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Eight-year outcomes of a competency-based residency training program in orthopedic surgery

Markku T. Nousiainen[a], Polina Mironova[a], Melissa Hynes[b], Susan Glover Takahashi[b], Richard Reznick[c], William Kraemer[a], Benjamin Alman[d], Peter Ferguson[a] and The CBC Planning Committee*

[a]Division of Orthopaedic Surgery, Department of Surgery, Faculty of Medicine, University of Toronto, Toronto, ON, Canada; [b]The Office of Postgraduate Medical Education, Faculty of Medicine, University of Toronto, Toronto, ON, Canada; [c]Faculty of Health Sciences, Queen's University, Southeastern Ontario Academic Medical Organization, Kingston, ON, Canada; [d]Department of Orthopaedics, Duke University, Sick Kids Research Institute, Hospital for Sick Children, Toronto, ON, Canada

ABSTRACT

Background: The Division of Orthopaedic Surgery at the University of Toronto implemented a pilot residency training program that used a competency-based framework in July of 2009. The competency-based curriculum (CBC) deployed an innovative, modularized approach that dramatically intensified both the structured learning elements and the assessment processes.

Methods: This paper discusses the initial curriculum design of the CBC pilot program; the refinement of the curriculum using curriculum mapping that allowed for efficiencies in educational delivery; details of evaluating resident competence; feedback from external reviews by accrediting bodies; and trainee and program outcomes for the first eight years of the program's implementation.

Results: Feedback from the residents, the faculty, and the postgraduate residency training accreditation bodies on the CBC has been positive and suggests that the essential framework of the program may provide a valuable tool to other programs that are contemplating embarking on transition to competency-based education.

Conclusions: While the goal of the program was not to shorten training per se, efficiencies gained through a modular, competency-based program have resulted in shortened time to completion of residency training for some learners.

Introduction

In July of 2009, the Division of Orthopaedic Surgery at the University of Toronto implemented a pilot program for a subset of trainees in their residency training program that used a competency-based framework (Alman et al. 2013; Ferguson et al. 2013). This was done in anticipation of an emerging movement to restructure postgraduate training across specialty education in Canada. The pilot training program, referred to as the competency-based curriculum (CBC), responded to the changing demands in postgraduate medical education and a growing understanding of the limits of a strictly time-based postgraduate system (Carraccio et al. 2002; Hodges 2010; Alman et al. 2013). The CBC was designed to not only meet the current accreditation and educational requirements of the postgraduate medical education accreditation body in Canada, the Royal College of Physicians and Surgeons of Canada (RCPSC), but also in anticipation of meeting the requirements for an initiative in Canada to transition all training programs to competency-based medical education (CBME). As such, the pilot was designed to contain the requisite elements for CBME, which include: an optimized and refreshed curriculum, the development of explicit expectations or milestones, the use of entrustable professional activities (EPAs), an intensive assessment process, and attestation of competence once a resident has met all of the stated curricular objectives, as opposed to a strictly time-based structure (Alman et al. 2013).

Practice points

- Competency-based medical education can respond to the changing demands in postgraduate medical education, particularly as they relate to the limits of a strictly time-based postgraduate system.
- Our competency-based curriculum (CBC) deployed an innovative, modularized approach that dramatically intensified both the structured learning elements and the assessment processes.
- In order to accomplish this, we used curriculum maps, entrustable professional activity assessments, the intensive use of skills labs, and summative and formative feedback sessions to determine the competence of our trainees.
- Many challenges were encountered, particularly the cost of implementing and maintaining the curriculum, faculty development, and asking our faculty to spend more time and effort in assessing and providing feedback to our trainees.
- Feedback from the residents, the faculty, and the postgraduate residency training accreditation bodies on the CBC has been positive and suggests that the essential framework of the program may provide a valuable tool to other programs that are contemplating embarking on transition to competency-based education.

CONTACT Markku T. Nousiainen Markku.nousiainen@sunnybrook.ca Division of Orthopaedic Surgery, Department of Surgery, Faculty of Medicine, University of Toronto, Toronto, ON, Canada Suite 621, 43 Wellesley St. East, Toronto, ON, M4Y 1H1, Canada

*The CBC Planning Committee includes: Drs. Oleg Safir, Ranil Sonnadara, John Murnaghan, Darrell Ogilvie-Harris, John Theodoropoulos, Jeremy Hall, Khalid Syed, Andrew Howard, Michael Ford, Timothy Daniels, Timothy Dwyer, Christian Veillette, Veronica Wadey, Unni Narayanan, Albert Yee, and Cari Whyne.

Based on the experience with the pilot, the Division of Orthopaedic Surgery fully transitioned to the CBC in the 2013–2014 academic year. That year, the RCPSC announced a competence by design (CBD) initiative, which mandated that all postgraduate specialty programs in Canada were to adopt a competency-based framework by the year 2022 (The Royal College of Physicians and Surgeons of Canada 2017). In this paper, we describe our journey toward CBME, the challenges we faced, the benefits we enjoyed, and the results we observed after eight years of operating within the new framework. The description of our experiences and initial results may be of benefit to programs that are currently transitioning to CBME.

Developing the novel training program

The CBC was developed following an extensive process of consultation resulting in broad support from the orthopedic surgeons on the faculty at the University of Toronto. The five principles that guided the CBC's initial curriculum development and implementation were: (1) breaking down the curriculum into discrete modules which reflected progressive development of expertise in defined areas of orthopedic surgery; (2) altering the delivery of objectives in core surgical training; (3) ensuring an early, more rapid ascent to technical surgical skills competence; (4) making intense use of simulation opportunities; and (5) employing an enhanced assessment and feedback scheme.

