigue, stress, skill-based restraints, and emotion management. Experts shared the importance of being confident and calm during the procedure to help manage the emotions of the family and team. Also, experts shared that there can be some psychological factors such as high or low confidence and high ego amongst trainees that can impact their performance. Participants in the current study did not share any social factors that would influence their performance; however, we did have one participant share the negative consequences of working with a team that is overly critical or judgmental which can create a toxic environment and impact patient care.

The last theme identified by the Domains of Intraoperative Performance Framework was advanced cognitive skills, which highlighted 21 subthemes.[68] Some of the subthemes encompassed the technical aspects specific to surgery; therefore, in this section we will group together some of these subthemes to allow for a more simplified analysis. First, Madani et al.[68] summarized the key takeaways of surgical planning and error prevention, which we divided into pre-operative, performance, and post-operative phases for a more simplified comparison. In the pre-operative phases, the framework identifies the importance of assessing the patient physically, patient tolerance for the procedure, the surgical field to ensure appropriate clinical management of the patient, and collaboration with other experts.[68] Additionally, the expert will collaborate with the patient and substitute decision-makers for care.[68] In the current study, experts took a similar approach; however, there was a greater emphasis on preparing for the procedures such as gathering equipment and personnel before assessing the patient. Furthermore, because surgery can be higher-stakes than medical procedures, there was more focus on risk assessment and management in the preparation phase of the Intraoperative Performance Framework compared to our findings.[68] Similar to our findings, during the performance phases, the expert is constantly using strategies for procedure optimization such as positioning the patient, ensure proper lighting, and appropriate force needed when utilizing equipment. Also, the expert shows awareness of the risks of repeat attempts at a task and therefore tries something new with each additional attempt. In the post-procedure phase, similar to our findings, expert surgeons also focus on testing and monitoring for the confirmation of procedure success and focus on infection control.[68] Lastly, in approaching unexpected events, the framework highlights similar steps to address these situations where the experts needs to identify the problem, develop a plan to solve the issue, and discuss the backup plans with the team.[68]

There were a couple skills that we identified in the current study that were not highlighted in the Domains of Intraoperative Performance Framework.[68] First, communication with the healthcare team and caregivers was not a main focus in the framework. There were some mentions of communication with the team; however, the participants of the current study identified communication as being weighed highly compared to other skills as it is needed in all procedures, regardless of the procedural category. Experts shared that communication is needed at every phase of the procedure emphasizing the procedural pause in the preparation phase to discuss the procedure plan and create a shared mental model of the procedure, during the procedure to identify the next steps, and in the post-procedure phases for monitoring and testing efforts. Communication with caregivers was also deemed important by experts as caregivers will usually be supporting patients in pediatrics and giving consent for the procedures. In the Domains of Intraoperative Performance Framework, there were greater efforts in discussing the goals and care plan of patients with the substitute decision-maker,[68] compared to the present study where experts mainly discussed communication with caregivers to obtain consent, communicate during the procedure if caregivers are in the room, or in the post-procedure phases to update the caregivers. Communication, especially in pediatric care, is a core competency involving the delivery of information and asking and answering questions.[81] Caregivers and clinicians both have communication and decision-making roles within pediatric care.[81] Caregivers are a unique aspect of pediatric care where they are usually the communicators and decision makers for pediatric patients.[81] Caregivers communicate regarding the patient's medical history and symptomatology, and they make decisions regarding the patient's care plans and healthcare needs.[81] Clinicians have similar responsibilities where they are communicating treatment plans and services to patients and caregivers, allowing them to make informed decisions.[81]

Lastly, experience with medical procedures was a minor point of discussion amongst our participants that The Domains of Intraoperative Performance Framework briefly addressed.[68] The framework identifies the need for in-depth knowledge and experience for some skills, such as tacit knowledge, to create a mental model for some clinical cases to support procedure performance and reduce cognitive load.[68] Additionally, a small number of participants in the present study mentioned the importance of experience in procedures to allow for greater focus on skills such as adaptability, as experience helps support pattern recognition in procedures and can allow conscious efforts to develop advanced skillsets.

To create a more holistic understanding of procedural expertise in pediatrics, The Domains of Intraoperative Performance Framework should be modified based on our findings, so that the framework provides a guide for domains of pediatric procedural performance. Specifically, the main modification should include a focus on communication skills with the healthcare team and caregivers before, during, and after a procedure. The addition of communication skills under these circumstances will allow the framework to be applicable to procedural expertise in various pediatric contexts. Furthermore, although not a skill, experience in medical procedures can be added to the framework as a point of the conceptualization of expertise as more experience within a subject matter can help the continuous building of expertise through greater pattern recognition and greater automaticity of various skills.

