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Efficacy of a pediatric procedure curriculum on resident training

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A B S T R A C T

Background: There is growing concern that residents are not receiving the necessary experience to become proficient with medical procedures. We created a structured curriculum to improve resident comprehension, experience and confidence with pediatric procedures.

Methods: A two-week procedure curriculum commenced with a three-day training course to review 26 pediatric procedures using lectures, videos, demonstrations and simulations. Residents spent the remainder of the rotation as the hospital's on-call *procedure resident*. Pre- and post-rotation surveys, knowledge testing and procedure logging were used to evaluate course effectiveness, along with follow up metrics a year after completing the rotation. Results were compared to a control group of residents completing their second year of residency who did not participate in the curriculum.

Results: Participants ($N = 35$) averaged 67.2 procedures over the 2 weeks, compared to 41.3 procedures for controls ($N = 20$) during their first 2 years of residency. Participants had a higher confidence than controls (3.0 vs. 2.5 on a five-point scale) and better knowledge (65% vs. 47% correct on testing), both statistically significant. Compared to their own individual pre-rotation scores, participants showed improved knowledge (49% vs. 65%) and confidence (2.0 vs. 3.0), both statistically significant. Long-term follow up showed that these improvements were mostly sustained a year later.

Conclusions: Overall, interns completing the rotation demonstrated procedure counts, knowledge levels, and confidence greater than rising third year residents. Participants were inclined to have superior confidence in procedures where higher procedure counts were achieved. Most results were sustained over the course of one year.

The Accreditation Council for Graduate Medical Education (ACGME) requires that all pediatric residencies competently educate their residents to perform procedures utilized by a pediatrician in general practice, and expose them to relevant subspecialty procedures if they choose to pursue a specific post-residency career (Table 1) [1]. There is growing concern that pediatric residents are not proficient in performing common pediatric procedures recommended by the Residency Review Committee [2–8]. Lagging proficiency in these skills has implications for general pediatric practice, and may be a handicap both for pediatric advanced life support and for pediatric subspecialty training programs with significant hands-on skill requirements – such as cardiology, emergency medicine, and critical care medicine.

There is no consensus on the most effective methodology to translate procedural education into improved clinical performance [8]. Simulation [9–12], video [13,14] and demonstration [14] have all been shown to provide procedural competence at the end of training, but fail to improve retention over time [9,10,15–17].

We designed a unique, multifaceted educational curriculum in hopes of enhancing resident experience, knowledge, and confidence with 26 pediatric procedures. These procedures ranged from relatively mundane skills – such as urethral catheterization and splinting – to more advanced, subspecialty-related procedures – like ultrasound-guided central line placement, cardioversion, and defibrillation. Our 2-week curriculum begins with 3-days of multimodal educational didactic

Abbreviations: ACGME, accreditation council for graduate medical education; [RPP(s)], representative pediatric procedure(s); NI, new innovations©; SRE, self-reported experience; PIV, peripheral intravenous access; GUC, genitourinary catheterization; LP, lumbar puncture; UA, umbilical access

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Table 1
Incorporated procedures and method of instruction.

Arterial lines	Simulator, Video
Arthrocentesis ®	Simulator, Video
Bag-Valve-Mask ventilation*◊®	Video, multiple simulators
Central venous lines	Multiple Simulators, Video
Cervical spine and trauma management	Simulator, Lecture
Chest tube	Simulator
Circumcision ®	Video
Clinical photography ®	Lecture, Demonstration
Defibrillation and cardioversion◊	High-fidelity simulation
Genitourinary catheterization*®	Simulator, Video
Incision and drainage*	Simulator, Video
Informed consent	Traditional lecture
Intraosseous access◊	Simulator, Video
Intravenous access and venipuncture*®	Simulator, Video
Laceration repair*®	Simulator, Video
Laryngeal mask airway	Simulator, Lecture
Lumbar puncture*®	Simulator, Video
Musculoskeletal examination	Lecture, Demonstration
Nasogastric tube	Simulator, Video
Neonatal intubation*○	Simulator, Lecture
Non-neonatal intubation ◊®	Video, multiple simulators
Pain management	Traditional lecture
Procedural Sedation ®	High-fidelity simulation
Splinting*®	Simulator, Video
Umbilical catheterization*○®	Simulator, Lecture

ACGME required* procedures and procedures involved in required pediatric advanced life support◊ and neonatal resuscitation program○ certification. ® Signifies Representative Pediatric Procedures (RPPs).

sessions followed by a focus on live patient encounters. To our knowledge, there have been no validated pediatric procedure curricula that utilize this structure.

