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REVIEW ARTICLE

Teaching and training in orthopaedics

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Abstract

This article aims to review the current trends in the pedagogy of orthopaedic surgery, with specific reference to teaching philosophies, training methods and assessments tools that may be used. Our expanding knowledge base and the complexity of skills required, combined with the pressure created by medical negligence litigation increases the emphasis on knowledge of disease in contrast to pure competency in practical procedures. At specialist level, the drive now appears stronger than ever to develop less- or non-invasive ways to treat musculoskeletal disease. As a disease specialist the trainee, therefore, needs to develop a wider vision than one held by a competent technician. A combination of educational philosophies can be employed to achieve these objectives. Cognitive task analysis (CTA) and constructivism may be useful strategies for skills acquisition. In terms of theoretical knowledge, the emphasis remains on an evidence-based approach, delivered in an active student-centred environment. Clinical teaching as a whole, however, demands the promotion of critical thinking and a problem-oriented approach in a situated learning setting. The pedagogy of skill and knowledge assessment in orthopaedics remains unresolved. However, the educational impact of assessment through its value as a driver for learning has been recognised.

Level of evidence: Level 5

Key words: teaching, training, assessment, orthopaedics, trauma, review

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Introduction

Orthopaedic surgery is expanding exponentially with evolving sub-specialities demanding increased technical and academic competencies. This results in both undergraduate and post-graduate students having to assimilate an intimidating amount of knowledge during their training. In addition, registrars are required to provide evidence of research proficiency to register as a specialist. With the concurrent service demands and training time constraints, we need to review the way we educate.

Teaching of surgical skills is challenging but not necessarily more important than theoretical knowledge as we cannot focus on creation of competent technicians alone. Theoretical knowledge is crucial in order to apply the technical skills, and forms the basis of clinical care in musculoskeletal medicine. Being able to perform a knee replacement does not mean you can treat osteoarthritis. This principle holds true for both under- and postgraduate students and trainees need to develop a wider vision than one held by competent technicians.[1]

This article aims to review the current trends in the pedagogy of orthopaedic surgery with regard to teaching philosophies, training methods and assessments tools.

Teaching and training

Skills acquisition

Orthopaedics is a procedure-oriented discipline. Teaching and training therefore requires emphasis on acquiring a heterogeneous group of technical and non-technical skills. Traditionally, this involved exposure to a high volume of cases.[2] The following factors challenge this strategy and necessitate a rethink:

- Increasing complexity of procedures, fixation devices and implants
- Reduced training time, primarily because of reduced availability of theatre-time
- Diluted exposure to high-cost elective cases as state hospitals are inundated with trauma
- Shortage of trainers in the clinical academic environment
- Greater awareness of medico-legal implications and ethical issues surrounding training involving patients

Mechanical and virtual reality simulation have been proposed as possible solutions to these problems. Although simulation allows surgeons to acquire psychomotor and technical skills, they do not address certain important non-technical skills like cognitive decision making. The importance of the cognitive phase of acquiring motor skills should not be underestimated and is underlined by Positron Emission Tomography (PET) neuroimaging studies that have demonstrated differences in regional brain activation in association with different forms of motor learning.[3] It has been suggested that cognitive ability comprises up to 75% of surgical training, while mechanical ability only contributes 25%.[4] Fitts and Posner developed their model for the learning of motor skills based on this principle.[5] This model described the cognitive stage as the primary process, which is then followed by the associative and automated stages. An 'automated' process has traditionally been associated with expert performance of the task. It has, however, been estimated that expert surgeons may leave up to 70% of vital steps out when imparting practical knowledge.[6] This may be attributed to the automation which occurs when clinicians reach expert level. Automation results in loss of the level of conscious awareness of the procedure.

Miller's hierarchical approach to clinical training involves knowledge, competence, performance and action.[7] While performance builds on competence, performance is also influenced by numerous other factors.[8] In the South African clinical environment, service delivery pressures may result in registrars having to 'perform' before they have established the necessary comprehensive knowledge base. Another factor that influences performance is the fact that orthopaedic pathology tends to be highly variable and no two fractures are the same. While a learner may be competent at intramedullary nailing it does not necessarily translate into adequate performance in all clinical scenarios involving intramedullary nailing. For example, the skills and techniques required to perform intramedullary nailing of a Seinsheimer type V femur fracture is radically different from that employed during the intramedullary nailing of a Winquist and Hansen type I diaphyseal femur fracture. Thus, even if the trainee is competent at a certain type of fracture fixation it does not mean they will be able to achieve adequate performance (in terms of the clinical outcome) for all possible fracture patterns. Errors in both decision making (choosing the wrong implant, for example) and execution (varus mal-alignment) may therefore affect performance. The Cambridge model acknowledges this shortcoming by distinguishing competence (the trainee can do the intramedullary nail on a saw bone) from performance (the trainee can perform it in the clinical scenario) and recommends assessing these two factors independently.[9]

In order to address these issues, the above-mentioned automated skills can be deconstructed by providing a detailed description of the task that makes the steps easier to understand.[10] This process is referred to as Cognitive Task Analysis (CTA). The trainee needs to understand the reason for each decision and therefore information should be provided on the specific cognitive decisions that are made at each step. Focusing on mental learning of the steps, CTA does not include only manual or technical aspects of surgical training.[5]