Breaking down the curriculum into discrete modules which reflect progressive development of competence

The process started with a comprehensive look at the requisite competencies as derived from the RCPSC's objectives for training in orthopedic surgery, which includes objectives requisite for all surgical specialties known as Surgical Foundations (core surgical training) and the objectives specific to orthopedic surgical training. For each area in the curriculum, consensus was developed around the specifics of what would need to be taught and what the threshold would be for demonstrating competence (Frank et al. 2010). Based on this process, a decision was made to divide the curriculum into 21 modules, as opposed to the traditional approach which defined certain obligate and optional rotations delivered over a set period of time. A faculty member was recruited to lead each module. Initially, each module was intended to focus on the enhanced teaching and assessment of all seven CanMEDS roles. CanMEDS refers to a framework developed by the RCPSC that identifies and describes the abilities physicians require to effectively meet the health care needs of the people they serve, grouped thematically under seven roles (Frank 2005). Because of the progressive complexities related to developing expertise in orthopedic surgical training, the 21 modules were grouped into three phases. Phase 1 contained foundational and basic orthopedic surgery learning modules that would teach and assess the basic knowledge and skills that related to training in an orthopedic surgery residency program. Phase 2 contained more advanced learning modules that would build upon the knowledge and skills learned in Phase 1. Phase 3 contained modules that would teach and assess the more complex aspects of orthopedic surgery, and would build upon the knowledge and skills learned in Phase 2. In 2016, the "transition to residency" and "transition to practice" periods were added at the beginning and the end of the curriculum, in anticipation of the new Royal College guidelines. With the addition of a specific module in hand, this increased the number of modules to 24. Figure 1 illustrates the current curriculum map that was implemented in 2016.

Altered delivery of objectives in core surgical training

One major curriculum change in the CBC pilot involved an alternative way of delivering the objectives of core surgical training (Alman et al. 2013). Instead of having residents spend time on off-service clinical rotations, it was thought that the core surgical learning objectives that would have been addressed on these rotations could be contextually delivered by incorporating them into several CBC modules. In addition to the clinical CBC modules, all trainees had to complete two modules which were ostensibly "non-clinical"; one focusing on basic core principles of surgery, which involved participating in surgical skills sessions and didactic lectures, and one focusing on the non-medical expert roles in the CanMEDS framework (including professionalism, communicator, manager/leader, health advocate, scholar, and collaborator roles), which involved completing on-line learning modules (Frank 2005). Cumulatively, the experiences in the Phase 1 section of the 21 modules would serve to prepare trainees for successful completion of the national examination, Surgical Foundations, which is the first component of attestation of completion of specialty certification training and is taken at the end of the second year of training.

An early, more rapid ascent to technical surgical skills competence and augmented use of simulation opportunities

In designing the orthopedic learning modules, the committee consulted with a number of content experts in surgical training, motor skills development, and curriculum development. The committee wanted to take the lessons learned from the literature on skills acquisition and apply them to the curriculum design at the outset (Seymour et al. 2002; Grantcharov et al. 2004; Backstein et al. 2005; Safir et al. 2012). These included findings that surgical skill acquisition and retention improves via focused educational design: (i) deliberate practice with frequent feedback; (ii) technical skill rehearsal in a non-operating room setting; (iii) personal constructive summative and formative feedback; (iv) small student-to-teacher ratio learning; (v) targeted teaching; and (vi) an appropriate assessment process. As such, most of the modules' design aimed to accelerate skill acquisition through the use of skills labs, simulation and structured practice. Importantly, an entire module is dedicated to the development of foundational technical competencies (Introduction to Basic Surgical Skills, also known as the "Boot Camp" module). In previous work we have shown that these essential skills can be rapidly taught, often to the level of more senior trainees, through a dedicated approach using the educational design principles mentioned above (Sonnadara et al. 2011, 2012, 2013).

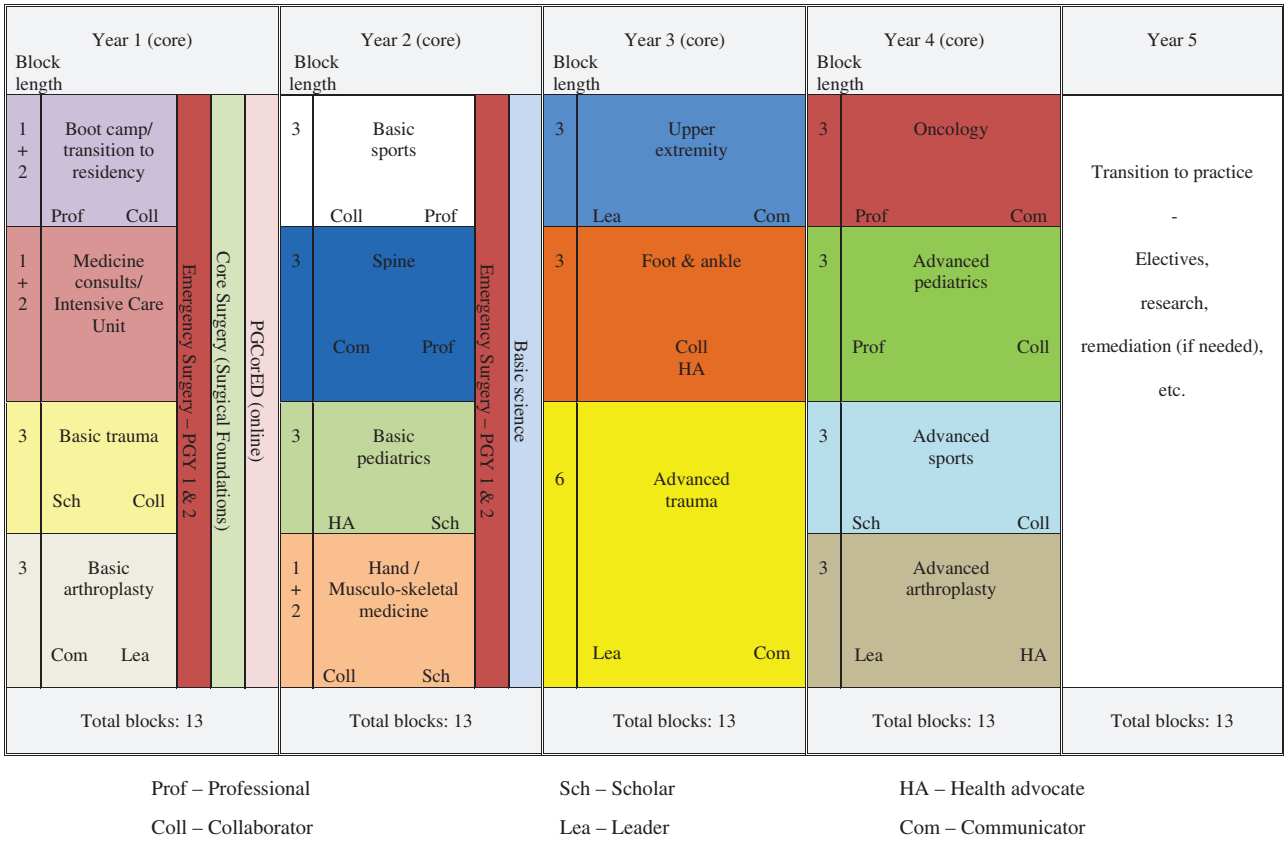

Figure 1. Curriculum map for the competency-based curriculum (2016). The intrinsic CanMEDs roles taught and assessed in each module are identified in abbreviated form.