4.7 Implications

The findings of this thesis suggest that procedural expertise requires both technical and non-technical skills with great emphasis on non-technical skills. The non-technical skills that we identified from our findings were knowledge, communication, decision-making, problem-solving, situational awareness, and emotion management. Incorporating teaching and assessment of these non-technical skills within the already existing medical education curricula that tends to focus on technical skills can support learners in developing procedural skills and allow learners to develop a more holistic understanding of medical procedures. We suggest that these skills be implemented within early training, through a layered approach, so that junior trainees could focus their procedural training on technical skills, especially psychomotor, and non-technical skills in less nuanced contexts (e.g., receiving consent from the patient/family for low stakes or common procedures, communicating with team members during the procedure when the procedure is moving forward as planned). With level appropriate learning and assessment objectives, these can be mostly done in simulation contexts using mannequins, task-trainers, virtual simulations, or having standardized patients, but junior trainees should continue to have clinical exposure. Then, as junior trainees progress through their training and take on senior roles (i.e. senior resident, fellow), their procedural training could continue to include technical skills (e.g., psychomotor, simple decision-making such as choosing the equipment), but have a major focus on non-technical skills in more nuanced contexts (e.g., developing and sharing a procedural mental model, decision-making regarding next steps when there is a complication, communicating with the patient, family, and team when there is complication during the procedure, managing time, managing their emotions and their team's emotions). These can also be done in simulation contexts including in-situ simulations and interprofessional team training, in addition to clinical exposure. Furthermore, within the current assessment approaches such as through EPA assessments, we suggest that the non-technical skills highlighted in this thesis be mapped onto current procedural EPAs and associated assessments, to ensure integration of non-technical skills with technical skills. With a more holistic approach to assessment, educators can ensure that learners understand the role and importance of non-technical skills for procedural performance, and that it is as important as technical skills for procedural success. For example, in 'Pediatrics: Core EPA #1 Resuscitating and stabilizing neonates following delivery', the milestones do not mention communication with health professionals or with caregivers however, based on the interviews, the importance of communication skills, especially in high stakes procedures such as resuscitation, was very clearly highlighted by participants. Additionally, even with the currently used EPA assessment forms, there can be further emphasis on the non-technical skills that we have identified that are not a part of the form. Furthermore, as mentioned before, the literature that has explored integrating non-technical skills within medical education assessment mostly used tools such as DOPS, OSANTS, and OSATS, even though these assessments are not commonly implemented as a part of learner assessment. Therefore, although these tools maybe helpful in assessment, we would recommend integration of technical and non-technical skills as a part of EPA assessment forms, which are currently implemented for learner assessment. Lastly, debriefing and feedback as a part of simulation or clinical assessment will be important with non-technical skills acquisition, as specific feedback given in a timely manner can help learners understand how improvement of non-technical skills is a part of the bigger picture of procedural performance. Debriefing can also be especially important for skills such as emotion management, a non-technical skill that can be difficult to teach and assess as it may not be outwardly visible to others; however, by discussing emotions especially in high stress situations, it can help learners understand how to manage emotions and its role in procedural success.

Within teaching practices, we suggest the incorporation of non-technical skills during procedural performance in both the simulation and clinical settings. In the simulation setting, oftentimes, some of the non-technical skills can be skipped because the focus is solely on technical performance, which is seen as foundational compared to non-technical skills. For example, before starting a simulation for an IO placement, the learner may mention that they spoke to the family, obtained consent, and are ready to begin the procedure, but simply stating the necessary pre-procedural non-technical skills may not be enough to develop expertise. Instead, we suggest that simulation training includes scenarios that would help learners practice those non-technical skills. Referring back to the IO example, having simulated patients in the room acting as a distressed caregiver could help learners be situationally aware of the patient and caregiver needs, while also needing to focus on technical aspects of performing the procedure and communication with the caregivers and the healthcare team. Additionally, one of the benefits of simulation is that learners and educators can stop and discuss during the simulation to support learning. Thus, pausing the simulation and discussing skills such as situational awareness, knowledge, and decision-making can help learners develop these skills. For example, in a resuscitation simulation, the educator can pause the simulation from time to time to assess the learner's knowledge and decision-making for the next steps of the procedure, or the educator can add more complex factors to help teach situational awareness. In the clinical setting, similar steps can be taken to teach non-technical skills; however, these opportunities may be more spontaneous and unpredictable depending on the clinical context and patient. As mentioned before, not all procedural cases will require the same skills with the same weighted importance (e.g. some procedures may require more situational awareness than others). Thus, the clinical setting can provide learners the opportunity to build on what they have learnt in the simulation setting, and train on technical and non-technical skills according to the demands of the clinical setting. Lastly, a key aspect of learning the technical aspects of procedural skills is observation of experts performing procedures, and we suggest a similar outlook on non-technical skills. By having learners observe clinicians perform non-technical skills such as communication, decision-making, and problem-solving, it will allow them to understand the interplay between technical and non-technical skills and help them apply these skills to their own performances. For example, a learner may observe that a clinician chooses to use drawings when they are explaining procedures to the caregivers, in turn, a learner may also choose to do the same.

