Competency Based Medical Education—Towards the Development of a Standardized Pediatric Radiology Testing Module

Denise Castro, MD, Joseph Yang, MD, Mary-Louise Greer, MD, Benjamin Kwan, MD, Eric Sauerbrei, MD, Wilma Hopman, PhD, Don Soboleski, MD

Rationale and Objectives: To introduce a process that allows for development of standardized competency based testing modules (CBTM) for evaluating resident progress and competence during their radiology training. This work focuses on the development of pediatric imaging CBTMs to be utilized during general radiology residency.

Materials and Methods: Multiple in-patient and ER imaging request audits along with surveys of training programs and text recommendations were obtained. A list of 200 total diagnoses accumulated by review was distributed into one of four CBTM folders. Imaging cases which made ≥90% of the indications of the audits were added to Folder 1. Distribution of remaining imaging diagnoses was based on consensus by three subspecialists. A pilot study was performed with residents dictating selected imaging cases in their usual manner mimicking a typical rotation.

Results: The pilot study demonstrated resident grading mean scores significantly associated with both the American College of Radiology (ACR) rank (rho = 0.636, $p = 0.035$) and the objective structured clinical examinations (OSCE) scores (rho = 0.694, $p = 0.018$). The mean scores positively associated with the ACR score (rho = 0.466), but fell short of statistical significance ($p = 0.149$). As expected, the ACR score, ACR rank and OSCE scores all significantly correlated with each other (< 0.01). PGY also significantly correlated with the ACR score (rho = 0.683, $p = 0.021$) and the OSCE (rho = 0.767, $p = 0.006$) but not with the ACR rank (rho = 0.408, $p = 0.213$).

Conclusion: The process utilized to develop a standardized CBTM can be used as a simulation tool to assess radiology resident competence during their training. The format allows for assessment of resident reasoning skills and knowledge base, which provides documentation of progression and throughout residency.

Key Words: Diagnostic radiology; Residency education; Competency-based medical education.

Abbreviations: ACR American College of Radiology, **CBTM** competency based testing modules, **ER** Emergency Room, **ED** Emergency Department, **OSCE** Objective Structured Clinical Examinations

INTRODUCTION

The traditional methods of training, evaluating, and promoting medical residents is being replaced with a competency based learning system (1,2). The transition to competency based medical education (CBME) of residents in the specialty of Diagnostic Imaging will require development of unique on-going assessment and evaluation processes. Many medical residencies allow for direct patient contact, assessment, treatment, and intervention. The process can often be monitored and graded in difficulty based on the level of training. Multiple simulation models have been developed to allow resident hands-on training and allow for assessment of competency (3–5). Subsequent patient experiences and outcomes can be evaluated and the entire process can provide objective means of resident evaluation. Radiology residency training primarily involves the analysis of images of patients referred from multiple practice settings with little direct patient exposure, and often little clinical follow-up or outcome assessment. There are three significant inherent limitations to this present system which

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From the Department of Radiology, Kingston Health Sciences Centre, Kingston, ON, Canada (D.C., B.K., E.S., D.S.); Queen's School of Medicine, Queen's University, Kingston, ON, Canada (J.Y.); Department of Diagnostic Imaging, The Hospital for Sick Children, Toronto, ON, Canada (M.-L.G.); WJ Henderson Centre for Patient Oriented Research, Kingston, ON, Canada (W.H.). Received September 29, 2019; revised November 7, 2019; accepted December 15, 2019. **Address correspondence to:** D.S. (daas@queensu.ca)

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need to be addressed to help allow for CBME implementation in the specialty of Diagnostic Radiology:

1. There is little control over the number or types of disease the resident will encounter in any particular rotation during their training. For example, a resident on one of their block pediatric radiology rotations may come across multiple imaging studies of patients presenting with signs of bowel obstruction, while the next resident may be exposed to few or no patients with this case scenario. It is likely that a resident will not encounter an "active" case of every disease entity. An adequate imaging knowledge and perception base in these scenarios will require didactic teaching and other resources for learning, much of which will need to be self-directed.
2. The degree of subtlety of the imaging findings for a particular pathology that the resident may encounter over the course of their training cannot be controlled. A junior resident may not perceive or understand the subtler changes noted on the imaging of cases to which they are exposed. Conversely, senior residents may only be exposed to more advanced obvious pathology with associated imaging during their rotation and have limited exposure to imaging with subtler changes. A defined and graded exposure to images of increasing difficulty in both perceptions of findings and interpretation is limited in the present system. This results in an inherent difficulty in objectively evaluating resident competence during the course of their training.
3. The general pediatric radiology training block is often uniquely difficult for assessing resident competence, perception skills, and learning progress as many residency programs allow for the entire 3 or 4 block training to occur together often later in their residency. These block rotations may occur at dedicated larger pediatric centers. Exposure to pediatric imaging before and after this extended block of training, along with contact with pediatric radiologists, may be limited.