An enhanced assessment scheme

The most significant change that the CBC pilot design brought to residency training was that trainees would be allowed to progress to the next learning module only if the objectives of the module they were currently on were achieved (Carraccio et al. 2002). In the pilot, trainees would be on a module for as long as it would take them to master the content. To our knowledge, this represented the first time in surgical training where residents would progress through a program that was not time-based.

During the early development phase of the teaching and assessment plan for each module, specific assessment instruments had to be created to capture the level of competence of the trainee for each of the seven CanMEDS roles. Because these types of assessment tools did not exist, especially as they pertained to orthopedic surgery, the committee members developed a new suite of assessment tools (Iobst et al. 2010). With the implementation of these tools, the augmented frequency of assessment in the CBC was dramatic, cumulatively amounting to a three- to five-fold increase in assessment episodes. This enhanced level of assessment enabled the Residency Program and Evaluation Committees (RPC/REC) to carefully follow each trainee through the curriculum.

From pilot to mainstream

Following the design of the CBC pilot, permission was sought and granted from the RCPSC to introduce the CBC as an alternate stream of accredited training to the "regular" residency program in Orthopaedic Surgery at the University of Toronto. In the 2009–2010 academic year, the Division accepted 3 of its incoming 12 residents into the alternate CBC stream. The CBC training program ran in parallel to the regular stream training program – residents would learn and work in the same teaching hospitals and with the same attending surgeons as the residents in the regular stream training program. Gradually, more incoming residents were enrolled into the CBC stream, and in 2013–2014 the "regular" program design ended in favor of the CBC program design. Once the entire program transitioned to the CBC, the curriculum was further refined to accommodate the larger number of trainees. The RPC made a decision to establish temporal anchors to module scheduling. Instead of an open-ended or variable completion date, most modules were scheduled to be delivered in three- or six-month increments. This hybrid approach was introduced to ensure the long-term sustainability of the CBC framework and to enhance predictability of resident assignments for the hospital sites (Holmboe et al. 2017). That said, if a resident was found not to have attained all of the competencies in a specific module, additional time was allocated for their completion.

Refining the curriculum

It became apparent that the formal teaching and assessment of all seven CanMEDS roles on each module was labor intensive and impractical. Upon consultation with experts in curricular design, the modules were streamlined to include formal teaching and assessment of up to three CanMEDS roles per module (e.g. medical expert plus two

intrinsic roles most suited to a particular module) so as to ensure that all CanMEDS roles were adequately taught and assessed across all modules. The focus on a smaller number of CanMEDS roles did not infer that the other roles would be ignored, as progress on all roles would be monitored and reported in the end of module final In-Training Evaluation Report (ITER).

An additional refinement of the curriculum involved curriculum mapping (Harden 2001; Willett 2008; Perlin 2011; Glover Takahashi et al. 2012). This was done to provide an explicit description and documentation of how the curriculum would be taught and assessed (this would include what educational strategies, types and contexts of teaching, learning outcomes, and assessment tools would be used) (Perlin 2011). The CBC curriculum map functions as a high level road map that guides its users – residents, faculty, and the curriculum committee – on which CanMEDS roles are taught and assessed in each module (see Figure 1). In addition to the program's overall curriculum map, other detailed maps were created for each module. These maps explicitly describe the learning context, CanMEDS roles to be taught and assessed, learning outcomes, source documents, specific competencies, learning/teaching strategies, and assessment methods that are used in each module. Figure 2 provides an example of a specific module's (advanced trauma) curriculum map.

To ensure that all intrinsic expert CanMEDS roles are assessed thoroughly and repetitively over the course of the CBC, each specific role is taught and assessed at least once in each of the three phases of the CBC and at least four times over the course of residency training, as illustrated in Figure 1.

Determining trainee competence

As noted, one of the principle features of the CBC module is a dramatically ramped-up assessment algorithm. The process to determine resident competence in each CBC module involves a minimum of three face-to-face meetings with the resident trainee and supervisor for the module. The first meeting occurs at the beginning of the module. At this time, the module leader reviews the curriculum map and its associated assessment forms with the trainee. The trainee is directed to the teaching package for the module. Most documents, training videos, and other education media are accessible on a secure, on-line server. The work schedule for the module is reviewed. Two future meeting dates are then organized – dates for the mid-module assessment and the final assessment.

During the mid-module assessment, the trainee is assessed by the module leader with oral and written assessment tools that assess competence in the medical expert CanMEDS role. In addition, the trainee is evaluated in performing an observed history and physical examination of a new patient in an outpatient clinic. Immediately upon completion of the mid-module assessment, a face-to-face meeting occurs where the module leader provides formative feedback to the trainee and reviews the results of summative assessments. If the trainee is found to be progressing satisfactorily, then a date for the end of module assessment is scheduled. If the trainee is found to have weaknesses, then a specific learning plan is organized to assist the trainee in overcoming the identified weaknesses. At this time, a recommendation can be made to extend the length of time spent on the module in order for the resident to