4.8 Limitations

A potential limitation of this study is selection bias. We recruited any pediatrician, who is currently accredited with the Royal College of Physicians and Surgeons of Canada, who performs procedures as a part of their clinical practice in pediatric emergency medicine, pediatric gastroenterology, neonatology, and pediatric critical care. We decided to follow this recruitment strategy as we believe that there are no criteria for procedural expertise that we could identify in the literature. Currently, some of the 'subjective' markers of procedural expertise include number of procedures performed and years in practice. However, as current literature suggests, such as Ericsson's work,[64,66] completing a task repeatedly does not automatically transfer to improvement or expertise. Instead, it can actually plateau development where no more improvements occur. Therefore, without having a clear criteria of an expert, we might have recruited physicians who may not be experts in pediatric procedures, which could have impacted our findings. Some may argue that there are current frameworks of expertise such as CANMEDS,[4,82] which encompasses both technical and non-technical aspects of a medical expert. However, it may not have been feasible for us to use the CANMEDS medical expert role as a selection criteria for expertise, as technically, all practicing physicians would embody the core role of a 'Medical Expert' once training is complete. Nonetheless, we certainly reviewed the CANMEDS framework as a part of our background literature search and to support our data collection. Furthermore, although we chose to recruit participants from procedural-heavy specialties, the transferability of our findings should still be considered in other contexts, as even within the specialties we included, there were differences in the importance of specific skills. Additionally, there are other non-procedure heavy specialties within pediatrics that we did not include in the study who are expected to perform a small number of procedures in their clinical practice. Pediatricians in those specialties could have had different understandings of procedural expertise. Also, contextual factors such as population (e.g., age group),[83] settings (e.g. small or large hospitals, rural regions),[83] advancements within medicine (e.g. moving to minimally invasive procedures), and institutional policies (e.g., institutes having guidelines regarding the number of attempts for a specific procedure before paging another specialty) should be considered in the transferability of our findings.

CHAPTER 5: CONCLUSION

The Royal College of Physicians and Surgeons have identified certain EPAs related to procedural skills that residents are expected to develop competency. Our current understanding of procedural skills depends heavily on technical skills, such as the psychomotor aspects of performance, creating a limited understanding of expertise in procedural skills. Without a full understanding of the domains of procedural expertise, teaching and assessing these skills may be inadequate for safe and effective patient care. In this thesis, we aimed to understand the core principles that guide expert performance during pediatric procedures, going beyond technical skill domains. We conducted a qualitative description study, guided by a constructivist perspective. For our methods, we conducted semi-structured interviews with faculty members from Departments of Pediatrics across Canada.

Our findings showed that there are non-technical skills required in procedural expertise that capture all phases of the procedure (e.g., preparation, performance, and post-performance) and these skills are especially important in navigating expected or unexpected events during procedures, such as complications. Specifically, we found that decision-making skills and situational awareness were key in procedural expertise as these skills were needed in all procedures but at different degrees depending on the procedural category.

Madani et al.[68] have worked to define the core principles that guide the intraoperative behaviours and decisions of expert surgeons and created a universal framework highlighting these skills. In this thesis, we found that the skills needed for procedural expertise outside of the operating room are similar to those of expert surgeons. Specifically, this thesis and Domains of Intraoperative Performance Framework uncover that skills such as psychomotor skills, knowledge, and situational awareness are all important aspects of expert performance. However, we found that with expert performance in medical procedures in pediatrics, there was more emphasis on communication with the healthcare team and caregivers. It is important to note that pediatrics is uniquely positioned where caregivers are heavily involved with the care of patients and thus there is an extra layer of communication and decision making that occurs in these settings, which can point to why communication was weighed with more importance in our findings.