1. Methods

1.1. Curriculum development and implementation

Under the direction of program leadership, a multidisciplinary team of faculty, nurses and ancillary staff convened to design, implement and teach the procedure rotation curriculum in a pediatric residency program of a free standing children's hospital. The committee chose 26 pediatric procedures that include both core ACGME and subspecialty procedures (Table 1). The curriculum is 2-weeks in duration, commencing with a 3-day training course (Figs. A & B). Our goal is to expose residents to a vast array of procedures, most of which can be reinforced by live patient encounters during the rotation. While recognizing that they did not represent all procedures to which a resident could be exposed, the curriculum development committee agreed upon the selected procedures as representing meaningful exposure for our residents.

Applicable components of the curriculum were assigned to faculty and staff that primarily taught these experiences (e.g., umbilical line education was created by a neonatologist). The curriculum uses various methods of teaching including readings, demonstrations, simulations, lectures, and videos from the New England Journal of Medicine© online series (Waltham, Massachusetts) [18] and the Patient Outcomes In Simulation Education Network (New York, New York) [19] (Table 1). The methodology of how to teach the procedure, the standardized step-by-step checklist and the complete curriculum for each procedure were reviewed by the curriculum committee. These formalized educational tools are used to teach participants during their introductory course, and are also provided in a procedure manual for the residents. This manual also contains a set of relevant articles selected by the faculty for each procedure, and several related topics such as informed consent and pain control.

Using the established curricular tools, each topic is taught by a faculty or staff member who has particular expertise in the procedure during the introductory 3-day course (e.g., a pediatric rheumatologist teaches arthrocentesis). Approximately 50 faculty and staff teach topics each year. Most sessions begin with a lecture or video followed by a guided simulation or demonstration performed by the resident with preceptor feedback. After their initial training, residents then spend the remainder of the rotation working 8–10, ten-hour shifts as the in-house procedure resident on-call for the hospital.

The resident on-call carries a phone specific for the rotation. Personnel throughout the hospital were educated regarding the curriculum's implementation and the resident's phone number is widely distributed. Hospital staffs are encouraged to contact the resident any time there is a procedure being performed. If the procedure is already being conducted by another trainee, procedure residents are expected to observe or assist. In doing so, there is no disruption to the educational development of others. We expect the procedure resident to be directly involved in all aspects of the procedure including the consent process. All in vivo procedures have preceptors who provide feedback and sign the resident's log. Preceptors can be any staff member who normally perform the given procedure(s): nurses, nurse practitioners, fellows, and attendings. There was no formal training for preceptors, although many served as instructors for the initial 3-day series of didactics.

1.2. Study population and setting

All 35 participants in the curriculum were interns starting their pediatric residency in June of 2012 or 2013. Typically, 2 to 3 residents were assigned to the rotation at a time. The control group was 20 rising third year residents in June of 2012 who did not participate in the curriculum (Table 2). The study was performed at an urban, academic, tertiary referral center that has 24-hour peripheral intravenous access (PIV) and phlebotomy teams, along with daytime sedation and peripherally inserted central catheter teams. The study was approved by our local Institutional Review Board. None of the participants on the rotation chose to opt out of the study during their orientation and thus consent was received. There was no other formalized procedure training for controls/participants except for pediatric advanced life support instruction and a 1-h suturing course prior to starting internship.

1.3. Outcomes

Pre- and post-rotation knowledge testing was done via web-based examination on all participants. The curriculum committee formulated a 20 question multiple-choice test based on the curriculum and literature provided to the participants. The questions were developed by content experts in each field using the literature provided, and then accepted by the committee to represent important components of the curriculum. These questions were not meant to cover every procedure, but were designed to discriminate deep understanding of key procedures. The questions focus on critical steps, complications, limitations and practical details that were emphasized in the teaching sessions (See Appendix 1). The pre- and post-rotation testing were identical and completed 1-week prior to and 1-week following the rotation accordingly. Trainees, and most faculty who did not directly formulate the questions, had no knowledge of these questions ahead of time and the answers were not divulged to minimize bias.

In addition, pre- and post-rotation confidence level was surveyed using 1 to 5 Likert type response items for the trainee's self-reported confidence to successfully complete the procedure (1 = 'No Confidence;' 2 = 'Slightly Confident;' 3 = 'Moderately Confident;' 4 = 'Very Confident;' 5 = 'Completely Confident'). The control group also completed this knowledge and comfort testing.