Module 17: Advanced trauma **Faculty Lead: Dr. XYZ**

Updated: day/month/year

Learning Context	CanMEDS Role (s)	Learning Outcomes: Goals/Objectives	Source Doc(s)	Specific Competencies	Learning/Teaching Strategies	Evaluation Method or Tools
This module will build on the trainees' basic fracture knowledge to acquire the ability to manage complex trauma and its complications	**Medical Expert**	Know: Demonstrate knowledge of Initial ATLS management	ATLS manual ATLS course in first year of residency	Be able to manage a trauma patient following the ATLS protocol	Review of source documentation and website materials Management of patients with fractures with trauma team, emergency medicine team, and orthopaedic team (including allied health professionals) in emergency room, operating room, clinic and ward Resident to be prepared to ask and answer impromptu questions from supervisor during observation and one-on-one teaching as they relate to the readings	Before start of rotation: 1) completion of ATLS course 2) completion of AO Basic course 3) completion of AO or OTA Advanced course (can be done concurrently during the module) <u>During rotation:</u> 1) Rotation through Sunnybrook Health Sciences Centre or St. Michael's Hospital taking mandatory call (as per PARO guidelines); resident should be responsible for being lead resident for each hospital's trauma room, to be shared with other residents on rotation at each hospital. As lead resident, will be responsible for organizing room, doing pre-op planning, etc. with staff supervision 2) Resident to fulfill checklist of cases (both seen and performed) off list of mandatory cases to know for trauma module by Royal College standards 3) List of special cases to seen by resident to be
		Demonstrate knowledge of the principles of the management of: all extremity and axial fractures, dislocations and fracture-dislocation (excluding the cervical, thoracic and lumbar spine)	Thomas P. Rüedi, Thomas P. Ruedi, Richard Buckley, Christopher G. Moran. *Principles of Fracture Management Vol. 1 & 2*	DO: Provide appropriate initial and definitive management of fractures and dislocations Be able to devise an appropriate pre-operative plan and execute the plan during surgery	Resident observation of staff surgeon performing all of the specific competencies, with the opportunity for questions and discussion afterwards Resident opportunity to perform assessments under supervision of supervisor Attendance at quarterly	

Figure 2. Advanced trauma module curriculum map.

Learning Context	CanMEDS Role (s)	Learning Outcomes: Goals/Objectives	Source Doc(s)	Specific Competencies	Learning/Teaching Strategies	Evaluation Method or Tools
				Demonstrate skill in the essential techniques of fracture fixation and soft tissue management	surgical skills labs that focus on the surgical management of upper and lower extremity fractures at Sunnybrook as well as annual/bi-annual skills lab sessions run by Drs. Nauth and Henry	provided 4) Feedback to be informally provided from supervisory surgeons on on-going basis 5) Determination to complete rotation to be provided by supervising surgeon during mid-module evaluation – review of checklist of cases, feedback from other surgeons <u>Mid-module evaluation</u> 1) written exam – multiple choice OITE trauma questions 2) 3 oral exam questions <u>End of module evaluation</u> 1) written exam – multiple choice OITE trauma questions 2) 3 oral exam questions 3) a minimum of 2 EPAs relevant to the module (to be completed during latter half of the module) 4) ITER from supervising surgeon evaluating all CanMEDS roles
		Prioritize injuries in trauma patients	Chapter 4.1 in Thomas P. Rüedi, Thomas P. Ruedi, Richard Buckley, Christopher G. Moran. *Principles of Fracture Management Vol. 1 & 2*	Demonstrate knowledge of the concepts of "damage control orthopedics" vs. "early total care"		
		Demonstrate knowledge of the principles of open fracture management	Chapter 4.2 in Thomas P. Rüedi, Thomas P. Ruedi, Richard Buckley, Christopher G. Moran. *Principles of Fracture Management Vol. 1 & 2*	DO: Provide appropriate initial and definitive management of open fractures and dislocations		
		Recognize the dysvascular limb and compartment syndrome	Chapter 1.6 in Thomas P. Rüedi, Thomas P. Ruedi, Richard Buckley, Christopher G. Moran. *Principles of Fracture Management Vol. 1 & 2*	Provide initial and definitive management of a dysvascular limb and compartment syndrome		
	Medical Expert	Demonstrate knowledge of the principles of the management of complications and issues in fracture care, including: • Acute and chronic infection • Malunion and nonunion • Segmental bone loss	Relevant chapters (5.1, 5.2, 5.3, 5.4) in Thomas P. Rüedi, Thomas P. Ruedi, Richard Buckley, Christopher G. Moran. *Principles of Fracture Management Vol. 1* DeCoster T, Gehlert R, et al. Management of Post-traumatic Segmental Bone Defects, *JAAOS* Jan 2004; 28-38 Masquelet AC, Fitoussi F, et al. Reconstruction des os longs par membrane induite et autogreffe spongieuse. *Ann Chir Plast Estet* 2000;45:346-53.	Provide initial and definitive management of these complications/ issues Be able to devise an appropriate pre-operative plan and execute the plan during surgery Demonstrate competence in the essential surgical techniques to manage such complications		

Figure 2. Continued.

achieve and demonstrate competence. Additional time may be appended at the end of the module, if possible, or later on in the current or next academic year.

During the latter half of the module, the trainee is assessed a minimum of two times in different clinical scenarios by the module leader. These occur in the operating room or surgical skills lab, where the trainee is assessed on his or her ability to act as a primary surgeon on "index" clinical cases related to the module. Index clinical cases are representative of the clinical scenarios that a trainee must be able to competently manage in the subspecialty that the module is based upon. This approach means that rather than demonstrating competence in each and every clinical scenario associated with the module, each resident is evaluated on a sample of the index clinical scenarios.