The purpose of this quality improvement project was to help establish a process that allows for development of a standardized competency based testing module (CBTM) to be used for evaluating diagnostic Radiology resident competence and progress during their training. This study focuses on the development of four modules dedicated to assess resident competency in pediatric radiologic imaging throughout their 4/5-year general radiology residency program. Each of the four modules is tailored to allow for resident assessment after each of their four "block" rotations. The goal is to provide an objective and standardized resident assessment tool which is tailored to the level of training that mirrors general radiology practice. The CBTM will aid in assessing resident competence in both perception skills and knowledge base and help document their progression towards subspecialty expertise. The format will help direct resident learning and improve comfort and confidence with subsequent on-call scenarios. The CBTM will help identify resident weaknesses earlier in training and provide objective data points to aid in determination of resident competence in providing more independent "on-call" services and to progress forward within the residency program.

METHODS

The established process for development and testing of a CBTM evaluation system for radiology residents required multiple steps. These are broken down into three main phases: system setup, case selection, and pilot trial. Multiple steps during each phase were undertaken to establish a process summarized in the flowchart (Fig 1). Research and ethics approval was obtained from the institution prior to conducting this project.

Phase A System Setup

Specific folders labeled pediatric radiology CBTM 1−4 were created by our IT specialists and added to our present Picture archiving and communication system (PACS) on an isolated viewing station. The created CBTM folders mimicked the typical folders used by radiologists and residents in their daily routines of reporting imaging cases on our PACS. One CBTM folder was developed for each of the four pediatric rotation blocks in our residency The IT setup allowed for the easy export of selected imaging studies to these folders by the specialist radiologist during their usual daily dictating routine. Each imaging case sent to a CBTM folder was anonymized by the IT department and given a unique ID number. Opening of a particular case within the folder triggered the powerscribe dictation system as per the usual routine. A window with a reporting template along with the appropriate patient history and unique ID number would appear, allowing the residents to follow a standardized reporting process as per their normal dictating routine. The reporting templates specific for each imaging modality were chosen by consensus of the pediatric radiologists after an on-line survey using RSNA/RadReport.org and focus group meeting to discuss available options.

Phase B-I Case Selection

A number of steps (a−c) were performed to determine the number and type of imaging cases to be included in the pediatric radiology folders.

a) An audit was performed to determine the number and percentage of pediatric patients (0−18 years old) presenting to the Emergency Department (ED) over 1 year. The indications for subsequent radiology imaging (X-ray, CT, Gastrointenstional (GI), GU, US, MRI) were tabulated along with the percentages of total ED imaging requests. The Imaging related to a diagnosis that would encompass ≥90% of the indications was placed in CBTM pediatric folder 1.

b) An audit was performed to determine the number of pediatric inpatient requests for imaging over 1 year. The indications were tabulated along with the percentages of total in-patient imaging requests for each modality (X-ray, US, GI, GU, CT, MRI). The imaging related to diagnoses that would encompass greater than ≥90% of the indications were placed in CBTM pediatric folder 1.