Participants kept procedure logs throughout the rotation that required the signature of the preceptor. A procedure could be

Time	Day 1	Day 2	Day 3
8 am	**Pediatric Residency Morning Report** ***Rotation Orientation***	**Pediatric Residency Morning Report** ***Break***	**Pediatric Residency Morning Report** ***Break***
9 am	**Informed Consent** **Pain Management**	**Bag-Valve-Mask** **Airway Adjuncts**	**Central Venous Lines**
10 am	**Intravenous Access**	**ET Placement** **LMA Placement**	**Central Venous Lines** **Arterial Lines**
11 am	**Intravenous Access**	**Trach Changes** **Intraosseous Lines**	**Pediatric Transport**
Noon	**Pediatric Residency Noon Conference**	**Pediatric Residency Noon Conference**	**Pediatric Residency Noon Conference**
1 pm	**Nasogastric Tubes** **Urethral Catheters**	**Lumbar Puncture**	**Arthrocentesis**
2 pm	**Clinical Photography** ***Break***	**C-Spine/Trauma** ***Break***	**Musculoskeletal Exam** ***Break***
3 pm	**Umbilical Lines**	**Wound Repair**	**Defibrillation &** **Cardioversion**
4 pm	**Neonatal Airway**	**Incision and** **Drainage** **Splinting**	**Procedural Sedation**
5 pm	**Chest Tubes** **Circumcision**	**Splinting**	**Procedural Sedation**

Fig. A. Schedule of initial 3-day didactic curriculum for the procedure rotation.

documented if it was observed, a failed attempt, or successfully completed. By signing a successful completion, the preceptor acknowledged that the participant was both competent in the procedure and obtained the desired outcome. Participants received reference number goals for each procedure during the rotation that were consistent with those set by the program director for residents to obtain during their 3 year residency. For the control group, web-based New Innovations© (Uniontown, Ohio) procedure logs from the first two years of residency were used to assess their experience. In New Innovations© (NI) there is only the ability to log unsuccessful or successful attempts, not observation. Controls were encouraged to complete procedure logs regularly, including their semi-annual reviews, but never as a formal course.

Representative Pediatric Procedures (RPPs) signified 12 of the 26 procedures that were chosen to be individually analyzed (listed in Table 1). The committee chose this heterogeneous group prior to curriculum implementation to investigate a sample mix of both generalist and subspecialty procedures. They also represent a blend of procedures that are perceived as either common or difficult to obtain at our residency.

Confidence in these RPPs was measured for both participants and controls. Experience for these RPPs was measured using 2 different methodologies: logged patient encounters during the rotation as outlined above and historically recalled, self-reported experience (SRE) of performed procedures (6-point Likert type item: 1 = never performed the procedure; 2 = performed 1–3 times; 3 = 3–5 times; 4 = 5–10 times; 5 = 10–20 times; 6 = 21 + times).

In addition to gathering the pre- and post-rotation metrics, the first class of interns to complete the rotation was reevaluated for retention as they started their third year of residency – 13 to 24 months after the rotation. The follow-up testing was identical to the pre- and post-testing. Procedure experience for both controls and participants was analyzed using their NI logs and SRE. This follow-up data was compared as a group against historical controls, and pairwise against each intern's own original results.

1.4. Statistical analysis

Ordinal data from knowledge and comfort testing were analyzed using Mann-Whitney U and Wilcoxon tests. Statistical analyses were performed using IBM® SPSS Statistics version 21 (Armonk, NY). Two-sided P values of < 0.05 indicated statistical significance. Given the fact that the procedure logs were collected differently for controls and participants, statistical confidence (p-values) was not calculated. For all other outcomes, we report point estimates and confidence intervals for differences between participants and controls.