A list of essential clinical scenarios that each of the CBC residents have to be competent in upon completion of each module was created (see Table 1). For each of these scenarios, specific assessment forms, which we named EPAs after the term developed by ten Cate (Ten Cate 2005; Hirsh et al. 2014), were designed. These forms capture the level of competence that a trainee has in managing all aspects of the clinical care of an essential clinical condition, including the pre-operative work-up, the intra-operative

Learning Context	CanMEDS Role (s)	Learning Outcomes: Goals/Objectives	Source Doc(s)	Specific Competencies	Learning/Teaching Strategies	Evaluation Method or Tools
	Medical Expert	Demonstrate an understanding of the management of associated conditions in patients sustaining musculoskeletal trauma, including: • Adult respiratory distress syndrome • DVT • Fat and pulmonary embolism • Multiple organ system failure • Chronic regional pain syndrome • Osteoporosis	Chapters 4.6, 4.7, and 4.8 in Thomas, Thomas P. Ruedi, Richard Buckley, Christopher G. Moran. *Principles of Fracture Management Vol. 1 & 2* Chapter 3, Complications of Fractures: Acute in *Orthopaedics*, RH Fitzgerald, H Kaufer, and AL Malkani eds	Provide initial and definitive management of these complications/ issues		
		Demonstrate awareness and recognition of: non-accidental trauma issues related to geriatric fractures and pathologic fractures	Chapter 17, Surgical Pathological and Impending Fracture in *Bone Metastases: A translational and clinical approach*, 2nd edition, D Kardamakis, V Vassiliou, and E Chow eds. (available from M. Nousiainen) Bhandari M, Sprague S, et al. The prevalence of intimate partner violence across orthopaedic fracture clinics in Ontario. *J Bone Joint Surg Am.* 2011 Jan 19;93(2):132-41.	Provide initial and definitive management of these complications/ issues Be able to devise an appropriate pre-operative plan and execute the plan during surgery Demonstrate competence in the essential surgical techniques to manage such complications		
	Communicator	Demonstrate skill in communicating with other members of the trauma team and other health care personnel involved in the care of the traumatized patients. Demonstrate skills in working with patients and families who present with communication challenges such as anger, confusion, and issues related to gender, ethnicity, cultural and religious background. This would also involve communication with those with traumatic brain injury and critical injuries.	The **CanMEDS 2015 Communicator** Expert Working Group Report. Royal College of Physicians and Surgeons of Canada. 774 Echo Drive. Ottawa, ON K1S 5N8.	Accurately convey relevant information and explanations to patients and families, colleagues and other professionals Communicate effectively with appropriate consultants and synthesize their input into the care plan. Be able to verbally present the findings and care plan for the patient. Clearly document the patient encounter including trauma records, progress notes, operative notes and discharge summaries.	Review of source documentation On-going application in clinical scenarios, especially with regards to performing the surgical checklist/time out	Observation of resident de-briefing patient and family after surgical procedure, explaining expected outcomes, complications, etc. Real-time assessment Summary review of communicator skills on end-of-rotation ITER

Figure 2. Continued.

management, and post-operative care. Figure 3 provides an example of an EPA used in the advanced trauma module.

In all instances, the supervising surgeon assists the trainee during the patient encounter or surgical procedure. Once part or all of the encounter or procedure has been completed, the supervising surgeon then provides immediate summative and formative feedback on the trainee's performance. The supervising surgeon fills out the EPA form to record the level of competence exhibited and to enhance the feedback process. Upon the completion of

Learning Context	CanMEDS Role (s)	Learning Outcomes: Goals/Objectives	Source Doc(s)	Specific Competencies	Learning/Teaching Strategies	Evaluation Method or Tools
				Be able to verbally present the findings and care plan for the patient.		
		Deliver information, including options of care, possible complications and long term prognosis, in a humane and understandable way. Encourage discussion and participation in developing a treatment plan. This will lead to obtaining informed consent	Informed Consent Tips and Resources Document http://www.cpso.on.ca/CPSO/media/uploadedfiles/policies/policies/policyitems/Consent.pdf?ext=.pdf	Obtain an appropriate informed consent for patients undergoing interventions Deliver bad news in a humane and compassionate manner.		
	Leader	Engage in the stewardship of health care resources, including allocating health care resources for optimal patient care and applying evidence and management processes to achieve cost-appropriate care Demonstrate an understanding the importance of allocation of resources for the trauma patient and prioritize care.	Surgical booking criteria at respective hospital trainee is working at The **CanMEDS 2015** Manager Expert Working Group Report. Royal College of Physicians and Surgeons of Canada. 774 Echo Drive. Ottawa, ON K1S 5N8	Triage patients on surgical emergency surgery waitlist	-Review of source documents -Work with surgical team on triaging patients on surgical waitlist	Real time assessment Summary review of communicator skills on end-of-rotation ITER
		Demonstrate an understanding of health care funding as it relates to trauma care and the principle of cost appropriate care.				

Medical Expert Reference Documents:

Thomas P. Rüedi, Richard E Buckley, Christopher G. Moran. *AO Principles of Fracture Management Vols. 1 & 2*, 2007 AO Publishing

DeCoster T, Gehlert R, Mikola E, et al. Management of Posttraumatic Segmental Bone Defects, *JAAOS* Jan 2004;28-38

Masquelet AC, Fitoussi F, et al. Reconstruction des os longs par membrane induite et autogreffe spongieuse. *Ann Chir Plast Estet* 2000;45:346-53.

JB Sernik, AJM Yee, MT Nousiainen in: Chapter 17, Pathological and Impending Bone Fracture in *Bone Metastases: A translational and clinical approach*, 2nd edition. Springer. V Vassiliou, E Chow, and D. Kardamakis eds.

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The CanMEDS 2015 Communicator Expert Working Group Report. Royal College of Physicians and Surgeons of Canada. 774 Echo Drive. Ottawa, ON K1S 5N8.

Leader/Manager Article:

The CanMEDS 2015 Manager Expert Working Group Report. Royal College of Physicians and Surgeons of Canada. 774 Echo Drive. Ottawa, ON K1S 5N8.

Figure 2. Continued.

Table 1. Entrustable professional activities (EPAs) assessed in each CBC module.