In conclusion, procedural performance is an important aspect of pediatric care, and trainees are expected to be competent in procedural skills to perform safely and independently. The findings of this thesis outline that procedural performance goes beyond technical skills, with great emphasis on non-technical skillsets. These findings can inform teaching and assessment efforts encompassing both technical and non-technical aspects of performance to help develop competency in procedural skills.

TABLES AND FIGURES

Table 1: Theme overview, definition, and examples.

Theme	**Definition and Examples**
Procedural Expertise Requires Skills that Go Beyond Psychomotor Skills, and Relies Heavily on Non-Technical Skills	Definition: This theme explores the different skills that are required to perform procedures at an expert level. These include technical skills (e.g., psychomotor skills) and non-technical skills (e.g., decision-making). Namely, the skills that were discussed the most by participants were knowledge, situational awareness, problem solving, communication, emotion management, and clinical experience. *Examples:* ● *"There is going to be a level of hand-eye coordination that you are going to need for all of them. You are going to need to know how to do your landmarking." P5* ● *"The decision-making sometimes doesn't come just with reading books, it comes with a lot of experience and having seen a lot of cases." P2* ● *"The communication in the room is hugely important. I mean, anything that's an intervention, the nurse needs to be communicating and closed loop communication back and forth for the proceduralist." P14*
The Generalization of Procedural Expertise is Dependent on the Skills, Specialty, and Contextual and Patient Factors	Definition: This theme explores the generalizability of the skills required to perform a procedure at an expert level

	independent of the procedural category. *Examples:* ● *"I think general principles need to apply for all procedures [...] I think that at the beginning, like my kind of approach through procedures, I think like that's the type of approach that people need to maintain throughout all procedures." P18* ● *"I do believe that there are general principles with specific points that need to be mentioned more strongly or less strongly for each category, but I do believe that the more you train your mind to think the same way, the [less] complications and unexpected things will happen." P2*
Approaching Expected/Unexpected Events in Procedures and Deciding on Adaptations is a Crucial Part of Expertise	Definition: This theme uncovers the variety of ways in which experts adapt during expected or unexpected events in a procedure, and the skills needed to make these decisions. *Examples:* ● *"If we are unable to complete the procedures in a high-stakes event then we will stop partway through. You know sort of reset and reassess the patient and try and figure out what it was that was causing the difficulty. You know try to change the environment or the context or the situation or the patient position or something to you know increase our chances of success. Try again with a*

	slightly different approach for different acquittance." P7 ● *"Yeah, so intubation we do have a backup plan. So, for example we have backup, we have a smaller tube if it doesn't fit or a second more experienced [intubator] if you have [failed] your two attempts. Or if you can't see you have suction, we have the video laryngoscope if that helps. So, we have those things in place, but you can get to the end of your backup solutions and then you are working on the fly." P10* ● *"So [...] I think the biggest thing in expertise, this might sound funny is when to not proceed. You know, people who don't have the experience will keep trying and then, you know, cause complications. The experts actually know when to stop. They know when to, you know, change the scope, change the patient position, do something differently to prevent complications." P14*
Pediatric Training Programs Use a Variety of Approaches in Procedural Training	Definition: This theme explores how trainees are trained for procedural skills. *Example:* ● *"For our trainees, yes, I think it goes to the procedural skills days where we will go through the same thing over and over and over again to ensure that they are getting more deliberate practice with regards to certain*

	procedures and ensuring that that's happening." P18
Decrease in Procedural Opportunities for Experts Lead to Skill Decay	Definition: This theme explores the procedural skill decay faced by experts and trainees. *Example*: ● *"The one thing I will say is that working in an academic center, it's actually really difficult to maintain yourself as an expert by also teaching trainees because all the things I just told you, I don't do the procedures myself very often anymore." P16*

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APPENDICES

APPENDIX A: INTERVIEW GUIDE

Title: Procedural Expertise: Sample Interview Questions

MSc Student: Ms. Jasmin Dhanoa

Supervisor: Dr Elif Bilgic

Before we dive deep into the interview, I will be providing a simple definition of Procedural Skills, just to make sure that we have a shared understanding. In simple terms, procedural skills can be defined as "the mental and motor activities required to execute a manual task. Procedural skill competence requires both safe technical performance and appropriate knowledge for decision-making in the preparation, performance and post-performance phases of the procedure."