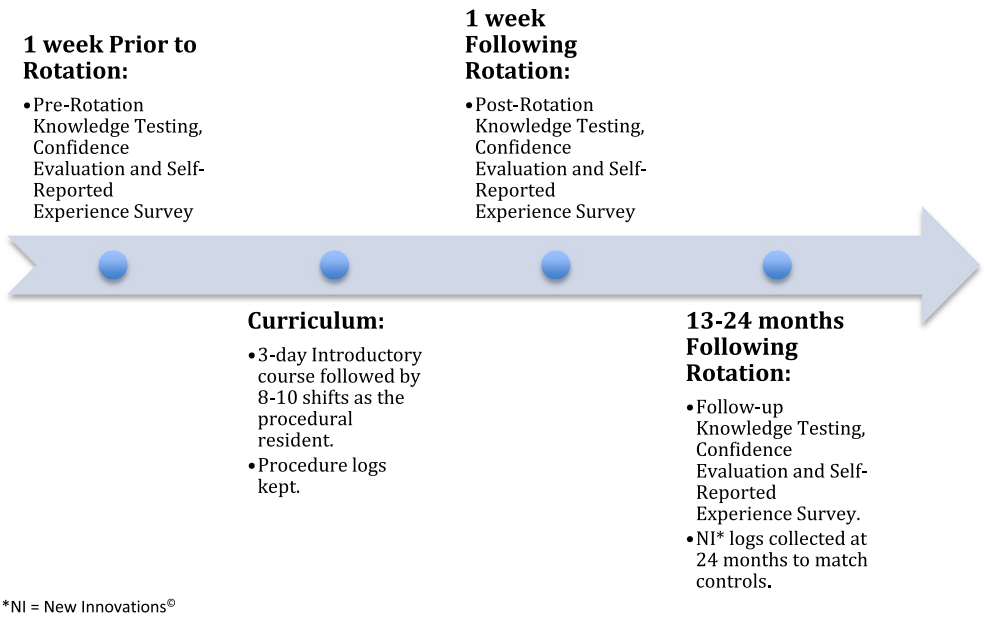

Fig. B. Curriculum timeline for participants.
*NI = New Innovations©.

Table 2
Subject characteristics.

	Control group	Participant group
Participant number	20	35
Gender, female, %	64	57
Age, mean (range), *years*	29.2 (26–35)	27.8 (25–30)

2. Results

There were 35 participants and 20 controls (Table 2). All participants completed the rotation successfully without any withdrawals, but only 28 completed all testing and surveys required for study eligibility. NI data were collected from the entire control group, while only 10 controls completed all required testing and surveys.

Rotation participants averaged 67.2 procedures over the 2 weeks vs. 41.3 procedures for controls during their first two years of residency (Table 3). For RPPs with comparable control data, participants averaged 51.5 logged RPPs over the 2-week curriculum vs. 37.2 in the control group over the first 2 years of their residency. On our 1–6 Likert, surveyed participants self-reported (SRE) a mean successful RPP score of 2.5 post-rotation vs. 2.4 for controls (Table 3).

Among participants, PIV was the most common procedure (17.6 per resident during the 2-weeks). The least common procedures were intraosseous access (2 over the entire study) and cardioversion/defibrillation (5 logged). Among controls, the most common NI procedures during their first 2 years of residency were lumbar punctures (LP; 9.7 per resident) and wound repairs (7.3 per resident). Least common procedures were genitourinary catheterization (GUC; 0 logged), and intraosseous access (2 logged). For RPPs with comparable logged control data, participants had higher logged procedure counts in GUC, PIV, procedural sedation and splinting. Controls had higher NI logged in circumcision, endotracheal intubation, laceration repair, LP and umbilical line access (UA). For SRE RPPs, participants had significantly more GUCs and PIVs. Controls had higher SRE RPPs in endotracheal intubation, LP and UA that were statistically significant.

Participants completing the rotation had a higher overall confidence score from all procedures compared to controls (3.0 vs. 2.5; $P < 0.005$). The confidence level and number of logged and SRE procedures for each individual RPP are compared in Table 3.

Participants also scored higher on knowledge testing compared to controls (65% vs. 47% correct; $P < 0.005$). Compared to their own individual pre-rotation scores, participants showed improved knowledge (49% vs. 65%; $P < 0.001$) and confidence (1.9 vs. 3.0; $P < 0.001$) following course completion (Table 4).

Nine interns from the first intern class completed metrics again as they began their third year of residency. Results of this long-term follow up are summarized in Tables 5 and 6. Additionally, NI logs for the original intern class was collected at the start of their third year and showed an average of 71 procedures per resident vs. 41 for controls. A breakout of RPP's for controls and trainees at the start of third year is included in Tables 5A & 5B.

Table 6 displays the long-term pairwise retention data for confidence and knowledge testing. Knowledge testing went from 49% correct pre-rotation to 62% post-rotation to 54% with long-term follow-up. Likewise, pairwise confidence went from 1.8 pre-rotation to 3.0 post-rotation to 3.0 at follow-up.

3. Discussion

Overall, intern participants had noticeably higher logged procedure counts during the 2-week rotation compared to controls over the first 2 years of residency (67.2 vs. 41.3). When considering the two opposing time frames between groups, we feel that this difference represents a significant improvement in exposure. This trend was also seen for RPP counts in both logged and SRE experiences – which were essentially identical for participants and controls for the contrasting time frames.

With the exception of splinting, experience seemed to be particularly improved in procedures that are traditionally performed by ancillary staff/services in our hospital (GUC, PIV). These are common procedures that many pediatricians will be required to perform during their careers. In these procedures, participants showed significant improvement over controls following the rotation. In contrast, controls showed stronger performance in procedures that have remained a primarily resident responsibility in our hospital (e.g., LP and UA). Therefore, there is not an easily discernable enhancement during the course of readily accessible procedures. For institutions with limited resources, it may be prudent to focus attention on procedures in which residents have inadequate exposure.