Module	EPAs used in module
Orthopaedic Boot Camp	Gowning and gloving for sterile procedure
	Surgical instrument identification
	Foley catheter insertion
	Wedge bone cut
	Open reduction and internal fixation of simple fracture
	Soft tissue closure
Basic Trauma	Hip hemiarthroplasty or open reduction and internal fixation for femoral neck fracture
	Sliding hip screw insertion for intertrochanteric hip fracture
	Open reduction and internal fixation for olecranon or patella fracture
	Open reduction and internal fixation for simple long bone fracture
Emergency Orthopedic Surgery	Fasciotomy for compartment syndrome
	Above knee amputation
	Below knee amputation
Basic Sports	Diagnostic shoulder arthroscopy
	Diagnostic knee arthroscopy
Basic Arthroplasty	Primary total hip arthroplasty (non-complex)
	Primary total knee arthroplasty (non-complex)
Basic Pediatrics	Supracondylar humerus fracture fixation
	Closed reduction and casting for forearm/wrist/ankle fracture
Spine	One-level lumbar microdiscectomy
	Single level lumbar decompression and instrumented fusion
Foot and Ankle	Hallux valgus correction
	Diagnostic ankle arthroscopy
	Tibio-talar fusion
Hand and Upper Extremity	Carpal tunnel decompression
	Shoulder hemiarthroplasty
	Arthroscopic shoulder decompression
Oncology	Soft tissue biopsy
	Open bone biopsy
Advanced Trauma	Open reduction and internal fixation for complex fracture (i.e. ankle, tibial plateau, distal radius, distal humerus, femoral or tibial shaft)
	Surgical management of a non- or malunion
Advanced Arthroplasty	Revision total hip arthroplasty
	Revision total knee arthroplasty
Advanced Pediatrics	Application of Pavlik harness
	Ponseti casting for clubfoot
	Application of hip spica for fracture
	Pre-operative planning for limb length discrepancy and malalignment
Advanced Sports	ACL reconstruction
	Open or arthroscopic shoulder rotator cuff decompression/repair

While each module formally assesses a minimum of two EPAs to determine competence, a variety of EPAs exist in each module so that the trainee and assessor have the ability to match the assessment with the type of clinical scenarios available at the time of assessment.

the entire curriculum, a trainee has been formally observed and evaluated managing a minimum of 30 clinical scenarios.

The end of module assessment focuses on the three CanMEDS roles associated with the module. Assessment tools for the medical expert role include oral and/or written examinations. In addition, the assessment forms for the observed history and physical and the two EPAs are reviewed. The forms designed for the intrinsic CanMEDS roles of the module as well as the final in-training assessment report are also completed. As noted, the assessment plan for the intrinsic roles involves a variety of tools. For example, for the communicator role, trainees are formally evaluated in how they communicate with a patient as they break bad news or obtain consent for a surgical procedure. All intrinsic CanMEDS roles can be evaluated by a variety of health professionals, including supervising surgeons, fellow trainees, and other health professionals (such as nurses or physical therapists). Feedback on trainee competencies is obtained through a variety of sources throughout the duration of the module; summary forms are then completed. If the resident is deemed to be competent in all aspects on the assessment process, then the resident is allowed to proceed on to the next module. If the resident is found to be dyscompetent, then a remediation plan is organized. The trainee does not complete the module until competence is demonstrated.

The augmented number of assessments and feedback sessions provided to the residents has allowed the RPC to gain a much better understanding of the competence of each trainee in the program. In most instances, trainees were found to have no difficulties in achieving competence in all the CanMEDS roles. Some of these trainees wished to accelerate their training as quickly as possible while others decided to take more time to acquire their competencies. In other less frequent instances, trainees were found to have weaknesses in exhibiting competence in certain CanMEDS roles. As such, special remediation plans were implemented so that competence could be achieved. Information on the mean time it took the residents to achieve the competencies in each module is shown in Table 2.

Review of the CBC curriculum by accrediting bodies

As noted, approval to run this alternate stream of residency training at the University of Toronto was obtained from the RCPSC in 2008. Since its introduction, the CBC has undergone several internal and external reviews. These have been organized to ensure that (i) the new training paradigm has, at minimum, provided a level of education that is equivalent to the regular residency education stream, and (ii) that the CBC stream has no negative influence on

University of Toronto, Division of Orthopaedic Surgery

EPA: Intramedullary Nailing of Femur – Antegrade

Resident:	**Staff:**	**Date:**
Duration:		

Fails to Meet Essential Competencies 1	**2**	**Meets Essential Competencies 3**	**4**	**Demonstrated Enhanced Competencies 5**	**U/A**
• Below the minimally acceptable level for competence in the specified practice context (i.e., patient population, learning environment, practice setting). • Does not know limits and/or ask for assistance when needed • Unable to manage usual volume of work in timely manner • Doesn't improve with or respond to feedback		• Demonstrates a solid understanding of the issues, interpretation of problems and basic implementation of solution(s) • Handles common or straightforward situations and presentations competently. • Does what is expected in a timely way • Knows and works within competence limits • Generally responds to feedback		• Demonstrated ease and efficiency in handling common, straightforward as well as increasingly complex situations and presentations. • Demonstrated excellence in his or her understanding of the issues, ability to interpret problems and implement solutions • Exceeds the benchmark for competent performance • Anticipates and develops areas needing refinement and strives for continuous improvement	

Components	1	2	3	4	5	U/A
Pre-operative management						
1. Appropriate pre-operative plan outlined i.e. Familiar with patient's medical history, comorbidities, test results, neurovascular status; x-rays reviewed						
2. Correctly interprets imaging: (x-ray, CT scan) ; identifies all fracture fragments; plans for appropriate reduction techniques						
3. Knowledge of surgical tactic & materials: has planned for antegrade femoral nail; understands pros and cons of retrograde versus antegrade femoral nail and can appropriately justify reasons for retrograde fixation ; has chosen and set up for appropriate table and patient positioning						
4. Checks consent; including the potential need for additional procedure (i.e. femur venting for prophylactic nails, etc.); patient marked						
Components						
5. Surgical time out conducted appropriately; Gets OR team attention prior to pause, reviews entire checklist and confirms with nurses and anesthesia						
6. Proper positioning and padding of the patient: supine either on radiolucent table or fracture table as appropriate; body parts padded and leg centered on table to ensure complete visualization with fluoroscopy including up to/past intertrochanteric area; sterile bolster or radiolucent triangle is in the room; distraction device in room and/or applied to obtain and maintain traction						
7. Proper prep: full prep of the leg from above iliac crest to distal to ankle, with all prep sticks from clean to dirty area. Adequate draping to allow for complete exposure as necessary						

Figure 3. EPA used in the advanced trauma module.

the regular stream training program. In all reviews, the CBC and regular stream residency training programs have received overwhelmingly positive reports. The most important program evaluations occurred in 2012 and 2014, when the RCPSC performed a formal external review of both training programs. The RCPSC's final report revealed that the CBC program, when analyzed using the conventional standards the RCPSC uses to accredit programs, had no major weaknesses and received full, unconditional approval.