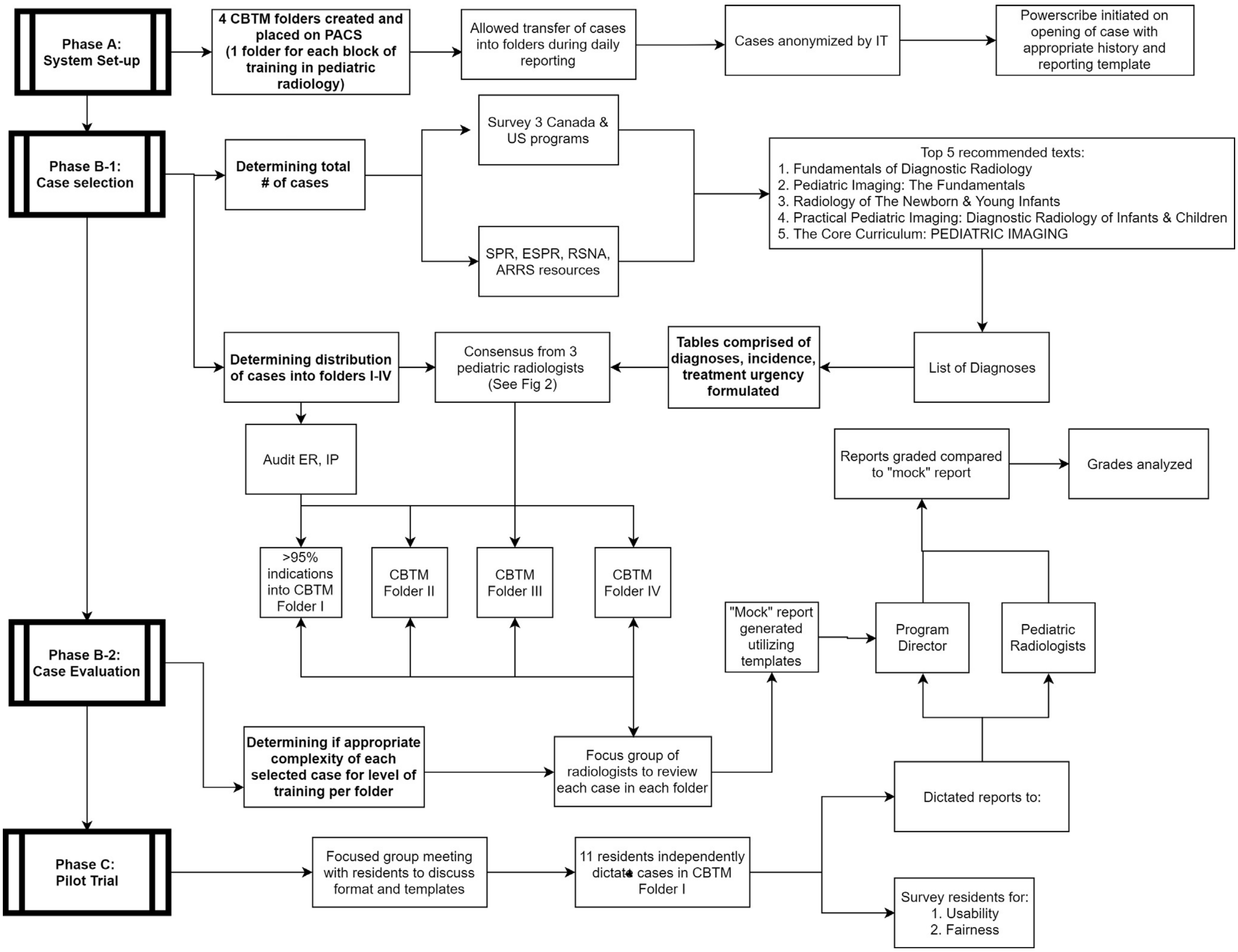

Figure 1. Flowchart detailing the establishment and evaluation of the CBTM for diagnostic radiology residents. CBTM, competency based testing modules.

c) A review of the literature and Royal College recommendations for suggested pediatric radiology reading in residency was performed. A survey of six residency programs was performed to determine the recommended text and websites utilized for establishing an adequate knowledge base in pediatric radiology during the general diagnostic imaging residency. Differential diagnostic lists obtained from the recommended texts were tabulated to establish the comprehensive list of diagnosis and associated imaging findings a resident should be familiar with to complete their general radiology training. Tables were formulated which included the incidence and treatment urgency for each diagnosis and, along with the ER and in-patient audits, acted as a template for three pediatric radiologists to determine which diagnosis was placed in each of the four CBTM folder (Fig 2). The general guidelines used to determine distribution of cases into the different CBTM folders included:

- Incidence of the disease process (relative increase incidence applied to earlier folder).
- Importance of rapid diagnosis in the clinical setting (processes requiring more urgent treatment for improved patient outcomes applied to earlier folder).
- Level of difficulty in perception of the imaging findings (The easier the perception of the findings related to the pathology the earlier folder utilized).
- The specialists independently assigned a number (1−4) for each diagnosis and an average was used to guide placement into one of the four folders. Disagreement was settled by consensus. There was an attempt at approximate equal distribution of the cases into the four folders.
- Five imaging cases with no abnormality including normal variants as described in T.Keats (6) were added to each folder.

Phase B-II

After placement of the appropriate available representative diagnostic cases into each CBTM folder as established in Phase B-I, a focus group meeting of the 3 pediatric specialists to review each particular case was undertaken to determine if

Disease process	Incidence	Treatment Medical	Treatment Surgical	Urgency	Radiologist Assignment
Appendicitis	10 per 100,000		X	Urgent	1
DDH	1 in 200 births	X		Non urgent	2
Arachnoid cyst	1% of all intracranial masses	X	X	Non urgent	3
Achondroplasia	1 in 15,000-40,000 births	X		Non urgent	4

Figure 2. Example of incidence and treatment urgency table which were formulated.

the complexity of the imaging findings for each case was appropriate for the level of resident training. For example, does the case have more obvious findings that a resident after their first pediatric radiology rotation should be expected to recognize compared to a case with subtle changes that only a resident further along in training would be expected to perceive? Cases with the same diagnosis but with differing degrees of subtlety could be placed in different folders. A mock report was created for each case by consensus of the subspecialists and used as a template for subsequent grading of resident reports. The 3 pediatric radiologists creating the mock reports had an average of 15 years of experience (range 10−25 years). The mock report included the allocation of points for the following features:

1) description of main abnormality
2) associated findings
3) significant "negative" findings
4) differential diagnosis/diagnosis
5) recommendations and consultations
6) ability to move patient forward on the illness spectrum (7).