As one would expect, the baseline confidence of our interns was

Table 3
Control versus Immediately Post-Intervention Group Results.

	Control Group			Participant Group			Difference (95% Confidence Interval)	
	# Logged NI/Resident° (n = 20)	# Reported (*n* = 10)	Confidence (n = 10)	# Logged/Resident° (n = 35)	# Reported (*n* = 28)	Confidence (n = 28)	# Reported	Confidence
All procedures	41.3	2.4	2.5	67.2	2.5	3.0	0.1 (−0.5, 0.3)	0.5 (0.1, 0.8)
RPPs								
Arthrocentesis	NA	1.0	1.0	0.3	1.2	2.0	0.2 (−0.1, 0.5)	1.0 (0.4, 1.6)
Bag-valve-mask ventilation	NA	2.4	2.9	0.7	1.8	3.2	−0.6 (−1.3, 0.2)	0.3 (−0.5, 1.0)
Circumcision	5.5	2.7	2.4	0.5	2.1	2.5	−0.5 (−1.6, 0.4)	0.1 (−0.7, 0.9)
Clinical photography	NA	2.3	3.8	2.4	2.6	4.1	0.3 (−0.4, 1.0)	0.3 (−0.4, 1.1)
Endotracheal intubation	3.3	2.2	2.1	0.8	1.5	2.1	−0.7 (−1.5, 0.1)	0.0 (−0.5, 0.6)
Genitourinary catheterization	0.01	1.3	1.9	5.3	3.0	3.8	1.7 (1.2, 2.3)	1.9 (1.1, 2.6)
Laceration repair	8.6	4.2	3.8	6.1	4.0	3.9	−0.2 (−1.0, 0.5)	0.1 (−0.5, 0.7)
Lumbar puncture	10.4	4.6	3.8	3.5	3.1	3.3	−1.5 (−2.2, −0.6)	−0.5 (−1.1, 0.1)
Peripheral access	2.5	1.4	1.5	18.0	4.1	3.1	2.7 (1.8, 3.5)	1.6 (1.1, 2.2)
Procedural sedation	0.5	1.2	1.4	5.7	1.5	1.8	0.3 (−0.4, 1.0)	0.4 (−0.1, 1.0)
Splinting	3.2	3.3	3.4	6.9	3.9	4.2	0.6 (−0.2, 1.3)	0.8 (0.1, 1.4)
Umbilical access	3.3	2.5	2.3	0.6	1.3	1.8	−1.2 (−1.7, −0.7)	−0.5 (−1.1, 0.1)

Likert Scale for # Reported: 1 = Never; 2 = 1–3 times; 3 = 3–5 times; 4 = 5–10 times; 5 = 10–20 times; 6 = 21+ times.
Likert Scale for Confidence: 1 = No Confidence; 2 = Slightly Confident; 3 = Moderately Confident; 4 = Very Confident; 5 = Completely Confident.
"NA" denotes data was not logged and is not available for control group.
"Difference" is the procedure group result minus the control group result. A positive value favors the procedure group, while a negative value favors the control group. A difference of zero (or confidence interval including zero) means control and procedure groups gave similar responses.
°Control procedures represent historical New Innovations© (NI) data which does not include observed procedures; Participant procedures come from the rotation procedure log which does include observed procedures.

Table 4
Participant pre- and post-intervention results.

	Pre-rotation (N = 28)	Post-rotation (*N* = 28)	Mean difference (95% confidence interval)
All procedures			
Knowledge Testing, correct out of 20, mean	9.7	13.1	3.4 (2.4, 4.3)
Confidence in performing procedures, mean	1.9	3.0	1.1 (0.9, 1.2)
RPPs			
Confidence in performing procedures, mean			
Arthrocentesis	1.3	2.0	0.7 (0.4, 1.0)
Bag-valve-mask ventilation	2.4	3.2	0.8 (0.4, 1.1)
Circumcision	2.0	2.5	0.5 (0.2, 0.8)
Clinical photography	2.1	4.1	2.0 (1.5, 2.5)
Endotracheal intubation	1.9	2.1	0.3 (0.0, 0.5)
Genitourinary catheterization	2.0	3.8	1.7 (1.3, 2.1)
Laceration repair	2.6	3.9	1.4 (1.0, 1.7)
Lumbar puncture	2.3	3.3	1.0 (0.8, 1.2)
Peripheral access	1.8	3.1	1.4 (1.0, 1.7)
Procedural sedation	1.1	1.8	0.8 (0.5, 1.0)
Splinting	1.8	4.2	2.4 (1.9, 2.8)
Umbilical access	1.4	1.8	0.4 (0.1, 0.6)