The feedback from the RCPSC's review in 2012 led to a landmark decision. For the first time in North America, a country's main regulatory body for medical education had approved a new paradigm in postgraduate education – a competency-based training program that was not time-based. In response to this and the data accrued that showed superiority of the outcomes when compared to the conventional program, the RPC and the Division decided to adopt the CBC curriculum as the

Intraoperative Management						
8. Deals calmly and effectively with unexpected events/complications						
9. Incision and dissection: anticipates pathway of guidewire, uses fluoro to mark out correct pathway of guidewire; appropriate skin incision made in hip area; minimal trauma during dissection, appropriately makes appropriate incision to get guidewire/reamers to tip of greater trochanter/piriformis fossa						
10. Start Point: identifies appropriate start point in greater trochanter/piriformis fossa; minimal damage upon confirming placement of pin or awl on appropriate start point; confirms correct guide wire placement in both AP and lateral views appropriately; uses mallet to secure guide wire safely						
11. Guide Rod: confidently attaches entry reamer to power and advances over guide wire to 6-8cm; inserts guide rod to fracture site, using careful technique, can describe anticipation for reducer or T-handle for help with passing of guide rod; position confirmed on radiographic imaging						
12. Fracture Reduction: clearly articulates correct angulation, displacement, and anticipates rotation with axial traction to team; reduces fracture expertly; passes guide rod distal to fracture site until it is center-center in AP and lateral views in distal femur; measures guide rod for nail length and can anticipate length with appropriately positioned in the femur						
13. Reaming: gently guides reamer past fracture site and determines appropriate chatter to ream in stepwise fashion 1.0 to 1.5 mm over anticipated nail diameter; expert technique to move reamer back and forth in canal to clear debris from flutes; uses obturator to control guide rod during reaming and anticipates need to confirm guide rod placement in proximal femur throughout reaming						
14. Nail Insertion: assembles nail and guide(s) and checks all holes for interlocking screws; locks nail into guide using screw mechanism, inserts construct atraumatically and passes nail beyond fracture site while confirming on fluoroscopy; checks distal end of nail placement on fluoro; confirms nail position in proximal femur using notched markings so that nail is appropriately countersunk						
Components						
15. Proximal Locking: appropriately assembles guides for proximal locking screws; uses skin knife and snaps to carefully dissect down to bone; tightens screws using screwdriver						
16. Fluoroscopic imaging for distal locking screws (free-hand): able to confidently obtain perfect circle views and locks using fluoroscopy safely						
17. Distal Locking: minimal soft tissue trauma while marking incision sites and uses knife and snap appropriately to minimally dissect down to femur; appropriately confirms drill placement by fluoroscopy or depth gauge; appropriately sizes distal locking screws						
18. Closure: Accurate re-approximation of myofascial layers; correct suture with no dog-ears; inverts skin edges; no skin damage: correct sequence of sterile dressing						
19. Controls bleeding from start of case in a timely and controlled fashion with no soft-tissue trauma						

Figure 3. Continued.

standard curriculum starting in the 2013–2014 academic year.

Resident outcomes

Of the 14 residents that were part of the CBC pilot, eight graduated in four years of training, as opposed to the conventional five-year time frame. Five of the remaining six completed the curriculum over the course of five years. One resident took time out from the clinical program to pursue a Master of Science degree and is anticipated to complete the CBC curriculum in four years. For the 11 trainees that entered the hybrid CBC program in 2013–2014, five graduated from the training program in four years, four are anticipated to complete the curriculum in five years, and three have taken time out of clinical training to pursue a Master of Science or Ph.D. degree. For the nine residents that entered the program in 2014–2015, four are anticipated to graduate in four years and five are anticipated to graduate in five years. Information on the mean time it took the residents to achieve the competencies in each module is shown in Table 2.

All graduates of the CBC have passed the licensing examination for orthopedic surgery from the RCPSC in their first attempt. In addition, each trainee has successfully completed a clinical fellowship/s after residency training. Of those that have completed fellowship training, three are now in academic practice (one of which is in the USA) and six are in a community practice in Canada.

While the goal of the program was not to shorten training, efficiencies gained through the program resulted in a

Post-operative management						
20. Ensures the patient is transferred safely from the operating table to bed; protects limb at all times						
21. Operative Note Dictation, including post-op orders, completed in a timely manner; including clear and concise note with outline of procedure and list of implants used; ensuring pain management, antibiotics, neurovascular checks, x-rays, weight-bearing and home meds						
22. Appropriately debriefs patient and/or family on outcome of surgery; answers questions to satisfaction of patient and/or family						
GLOBAL RATING						
OVERALL Rating: Possesses knowledge, skills, and attitudes for satisfactory completion of this surgical procedure						

Comments

Evaluator Code: _____

Figure 3. Continued.

shortened time to completion for some learners. The benefit of this to the program and the post-graduate medical education office was that one less year of funding was necessary for a resident salary, assessment, and feedback. The downside was that there was one less year provided for patient care at the senior resident level.

Challenges faced

Despite the many benefits of the CBC for the trainees and the training program, several significant challenges had to be overcome (Hawkins et al. 2015; Touchie and ten Cate 2016). One important challenge involved managing the increased financial costs for implementing and continuing the training program and the increased labor required by staff to provide the enhanced teaching and assessment sessions. As Nousiainen et al. (2016) indicated in an earlier publication, the financial cost of using a simulation-intensive approach to teaching and assessment in the CBC rose by 15.5 times (CDN 155,750) compared to the year prior to the new curriculum's implementation (CDN 10,090). It is also of note that the orthopedic faculty as a whole dedicated more hours to the teaching and assessment mission, roughly three-fold greater than in the conventional curriculum. These data do not incorporate the dollars and extra hours related to hiring an extra 0.5 FTE administrative assistant for the Division (whose sole responsibility was to implement and maintain the new curriculum), the relationships that the Division developed with the surgical skills lab and implant vendors to provide services at discounted rates, and the extra time faculty have spent in performing assessments and providing feedback outside the skills laboratory. Since the pilot program, cost efficiencies in the use of simulation have been realized and have brought the time required by faculty for assessment and the cost down by approximately one-half (unpublished data). Additional cost-sharing agreements with the Division and Department of Surgery have made the budget sustainable in our environment.