Each case thus had a specific number of available grading points available. The grading scheme was previously developed and tested to confirm its reliability and interobserver variability and was presented at the annual European Society of Pediatric Radiology 2019 meeting in Helsinki (8). The details are beyond the scope of this quality improvement study.

Phase C Pilot Trial

To help confirm the functionality of the system and provide input on adequate case selection, each resident at our center independently reported 12 cases placed in a pediatric radiology CBTM folder on our PACS utilizing the attached structured reporting template and powerscribe function. The 12 cases were selected from the CBTM 1 folder to best allow assessment of the more junior residents. The cases selected included those utilizing plain radiographs of chest/abdomen/skeleton, contrast GI, voiding cystourethrogram (VCUG), sonograms, or CT images. No MR cases were placed in the pilot folder. Each resident dictated the cases from the isolated work station. The resident was allowed off their present rotation to perform the simulation testing. No time limit was given to the residents to dictate the cases. However, all residents finished in approximately 70 minutes. No normal/normal variant cases were placed in the pilot study. The residents were not informed of which type of cases to expect. After completion of the cases, the resident reports were extracted by IT and sent to the pediatric radiologists. After report extraction the CBTM file was then made available for the next resident to access. The residents were presented the general results based on year without individual identification so as to provide and elicit feedback. A questionnaire was given to the residents after folder completion (Fig 3).

Statistical Analysis

Post graduate year (PGY) of study and the Resident scores on the 12 cases were entered into an Excel file designed for the study, and imported into IBM SPSS (version 25.0 for Windows, Armonk, New York) for statistical analysis. The scores were standardized to be out of 100. Following a descriptive analysis, mean scores on the 12 cases, and responses to the three-item questionnaire, were compared across PGY levels using one-way ANOVA with Tukey's post hoc testing. Concurrent validity was tested using Spearman correlation to assess the association between mean scores on the 12 cases and the American College of Radiology (ACR) in-training examination scores, and the scores on the Objective Structured Clinical Examinations (OSCE) scores.

1) How did you find the functionality of the system?
0 (most difficult), 1, 2, 3, 4 ,5 (intuitive/straight forward)
2) The cases chosen were appropriate for my training level:
0 (too difficult), 1, 2, 3, 4, 5 (appropriate)
3) Do you think the process is a tool that can help in resident assessment of competence?
0 (no - not relevant), 1, 2, 3, 4, 5 (yes - can be a useful as a marker for competence level)

Figure 3. Questionnaire provided to residents for CBTM evaluation. CBTM, competency based testing modules.

Chest X-Ray – indication:
- lung parenchyma
- pleural space
- cardiac and mediastinum/hilum
- thoracic cage
- line/tube placement

MSK – indication:
- bony structures
- joint spaces
- soft tissues

GI contrast study – indication:
- complications
- esophagus
- GE junction/stomach/pylorus
- D-J flexure
- duodenum/small bowel

US Neuro – indication:
- gestational age
- ventricular system
- intra-axial space
  - mass
  - mass effect
  - parenchymal echogenicity
- extra-axial space
  - mass
  - mass effect
  - doppler indices

GU contrast study (VCUG) – indication:
- complications
- bladder size and configuration
- VUR grade 1-5
- urethra configuration
- skeletal appearance

Figure 4. Utilized templates for CBTM responses used for grading. CBTM, competency based testing modules.

RESULTS

Phase A System Setup

Four CBTM folders labeled Pedi 1−4 were setup on an isolated PACS. On selection of each anonymized case within the folder the powerscribe dictating system was initiated with one of the following reporting templates (Fig 4). An anonymized order requisition with appropriate clinical history for the study was included with each case.

Phase B-I Case Selection

I-a)—Of 48,604 imaging tests ordered by the ED over a 1-year time span, pediatric imaging at our institution comprised 6294. Table 1 depicts the types of imaging tests ordered by the ED over a 1-year time span.

TABLE 1. Imaging Ordered by the ER Over a 1-Year Time Span

	Chest	Neuro	Body	MSK
XR	1632	1	271	3820
CT	6	128	57	19
MR	0	5	0	3
US	1	3	344	0
Total	*1639*	*137*	*672*	*3842*

ER, emergency room.

A summary breakdown of the most common indications for each of the ER imaging requests is noted in Figure 5, and the anatomical distribution of ER fractures is shown in Figure 6. Imaging related to the previous indications making up greater than 90% of the indications in each section were added to the CBME folder 1

Phase B

I-b)—Of the 38,553 imaging tests ordered on in-patients over a 1 year time span, pediatric imaging comprised 5.2% (1996 studies). Table 2 illustrates the types of inpatient imaging tests ordered over a 1-year time frame.

A breakdown of the indications for inpatient pediatric imaging is shown in Figure 7. Imaging related indications making up greater than 90 % were added to the CBTM 1 folder.