Confidence outcomes were measured by self-reported scores on a 5-point Likert scale where 1 = 'No confidence' and 5 = 'Completely confident'.

lower than our controls. The post-rotation confidence of our participants was statistically higher than the control group (3.0 vs. 2.5). The clinical implication of this confidence difference is more difficult to assess, but may vary by individual procedure. It is interesting that there was a general trend for increased or similar confidence even in procedures where controls had higher procedure counts. This may be explained by the nature of the curriculum, in which there is formal education followed by in vivo practice that can promote confidence.

For individual RPPs, participants had a statistically significant higher confidence than controls in arthrocentesis, GUC, PIV and splinting. Controls had higher confidence in certain RPPs, but none were statistically meaningful. There was a general tendency for enhanced confidence in RPPs where participants had higher counts than controls (GUC, arthrocentesis, PIV, splinting). One may infer that the number of experienced procedures plays a crucial role in formulating performer confidence.

Post-rotation knowledge was significantly higher for participants compared to controls (65% vs. 49% correct, $p < 0.001$). This knowledge gap is more profound when one considers their different level of training. Participants also demonstrated vast knowledge advancement from pre- to post-rotation. Though the knowledge scores may be viewed as relatively low overall, we believe this is attributed to the purposefully challenging design of the knowledge exam. It is interesting to note that the pre-rotation knowledge of our participants almost mirrored that of our rising third-year control group. This finding once again questions the procedural competency of residents and recent graduates even prior to the 2011 ACGME duty hour regulations, and brings into question the level of skills they bring to their subsequent fellowship

Table 5A
Self-Reported Outcomes – Historical Control Group versus Participant Group Results at Start of Third Year of Residency.

Procedure	Control group		Participant group		Difference (95% confidence interval)	
	# Reported (n = 10)	Confidence (n = 10)	# Reported (*n* = 9)	Confidence (n = 9)	# Reported	Confidence
All procedures	2.4	2.5	3.3	3.0	0.8 (0.2, 1.5)	0.5 (0.0, 0.9)
RPPs						
Arthrocentesis	1.0	1.0	1.6	2.1	0.6 (−0.1, 1.1)	1.1 (0.5, 1.8)
Bag-valve-mask ventilation	2.4	2.9	3.1	3.3	0.7 (−0.7, 2.1)	0.4 (−1.0, 1.7)
Circumcision	2.7	2.4	4.0	3.4	1.3 (0.1, 2.5)	1.0 (0.3, 1.7)
Clinical photography	2.3	3.8	3.1	4.3	0.8 (−0.1, 1.7)	0.5 (−0.6, 1.5)
Endotracheal intubation	2.2	2.1	2.0	1.9	−0.2 (−1.3, 0.9)	−0.2 (−0.9, 0.5)
Genitourinary catheterization	1.3	1.9	3.1	3.1	1.8 (1.0, 2.6)	1.2 (0.2, 2.2)
Laceration repair	4.2	3.8	5.0	4.1	0.8 (−0.3, 1.9)	0.3 (−0.6, 1.2)
Lumbar puncture	4.6	3.8	4.7	4.1	0.1 (−1.1, 1.2)	0.3 (−0.7, 1.3)
Peripheral access	1.4	1.5	4.3	2.6	2.9 (1.9, 3.8)	1.1 (0.3, 1.9)
Procedural sedation	1.2	1.4	1.7	1.5	0.5 (−0.3, 1.3)	0.1 (−0.5, 0.7)
Splinting	3.3	3.4	4.3	3.5	1.0 (0.0, 2.1)	0.1 (−1.0, 1.1)
Umbilical access	2.5	2.3	2.4	2.3	−0.1 (−1.0, 0.9)	−0.1 (−0.9, 0.8)

Likert Scale for # Reported: 1 = Never; 2 = 1–3 times; 3 = 3–5 times; 4 = 5–10 times; 5 = 10–20 times; 6 = 21+ times.
Likert Scale for Confidence: 1 = No Confidence; 2 = Slightly Confident; 3 = Moderately Confident; 4 = Very Confident; 5 = Completely Confident.
Due to rounding, small discrepancies appear in some rows of the table.
"Difference" is the procedure group result minus the control group result. A positive value favors the procedure group, while a negative value favors the control group. A difference of zero (or confidence interval including zero) means control and procedure groups gave similar responses.

training or to their general pediatrics practice [2–8]. Going forward, there clearly exist opportunities to improve the curriculum to increase procedural knowledge. Better alignment of formal teaching session content with the expected (tested) knowledge set will be a point of ongoing work.