Table 2. Mean time spent on each module for CBC graduates up to 2016–2017 ($n = 13$).

Module	Mean number of months spent on each module	Standard deviation (in months)
1 – Introduction/Boot Camp	1.35	0.41
2 – Basic trauma	4.81	0.75
3 – Emergency surgery	1.00	0.00
4 – Medicine consults	1.00	0.00
5 – Basic sports	2.69	0.46
6 – Basic arthroplasty	2.04	0.13
7 – Intensive Care Unit	2.06	0.28
10 – Basic pediatrics	2.04	0.13
11 – Spine	3.06	0.48
12 – Foot and ankle	2.98	0.68
14 – Hand and upper extremity	4.63	1.85
15 – Musculoskeletal medicine	2.21	0.44
16 – Oncology	2.08	0.47
17 – Advanced trauma	3.65	1.45
18 – Advanced arthroplasty	3.65	1.53
19 – Advanced pediatrics	3.60	0.88
20 – Advanced sports	3.38	1.58
21 – Research	0.90	0.58
Community ortho/electives	3.08	2.14
Total months, excluding time off	49.67	

Another challenge faced was the need for an effective information technology platform that would allow the trainees, supervisors, and the program administrators access to the on-line curriculum maps, learning resources, and assessment forms. When the CBC was initiated, all assessment documents were completed in paper form. The use of paper led to delays in form completion and delivery to the Divisional office. Since 2014, the Division has used an on-line server that allows trainees and their evaluators the ability to have point-of-care assessments be performed immediately on a web-based server that can be accessed by a smart phone or computer mainframe. Once completed, the forms are electronically delivered to the Divisional office where they are entered into the trainee's academic portfolio. Although this server has markedly improved the timeliness and completion rate of assessments, the technological platform has required on-going

refinement, particularly in its user-friendliness. In doing so, it has decreased the amount of time faculty spend on assessment completion.

The implementation of the CBME paradigm also necessitated that all residents be active participants for their education. When the CBC was initiated, it was the faculty's responsibility to ensure that all assessment forms were completed on a timely basis and that the residents be walked through the curriculum maps for each module. We found that a more successful approach mandated that the trainees be responsible for familiarizing themselves with the curriculum maps, learning tools, and assessment forms for each module. In addition, residents were now to be responsible for actively organizing the orientation and assessment/feedback session meetings they were to have with their supervisors.

The last challenge faced was that of faculty development (Iobst et al. 2010). Although there were many early adopters to the pilot, there were faculty who had difficulty understanding the concepts of CBME and how it related to the new training program, particularly as it translated to the role of the trainee in the operating room and how to manage a trainee that was found not to be competent. Multiple formal meetings were organized with faculty to go over the curriculum maps, learning tools, and assessment forms and answer all questions and concerns they had about them. This was managed largely by assuring front-line faculty that their responsibilities were to teach trainees as they had in the past, with the add-on of having to spend some extra time in the augmented assessment process.

It was necessary to assure faculty that the RPC and program director would be tasked in organizing remediation sessions, if necessary. With time, the faculty understood the premise and processes involved; as a consequence, the Division's faculty was ready when the entire program moved fully to the CBC in the academic year of 2013–2014.

Conclusions

Since the program's inception in July of 2009, the design and implementation of both the teaching and assessment components of the CBC have undergone dynamic change. We have learned that although the original plans that were organized were well-conceived, changes were necessary to reflect the ongoing feedback we received from our module leaders, faculty, colleagues, and trainees as they went through the curriculum.

One of the key strengths of the approach with the CBC program has been its ability to be modified when weaknesses have been noted and expanded when strengths have been recognized (Frank et al. 2010). Approval of our novel training program by the RCPSC has provided us with a strong mandate to continue forward. Both the faculty and residents have viewed the CBC program as a success. As such, the decision was taken to fully adopt the CBC as the sole mode of training and assessment in the residency training program in the 2013–14 academic year.

We believe this program is a leading-edge example transforming a conventional curriculum into a competency-based framework. Although there have been several benefits of implementing this novel curriculum, particularly as they relate to curriculum design and enhanced assessment and feedback processes, significant challenges have been faced and resolved. These include the cost of implementing and maintaining the curriculum, work on faculty development, and asking our faculty to spend more time and effort in assessing and providing feedback to our trainees. Considering our experience with the CBC since 2009, we are confident that the altered framework for residency education leads to better resident outcomes, delivered in a more efficient manner. CBME results in a more explicit attestation of competence and is delivered in a manner that is more learner centered, and one that is more empowering for the residents.

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Notes on contributors

Dr. Nousiainen, MS, MEd, MD, FRCSC, is an Associate Professor and Program Director of the residency training program, Division of Orthopaedic Surgery, Department of Surgery, Faculty of Medicine, University of Toronto.

Polina Mironova, MS, is the assistant program administrator in the Division of Orthopaedic Surgery, Department of Surgery, Faculty of Medicine, University of Toronto.

Ms. Hynes, MA, PhD(c), is a research officer at PostMD Education, Faculty of Medicine, University of Toronto.

Dr. Glover Takahashi, MA (Ed), PhD, is Director of Education, Integration and Research, PostMD Education, Faculty of Medicine, University of Toronto.

Dr. Reznick, MD, FRCSC, is Dean of Faculty of Health Sciences at Queen's University and CEO of Southeastern Ontario Academic Medical Organization.

Dr. Kraemer, MD, FRCSC, is an Assistant Professor, Division of Orthopaedic Surgery, Department of Surgery, Faculty of Medicine, University of Toronto.

Dr. Alman, MD, FRCSC, is Professor and Chair, Department of Orthopaedics, Duke University and Adjunct Scientist with the Sick Kids Research Institute, Hospital for Sick Children, Toronto, ON.

Dr. Ferguson, MS, MD, FRCSC, is an Associate Professor and Albert and Temmy Latner Chair, Division of Orthopaedic Surgery, Department of Surgery, Faculty of Medicine, University of Toronto.

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