Phase B

I-c) The top five recommended texts suggested to residents for advancement of knowledge based on The Society for Pediatric Radiology, The Royal College of Physicians and Surgeons, ACR and six residency program recommendations were:

The Core Curriculum: PEDIATRIC IMAGING − Marilyn J. Siegel, MD and Brian D. Coley, MD

Fundamentals of Diagnostic Radiology (Brant and Helms)

Pediatric Imaging: The Fundamentals (Donnelly)

Radiology of The Newborn & Young Infants (Swischuk)

Practical Pediatric Imaging: Diagnostic Radiology of Infants & Children (Kirks)

There was a diverse list of suggested readings, many of which were general texts. Four of the six teaching centers recommended specific pediatric radiology general texts while two centers recommended general radiology texts that included pediatric sections. The Society for Pediatric Radiology recommended the core curriculum pediatric imaging series. The complete list of diagnosis obtained from these suggested texts and the case diagnosis distribution into the 4 CBTM folders is illustrated in Table 3. Most common indications for pediatric imaging as determined by the in-patient and ER audits are highlighted in the CBTM #1 folder.

	Volume	% of Total
Chest		
Pneumonia/Fever/Cough/Infection/Abscess	1081	66.0%
Chest Pain/Pneumothorax	129	7.9%
N/A	102	6.2%
Shortness of Breath/Pulmonary Edema	78	4.8%
Trauma/Fracture	64	3.9%
Foreign Body	49	3.0%
Neuro		
Trauma/Fracture	93	67.9%
Cancer (mass, tumor, cyst, metastasis, lymphoma)	12	8.8%
Stroke/LOC	6	4.4%
Seizure	5	3.6%
Infection / Abscess	5	3.6%
Hydrocephalus/Shunt Dysfunction/Vomiting	5	3.6%
Abdomen		
Abdominal Pain (appendicitis, inflammatory bowel disease, bloody stool, intussusception)	356	53.0%
Obstruction (duodenal atresia, bowel gas, constipation, Hirshsprung's, dilated bowel loops, bilious aspirate, pyloric stenosis, GI anomaly, ileocolic intussusception)	139	20.7%
Cancer (mass, tumor, cyst, metastasis, lymphoma)	28	4.2%
Trauma	28	4.2%
Foreign Body	19	2.8%
Renal Anomaly	19	2.8%
Infection / Abscess	12	1.8%
Testicular Torsion	11	1.6%
MSK		
Trauma/Fracture	3552	92.5%
Pain	148	3.9%
N/A	71	1.8%
Foreign Body	28	0.7%
Infection / Abscess	11	0.3%
Cancer (mass, tumor, cyst, metastasis, lymphoma)	8	0.2%
Post Operative	7	0.2%
Joint Effusion	4	0.1%

Figure 5. Most common indications for each of the ER imaging requests. ER, emergency room.

Phase C

Pilot Trial—The following cases were placed in a CBTM 1 folder to allow assessment of the process:

1) Supracondylar fracture
2) Surfactant deficiency disorder
3) Left lower lobe pneumonia
4) Slipped capital femoral epiphysis
5) Germinal matrix bleed on ultrasound
6) Pneumothorax
7) Malrotation on GI contrast study
8) Wilms tumor on CT
9) Vesicoureteral reflux on VCUG
10) Tilleaux fracture
11) Monteggia fracture/dislocation
12) malposition lines in neonatal intensive care unit

Eleven residents (3 PGY2; 2 PGY3; 3 PGY4, and 3 PGY5) were allowed access to the pilot CBTM 1 folder for dictation.

	Volume	% of Total
Wrist/Hand	881	24.8%
Ankle	518	14.6%
Foot	403	11.3%
Elbow	304	8.6%
Finger	260	7.3%
Radius and Ulna	255	7.2%
Knee	198	5.6%
Shoulder	136	3.8%
Tibia and Fibula	112	3.2%
Clavicle	91	2.6%
Cervical Spine	76	2.1%
Pelvis/Hip(s)	70	2.0%
		93. 1 % of fractures

Figure 6. Anatomical distribution of ER fractures. ER, emergency room.

TABLE 2. Imaging Ordered by In-Patient Unit Over a 1-Year Time Span

	Chest	Neuro	Body	MSK
XR	783	0	174	277
CT	11	43	20	4
MR	1	73	4	12
US	18	186	262	6
Total	*818*	*303*	*488*	*303*

Scores ranged from a low of 27.3 ± 33.8 (Case 6) to a high of 95.5 ± 10.1 (Case 1), with an overall average of 59.3 ± 31.8. Analysis of resident grades overall correlated reasonably well with year of residency. Mean scores by PGY level were 52.5 ± 33.8 (PGY 2), 40.1 ± 30.8 (PGY3), 64.1 ± (26.8 (PGY4) and 74.2 ± 27.3 (PGY5), $p < 0.001$ on one-way ANOVA. On post hoc testing, PGY 2 differed from PGY 5 ($p = 0.013$), and PGY 3 differed from PGY 4 ($p = 0.014$) and PGY 5 ($p < 0.001$).