Similar to our control group, retention data for the first class of participants were obtained prior to entering their third year. Interns did show some decay compared to their post-rotation results (Tables 5A, B & 6). However despite this falloff, there was a significant improvement in participant SRE when compared to controls (71 vs. 41 NI; 3.3 vs. 2.4 SRE, $p = 0.02$). There was also a tendency for improved confidence versus controls. While our small sample size makes it difficult to discern knowledge retention (62% post-rotation vs. 54% long term follow-up), point estimates of confidence on follow-up (3 post-rotation vs. 3 long term) suggest a sustained confidence. This is also seen in long-term pair-wise confidence for each RPP, where residents retained and improved on confidence in most RPPs, but it was once again not statistically significant. It is imperative that knowledge and confidence retention be evaluated over time, and our data suggest that further curriculum improvement to enhance knowledge retention is a clear opportunity.

3.1. Limitations

Generalizability is a key component to any educational model. It is important to recognize that these are the findings of a single residency and hospital. Its success when adapted to other institutions of differing sizes and resources has not been analyzed.

Follow-up survey response was a barrier that may have limited our long-term assessments and conclusions. This variable response rate was likely due to the extensive time commitment to complete these surveys and testing. Long-term validation of this educational model with more participants is warranted to fully evaluate retention of skills.

Measurement of procedural experience was distinct between the two groups. The control group may have underreported the number of procedures performed in NI. However, considering the opposing time frames for controls and participants, a true enhancement in procedure experience cannot be discounted. We were also limited by the fact that NI did not allow controls to log observations. Conversely, follow up experience for both participants and controls was identically assessed via NI (without observations) and SRE data. During data analysis, overlap of some denominations of the Likert for SRE were discovered (e.g. 2 = performed the procedure 1–3 times; 3 = 3–5 times). The exact effect of this subtle overlap is unknown but unlikely to have impacted the results on a categorical scale.

Standardized, in vivo feedback and supervision training for all preceptors in the hospital was not feasible. In addition, success of procedures was not objectively defined for each of the procedures via a standardized checklist manner. For both of these barriers, we relied on the supervising expert to gauge success and provide appropriate feedback. Because there was no change in this practice across the study period, supervision for patient encounters was likely similar for both controls and participants. Therefore, our results primarily reflect the initial 3-day instruction and actual procedure encounters as the main interventions.

The knowledge testing utilized for our study has not been validated, nor was it comprehensive of the curriculum as a whole.

Though it is difficult to assess which component of the curriculum was more important to its success, the authors strongly believe that creating a curriculum with an introductory course was imperative in

Table 5B
Logged Procedures – Historical Control Group versus Participant Group Results at Start of Third Year of Residency.

Procedure	Control Group # Logged NI/Resident (n = 20)	Participant Group # Logged NI/Resident (*n* = 21)	Difference (95% Confidence Interval) # Logged NI per Resident
All procedures	41.3	70.6	29.3 (13.9, 44.6)
RPPs			
Arthrocentesis	NA	NA	NA
Bag-valve-mask ventilation	NA	NA	NA
Circumcision	2.4	3.9	1.6 (−0.1, 3.2)
Clinical photography	NA	NA	NA
Endotracheal intubation	2.3	2.0	−0.3 (−1.5, 0.9)
Genitourinary catheterization	0.0	3.9	3.9 (3.2, 4.7)
Laceration repair	7.3	9.5	2.2 (−1.0, 5.4)
Lumbar puncture	9.7	10.1	0.4 (−2.9, 3.8)
Peripheral access	2.1	13.3	11.2 (7.6, 14.8)
Procedural sedation	1.8	4.7	3.0 (−1.1, 7.1)
Splinting	2.2	6.3	4.1 (1.3, 7.0)
Umbilical access	3.3	3.2	−0.1 (−2.7, 2.4)

Both control and participant data represent procedures logged in New Innovations© (NI) data.
Due to rounding, small discrepancies appear in some rows of the table.
"NA" denotes data was not logged in New Innovations® and is not available for the group.
"Difference" is the procedure group result minus the control group result. A positive value favors the procedure group, while a negative value favors the control group. A difference of zero (or confidence interval including zero) means control and procedure groups gave similar responses.

the residents' stepwise development prior to performing live procedures. We think resident confidence in procedural skills has spillover into overall confidence as young doctors and may lead trainees to pursue interest in subspecialties – such as cardiology, emergency, critical care, and others – in which procedural skill plays a prominent role.