1. Before we dive into the questions, can you please tell me a little bit about your medical training, background, and faculty position in the hospital.
2. Within your practice, what are the procedures that you perform that you would categorize as high stakes versus low stakes?
    - **a.** What makes these procedures high stakes?
    - **b.** What makes these procedures low stakes?
3. What are the procedures that you perform that you would categorize as easy versus difficult?
    - **a.** What makes these procedures easy?
    - **b.** What makes these procedures difficult?
4. What are the procedures that you perform that you would categorize as common versus rare?
    - **a.** What makes these procedures common?
    - **b.** What makes these procedures rare?

With the following questions in this interview, we want to unpack what expertise is for procedures, based on your own experiences and perceptions. Just so that we have a shared understanding, an expert can be defined as an individual who "devote[s] most of their lives to attaining the highest levels of performance in a highly constrained activity."

We understand that each procedure has their own unique required clinical skills, but we ask that you think of the different procedures you perform/expected to perform across *the 3 categories and provide us with your perspective on how you approach a procedure. And feel free to give examples from specific procedures.*

5. Please describe the major steps and tasks required to perform the high stakes procedures. I know that there are several procedures that you have categorized as high stakes, so we are interested in the general approach that you take before, during, and after performing a high stakes procedure. You can use one of the procedures as an example to start with.
    - **a.** How is your approach, including major steps and tasks, similar or different when performing one of the low stakes procedures?
    - **b.** What about for the easy versus difficult procedures?
    - **c.** Common versus rare?
6. Based on your experiences, when you are the lead physician what knowledge and skills (technical and non-technical) do you believe are necessary to perform a procedure at the expert level? We will first start with the high stakes procedures that you perform, and feel free to give examples from specific procedures.
    - **a.** How do you approach unexpected events (e.g., complications, inability to move forward to due anatomy) in the high stakes procedures that might be different than the routine course of action?
    - **b.** How do you decide when adaptations are necessary and which adaptation to choose in the high stakes procedures?

   How are your responses similar or different to low stakes procedures?
    - **c.** How do you approach unexpected events in the low stakes procedures?
    - **d.** How do you decide when adaptations are necessary and which adaptation to choose in the low stakes procedures?
7. Now think of the easy versus difficult procedures. What skills (technical and non-technical) do you believe are necessary to perform these procedures at the expert level?
    - **a.** Are there any differences to how you would approach unexpected events in easy versus difficult procedures?
    - **b.** What about when deciding that adaptations are necessary and which adaptation to choose?
8. Now think of the common versus rare procedures. What skills (technical and non-technical) do you believe are necessary to perform these procedures at the expert level?
    - **a.** Are there any differences to how you would approach unexpected events compared to your responses before?
    - **b.** Are there any differences when deciding that adaptations are necessary and which adaptation to choose?

9. When you perform one of the high stakes procedures with a (junior or senior) trainee, which skills do you observe them struggling with? Again, feel free to give examples from specific procedures.
   a. How about the low stakes procedures?

10. What skills in the easy procedures do you observe trainees having an easier time performing (junior or senior residents)? Please give specific examples.
   a. How about the difficult procedures?
   b. Do you think these are still important for procedural performance at the expert level?

11. What about for easy procedures, which skills do you observe trainees (a) struggling with, and (b) having an easier time with?
   a. How about for the difficult procedures?

12. Are there any differences in your responses for common versus rare procedures, regarding which skills do you observe trainees (a) struggling with, and (b) having an easier time with?

13. How does your program currently train trainees (residents, subspecialty residents/fellows) for procedures? *(probe: watching videos, conferences, professional development workshops, simulation training etc.)*

14. Based on all the answers that you have given above, do you think the features of expertise that you have mentioned across the 3 procedure categories are specific to a certain procedure or could there be general principles that apply to all procedures?

15. How much simulation training is involved in your program to teach procedural skills?
   a. Which of the 3 procedure category(ies) is the focus of simulation training?
   b. Types of simulators used for which skill
   c. Frequency of the sessions
   d. Instructors
   e. How effective do you think this training is?
   f. Are there unmet needs not being addressed by the current simulation efforts to teach procedural skills?

16. Deliberate practice can be defined as purposeful training to improve performance in a specific skill. Do you use deliberate practice in your own continuing professional development and/or to train trainees for procedural skills, in the clinical and simulation settings?
   a. If yes, what are some examples of instances where you use deliberate practice in your own career and/or in training trainees?

17. Before we conclude the interview, is there anything else you'd like to share with me about procedural expertise that we haven't yet covered?