Concurrent validity was tested by comparing the mean scores per resident across all 12 cases with their ACR and OSCE scores. The mean scores were positively associated with the ACR score (rho = 0.466) but this fell short of statistical significance ($p = 0.149$). However, the mean scores were significantly associated with both the ACR rank (rho = 0.636, $p = 0.035$) and the OSCE scores (rho = 0.694, $p = 0.018$). As expected, the ACR score, ACR rank and OSCE scores were all significantly correlated with each other ($p < 0.01$ for all). PGY was also significantly correlated with the ACR score (rho = 0.683, $p = 0.021$) and the OSCE (rho = 0.767, $p = 0.006$) but not with the ACR rank (rho = 0.408, $p = 0.213$). In all cases, the actual correlation coefficients were moderate to high, with the sample size of 11 residents being a limiting factor when testing for statistical significance.

Results of the questionnaire had the process receiving high marks for functionality/usability (mean score of 4.9 ± 0.3), and ability to act as a potential means to assess competence (mean score 4.6 ± 0.7). The survey revealed only moderate agreement on appropriateness of cases (mean score of 4.3 ± 0.7). This is believed due to an inherent difficulty with most programs where the residents have little exposure to pediatric radiology until their specific rotation. Interestingly, the resident receiving the highest mark was the one who had just returned from their 3-month block of pediatric training at the specialist center. An evaluation of the responses by PGY showed that the PGY3 was lower for functionality as compared to the other three years ($p = 0.001$), but the responses did not differ significantly by year for the other two questions ($p = 0.310$ for question 2, and $p = 0.612$ for question 3), although the PGY3 Residents had the lowest scores on all three items.

DISCUSSION

Reliable standardized assessment of on-going resident progress and competence allows for early intervention and useful feedback both to the residents and to the academic staff tasked with the determination of resident ability to move forward in training. This may be particularity important when deciding when residents are able to perform independent "on-call" services guiding urgent patient care. There is limited evidence based data on assessment of how radiology is taught or evaluated at present (9,10). The move to CBME at academic centers will require development of in-training assessment tools that will vary from specialty to specialty. The goal of this project was to help determine if the process utilized to develop a CBTM could provide an objective on-going means to evaluate radiology residents in the difficult area of pediatric imaging. The CBTM format is basically a high fidelity simulator. Multiple types of simulation have been used in medicine and have proven of great value in teaching and assessment (11−13). It likely that radiology training programs will place varying importance on each particular aspect of the described process and specific imaging cases based on their clinical environment and resident expectations.

There are many strengths of the process used to create CBTMs. Importantly, the system mirrors the typical radiologic practice and allows for a standardized graded approach to on-going resident evaluation. Earlier endeavors have focused on mainly written questions without the ability to assess resident reports .We believe the resident report helps allow evaluating of their thought process and progression to a specialty expertise level. The four folder format may better allow for dedicated assessment of a particular resident level in a setting which mimics typical radiology practice (14,15). A second strength of the process is the early assessment of competence in cases in which the resident is more likely to come across early in training and in particular emergency "on-call" imaging. Residents in general begin covering on-call services early in training often before exposure to the disease processes during their block rotations. Assessment of resident competence by the clinical staff with these cases may be limited and potentially lead to inappropriate patient care. This format may result in residents altering the typical study pattern which

	Volume	% of Total
Chest		
Line/Tube Placement	342	41.8%
Pneumonia/Fever/Cough/Infection/Abscess	146	17.8%
Pleural Effusion	76	9.3%
Chest Pain/Pneumothorax	60	7.3%
Shortness of Breath/Pulmonary Edema	48	5.9%
Routine	39	4.8%
Lung volumes/premature	26	3.2%
Cancer (mass, tumor, cyst, metastasis, lymphoma)	20	2.4%
Neuro		
Premature	136	44.9%
Stroke/LOC	43	14.2%
Cancer (mass, tumor, cyst, metastasis, lymphoma)	38	12.5%
Infection / Abscess	19	6.3%
Trauma/Fracture	18	5.9%
Seizure	16	5.3%
Developmental Delay/ Morphological Abnormalities	7	2.3%
Abdomen		
Obstruction (duodenal atresia, bowel gas, constipation, Hirshsprung's, dilated bowel loops, bilious aspirate, pyloric stenosis, GI anomaly, ileocolic intussusception)	97	19.9%
Abdominal Pain (appendicitis, inflammatory bowel disease, bloody stool, intussusception)	83	17.0%
Cancer (mass, tumor, cyst, metastasis, lymphoma)	63	12.9%
Renal Anomaly	59	12.1%
Infection / Abscess	44	9.0%
Necrotizing Enterocolitis	34	7.0%
Line/Tube Placement	26	5.3%
DVT	15	3.1%
Recheck	10	2.0%
Post-Operative	8	1.6%
Trauma	7	1.4%
MSK		
Post-Operative	121	39.9%
Trauma/Fracture	112	37.0%
Infection / Abscess	16	5.3%
Scoliosis	8	2.6%
Pain	7	2.3%
Routine	7	2.3%
Rickets/Genetic Syndrome	7	2.3%
Cancer (mass, tumor, cyst, metastasis, lymphoma)	5	1.7%