4. Conclusion

Overall, pediatric interns completing our curriculum demonstrated greater procedure counts, knowledge, and confidence than rising third year residents. Participants were inclined to have superior confidence in RPPs where higher procedure counts were achieved compared to controls. Though there may have been some decay in follow-up knowledge retention, multiple areas of procedural competency demonstrated sustained advancement that is noteworthy. As more participants complete pairwise retention analysis, a validation of this educational model may be possible. A curriculum that emphasizes in vivo patient encounters following a multimodal educational introduction provides a novel paradigm for resident procedure education in the future.

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Declaration of Competing Interest

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Appendix 1. Example set of test questions for participants and controls

1. The typical order in which components of a central line kit come in contact with the patient is:

A. Finder needle, guide wire, dilator, insertion needle, catheter
B. Dilator, insertion needle, scalpel, guide wire
C. Guide wire, dilator, finder needle, insertion needle
D. Finder needle, scalpel, guide wire, catheter
E. Finder needle, insertion needle, guide wire, dilator

Table 6
Participant pairwise follow up data at start of third year of residency.

	Pre-rotation (*N* = 9)	Post-rotation (N = 9)	Follow up (N = 9)	Follow up minus post-rotation difference (95% confidence interval)
All procedures				
Knowledge testing, correct out of 20, mean	9.7	12.3	10.8	−1.5 (−4.5, 1.5)
Confidence in performing procedures, mean	1.8	3.0	3.0	0.0 (−0.5, 0.5)
RPPs				
Confidence in performing procedures, mean				
Arthrocentesis	1.3	2.0	2.1	0.1 (−0.5, 0.8)
Bag-valve-mask ventilation	2.0	2.7	3.3	0.6 (−1.2, 2.3)
Circumcision	2.1	2.4	3.4	1.0 (−0.3, 2.3)
Clinical photography	2.1	4.3	4.3	0.0 (−0.8, 0.8)
Endotracheal intubation	1.7	1.7	1.7	0.0 (−0.5, 0.5)
Genitourinary catheterization	2.4	3.9	3.3	−0.6 (−1.2, 0.2)
Laceration repair	2.8	3.9	4.0	0.1 (−0.7, 1.0)
Lumbar puncture	2.4	3.1	4.0	0.9 (−0.2, 2.0)
Peripheral Access	1.6	3.7	2.7	−1.0 (−1.5, −0.5)
Procedural sedation	1.0	2.2	1.6	−0.7 (−1.4, 0.0)
Splinting	1.6	4.0	3.6	−0.4 (−1.3, 0.5)
Umbilical access	1.4	1.9	2.1	0.3 (−0.9, 1.4)

Nine of the original class of interns completed follow up evaluations (N = 9 full sets of pairwise data).
Confidence outcomes were measured by self-reported scores on a 5-point Likert scale where 1 = 'No confidence' and 5 = 'Completely confident'.

2. A 5-year-old fussy, febrile girl has an ultrasound-proven 3 cm abscess in her left buttock. Bedside incision and drainage can be performed in this patient **UNLESS** which of the following is true?

A. The child becomes agitated when her mother is not sitting beside her
B. On ultrasound the abscess appears to be loculated
C. The child has a prosthetic heart valve
D. The child's tetanus booster at age 4 was missed
E. Redness and exquisite tenderness extends down both legs to the knees

3. Which of the following items is **NOT** a required component for the informed consent of a bedside medical procedure?

A. The written consent with signature of a parent or legal guardian placed on the chart
B. The current diagnosis and prognosis of the patient
C. The nature and purpose of the proposed treatment
D. The significant risks of the treatment and reasonable estimate of success
E. The feasible alternatives, their risks and benefits and likely outcomes

4. Which of the following items is the most sensitive to breathing complications in an otherwise healthy 2-year-old male patient with new onset seizures undergoing MRI with procedural sedation?

A. Auscultation (stethoscope)
B. Pulse oximetry (O2 saturation monitor)
C. Respiration monitor
D. 3-lead cardiac monitor
E. End-tidal CO2 monitor

5. A 16-year-old obtunded girl with a psychiatric history is in the ER for overdosing on her anxiety medications. To deliver activated charcoal, a nasogastric (NG) tube will be placed. Which of the following is **TRUE**?

A. The length of the tubing is estimated using the distance from the patient's earlobe to her umbilicus
B. The length of the tubing is estimated using the distance from the angle of her mandible to her xiphoid process
C. The patient will not be able to talk clearly once the NG tube is in place
D. The patient should be intubated first
E. Insufflating 30 mL of air while auscultating over the epigastrium is the test of choice before infusing medications like activated charcoal through the NG tube

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