Figure 7. Most common indications for inpatient pediatric imaging requests.

focuses on acquiring more comprehensive knowledge of a particular subspecialty while on that block rotation to an approach focusing on disease processes they are more likely to come across and that may require more urgent accurate diagnosis and intervention. It is believed this approach may help improve resident confidence with on-call scenarios. Although resident exposure to imaging at dedicated large pediatric centers allows for access to often rare and complex pathologies the development and progression over time of perception skills and approaches to the more common patient presentations often more typical in the general hospital setting can be difficult to assess or overlooked. The process may allow for on-going assessment in these scenarios which is advantageous.

Further strengths include a comprehensive nature to the CBTM structured as a deliberate practice to allow assessment of the resident through to a level of specialty expertise (10). Similar to OSCE's the large number of cases evaluated allows for

TABLE 3. Complete List of Diagnosis Obtained From Suggested Texts and the Case Diagnosis Distribution into the 4 CBTM Folders

Folder 1 (more urgent diagnosis and treatment required—totaling 50 cases)			
Epiglottitis	Germinal matrix hemorrhage	Ovarian torsion	Hypoxic-ischemic encephalopathy
Retropharyngeal abscess	Hydrocephalus	Testicular torsion	Pneumothorax
Intestinal malrotation	Orbital cellulitis	Pilocytic astrocytoma	Neuroblastoma
Intussusception	Pyloric stenosis	Pyelonephritis	Wilms tumor
Appendicitis	Congenital diaphragmatic hernia	Osteomyelitis	Duodenal atresia
Necrotizing enterocolitis (NEC)	Decreased lung vascularity TOF	Slipped upper femoral epiphysis	Pleural effusion
Hypoperfusion complex	Meconium Ileus	Salter-Harris fractures	Lymphoma
Trauma-liver/kidney/spl #	Ventricular septal defect	Supracondylar fractures	Trauma—chest
Foreign body aspiration/ ingestion	Posterior urethral valve	Lateral condyle fractures	Endotracheal, Umbilical vein/umbilical artery line malplacement
Pneumonia—bacterial	Polycystic kidney disease	Toddler fractures	Viral pneumonia
Surfactant deficiency disease	Atlanto-axial Injury	Osteosarcoma	Stroke
Pulmonary edema	Trauma—neuro	Nonaccidental abuse	Transient tachypnea of the newborn
Neuro infection/abscess	Meconium aspiration		
Folder 2—totaling 51 cases:			
Hirschsprung's Disease	Encephalitis	Ureteropelvic junction obstruction	Ependymoma
Normal Thymus	Croup	Mesenteric adenitis	Brainstem glioma
Cardiomyopathy	dandy walker	Osteochondritis dissecans	Acute disseminated encephalomyelitis
Toxoplasmosis, other, rubella, cytomegalovirus, herpes simplex virus	Cystic fibrosis	Osgoode-Schlatter disease	Myelomeningocele
Developmental dysplasia of the hip	Spondylolysis	Brachial cleft cyst	Pulmonary stenosis
LCH	Hepatoblastoma	Dermoid	Adrenal hemorrhage
Parenchymal interstitial emphysema	Avulsion fracture	Bronchopulmonary dysplasia	Ewing tumor
Asthma	ASD	Gastroesophageal reflux	VU REFLUX
Hydrometrocolpos	Ovarian teratoma	Rhabdomyosarcoma	Urachal cyst
Fibromatosis coli	Chiari malformation	Lymphatic malformation	Vein of Galen aneurysm
Colloid cyst	Tracheitis	Avulsion fracture	Medulloblastoma
Megaureter	Neurogenic bladder	Duplex kidney	Thyroglossal duct cyst
Tracheo-esophageal fistula	Legg-calvé-perthes disease	Epididymitis	
Folder 3—totaling 51 cases:			
Duplication cyst	Retinoblastoma	Neurofibromatosis	Tarsal coalition
Multicystic dysplastic kidney	Osteoid osteoma	Tuberous sclerosis	Stress fracture
corpus callosus agenesis	Scoliosis	Ventricular septal defect	Spinal cord astrocytoma
Choroid plexus carcinoma	Clubfoot	Caroli's disease	Choledochal cyst
Arachnoid cyst	Colloid cyst	Tracheomalacia	Neutropenic colitis
Subglottic hemangioma	Germinoma	Germ dell tumor	Pseudomembranous colitis
Ulcerative colitis	Choroid plexus papilloma	patent ductus arteriosus	Hydrometrocolpos
Rickets	Tethered cord syndrome	Omphalocele	Rhabdomyosarcoma
SC disease	Transplant complications	GASTROSCHISIS	Ovarian teratoma
Pulmonary sequestration	Osteogenesis imperfecta	Meconium plug syndrome	Anorectal malformation
Meckel's diverticulum	Vascular malformation	Meconium peritonitis	Sacro-coccygeal teratoma
Biliary atresia	Aortic coarctation	Juvenile rheumatoid arthritis	Leukemia
Urachal cyst	Congenital cystic adenomatoid malformation	Jejeunal atresia	

(*continued*)

Folder 4 (rarer and more complex—Totaling 48 cases):			
Hemangioendothelioma	Scimitar syndrome	Fibroxanthoma	Osteopetrosis
Ebstein anomaly	Pulmonary Atc	Aural atresia	Fibromatosis
Double aortic arch	Heterotaxia syndrome	Orbital hemangioma	Holoprosencephaly
Pulmonary sling	Aortic stenosis	Hypoplastic left heart syndrome	Hemimegalencephaly
Congenital lobar emphysema	Kawasaki syndrome	Transposition	Schizencephaly
Bronchial cyst	Post-op cardiac changes	Truncus arterosus	Diastematomyelia
Achondroplasia	Right ventricular dysplasia	Bronchial atresia	Nasal sinus dermal
Papillomatosis	Lymphoproliferative disease	Pulmonary blastoma	Mitochondrial encephalopathy
Rhabdomyoma	Graft versus host disease	Sickle cell disease	Juvenile nasopharyngeal angiofibroma
Mesenchymal hamartoma	Syphilis	Total anomalous pulmonary venous return	Leukodystrophy
Cholesteatoma	Choanal atresia	Bezoar	Angiomyolipoma
Nephroblastoma	Proximal femoral focal dysplasia	Mesoblastic nephroma	Muccopolysacc

CBTM, competency based testing modules.

increased reliability and reproducibility (14). Identification of inadequacies in both knowledge base and in perceptual skills may be identified early on in training allowing for remediation and staff guidance. The process allows for on-going easy inclusion of new cases deemed appropriate for resident testing so future residents may not take advantage of past resident experience. A potential further strength of the developed process may be in the assessment of foreign graduates starting pediatric radiology fellowships in determining appropriate knowledge base and perceptual skills required for more independent functioning generally required within these departments.

There are multiple limitations of the developed process to note. Importantly, the process is only designed to assess competency in image interpretation and particular case management. The further skills as defined by Accreditation Council for Graduate Medical Education (ACGME) and CanMeds including interpersonal, communication, collaborative, scholarly, along with leadership and health advocate roles that the resident needs to fulfill the competency requirements is not tested (16). The process does allow for establishment of Entrustable Professional Activities and milestones to allow for on-going assessment during training (2).

Although the identification and transfer of cases was technically easy, the process of generating a standardized report with grading and the marking of resident exams was time-consuming requiring multiple specialists to obtain consensus which is a significant limitation. Once a sufficient number of cases are accumulated this may become less an issue. A further limitation is the amount of time required to come across the rarer cases and generate the associated mock report to add to the CBTM folders. Larger institutions may be at an advantage in this regard. Although not performed in our setup, it would be possible to obtain outside cases and evaluate for their placement into the appropriate folders.

The relatively small size of our residency program and small number of cases included in the pilot study are significant limitations. Determination of what grade requirement for each case should be used to help determine resident competence or a pass-fail grade is not possible at this time. Further on-going pilot tests during the residents training to include correlation with other the resident evaluation tools (ACR, OSCE etc.) will be needed to establish the baseline. The grading system utilized (8) allowed for reproducible marking and is an important component of any assessment tool. Our grading correlated well with both year of training and whether the resident had completed their pediatric rotation, which supported its use. The correlation with other measurement tools such as OSCEs and the ACR in-training evaluation helps supports the validity of the process for determining resident competence. We did not place normal variants in the "pilot" test folder which may have caused a bias and a further limitation.

Although numerous imaging scenarios would ideally be placed in the first CBTM folder so as to assess resident competence in all severe diagnoses, it was not practical or feasible to expect residents to acquire such a large knowledge base and perceptual skills in such a short time period. Audit results helped guide placement of the cases however each scenario the resident is exposed to may be rare or have atypical findings of varying urgency which is an inherent limitation to the developed process.

CONCLUSION

The quality improvement project/process utilized to develop a standardized CBTM can be used as an aid and potential milestone in assessment of radiology resident competence during their training in the subspecialty of pediatric radiology. The format allows for assessment of resident reasoning skills and knowledge base and can help provide documentation of progression and adequacy of perception skills. Most importantly it allows for a comprehensive milestone to determine if our residents are progressing towards the goal of being an independent and competent medical radiology specialist. This stimulation tool can allow for graded teaching at all levels of training and may also be expanded to allow for ongoing competency assessment during our radiology careers.

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IRB STATEMENT

This study was reviewed and approved by the Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board.

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