Constructivism is the theory that learners acquire knowledge and understanding through the interaction of their experiences with their ideas.[11] This implies that trainees are more likely to acquire a practical skill if it is based on a similar previous clinical or learning experience. It is a useful method in orthopaedics and can be implemented by means of promoting pattern recognition and procedure-oriented problem list development. Building on the competence a trainee has acquired in terms of the basic skills to perform a surgical procedure (intramedullary nailing of a Winquist and Hansen type I diaphyseal femur fracture, for example) the trainee is taught to identify patterns (Seinsheimer type V femur fracture, for example) that necessitate the implementation of more advanced techniques, building on the same skill set. Once the trainee has shown adequate comprehension, the pathology can be broken down into the problems that specifically need to be addressed over and above the standard procedural technique that is required. The trainee then has to develop his operative plan with cognisance of this problem list. This process then ties in with the CTA methodology used in the learning of the intervention.

Theoretical knowledge

Teaching in surgical disciplines differs from other forms of teaching in that our practice relies as much on the practical aspects as it does on theory.[12] This leads to the tendency to base our practice, and thus our teaching, on past experience. The mentor who relies only on his or her own experience (even if it can be qualified as an expert opinion) has, however, not completely fulfilled their role as a teacher. For this reason, evidence-based medicine (EBM) emerged as a key principle in surgical training. With several treatment options available for each fracture or pathology (a lot of which is based on rapidly advancing biomedical technology associated with significant commercial interest), selection of the optimal treatment method has to be based on sound clinical evidence. While the need for an evidence-based approach is widely accepted it has been criticised and it may, however, not always contribute to improve patient outcomes.[13]

The pedagogy of 'what' is taught appears to be a lot more evolved than 'how' it should happen. In accordance with the recognised principles of evidence-based surgery, teaching methods should be patient- and learner-centred, as well as active and interactive.[14] Educational theory suggests that interactive discussion is not only more popular but possibly also better at promoting knowledge retention in comparison to didactic lectures. This has also been shown in randomised trials involving group discussions in orthopaedics.[15] While not always possible, discussions in small group format is preferred.[16] In order to minimise didactic lecturers (level 3 EBM teaching) and increase learner-centred, interactive, clinically orientated teaching (level 1 EBM teaching) the 'flipped classroom' model can be employed.[17,18] The first step involves providing evidence-based material to learners to study in their own time. These student-centred assignments promote self-paced student involvement. It is thought that the actual practice of offloading content and engaging in active learning in the classroom is far more important than the specific method of offloading.[18] The scheduled teaching event that follows then involves patient-centred problems-based discussion followed by inquiry. This may become quite chaotic and focus should be maintained through micro-lectures and clinical examples. In this way, the classroom time is active, student-centred and clinically orientated with the emphasis on an evidence-based approach. This teaching method can be highly effective as it reinforces the knowledge attained through interaction with well-prepared learners. It may also result in improved attitudes towards learning and knowledge retention. The main drawback of this method is that it is more time-consuming than more traditional teaching methods. While less active, a didactic platform may still be required to facilitate exposure to vital knowledge not covered in the more active components of the teaching programme.

Clinical teaching

Contemporary educational themes in clinical teaching methodology include:

- Critical thinking
- Problem-oriented learning
- Evidence-based approach
- Situated learning
- CANMED principles

Critical thinking can be defined as the ability to apply cognitive skills (analysis, synthesis, perspective-taking) and the disposition to be deliberate about thinking (being open-minded or intellectually honest) that leads to action that is logical and appropriate.[19] It is a fundamental skill for clinicians who have to gather, integrate and act upon constantly changing complex data.[20] Deficits in critical thinking have significant implications in practice, including misdiagnosis, delays in diagnosis and treatment errors.[21-23] It has been suggested that a significant portion of students are not acquiring the necessary critical thinking skills thought to be at the core of higher education.[24] The sheer volume of available 'evidence' (literature) and the rapid advance of the science of orthopaedic surgery may distract somewhat from the focus on acquisition of complex reasoning skills. In order to address this, a problem-oriented approach with emphasis on pattern recognition and solution-oriented problem-list development can be employed. The aim is to engender a culture of higher-order thinking during problem analysis, synthesis and solution. Reflective thinking should be promoted and learners should acquire the ability to zoom in and out during the process (between critical technical detail and the 'big picture' of ultimate clinical outcome). This should ideally be performed in the clinical environment and during small group discussions (morning X-ray meetings, peer-review sessions, out-patient clinics, ward rounds or theatre planning sessions). Irrespective of the setting, one should strive to keep the discussion patient-centred and clinically relevant. Methods used to facilitate higher-order thinking include questioning (asking the student to explain his or her reasoning) and group interaction (obtaining varied opinions on a problem from not only the person presenting the case but also the other members of the group).[25] Critical thinking can be promoted by, for example, asking learners to describe all treatment options along with their reasoning as to why or why not they would select it. Group interaction is encouraged by asking the entire group to vote on a treatment option, for example, and individuals are asked to explain their reasoning or developing a problem list as a group through sequential individual contributions. Group interaction is particularly useful in orthopaedics as there is typically more than one solution to the problem. One should be mindful of keeping the process inclusive and if either trainees or consultants are not participating they can be asked for their opinion on the matter. The one major advantage of the critical thinking approach is that it places a premium on EBM. The trainee quickly learns that ultimately the available evidence should guide their thought process.

Teaching EBM can be achieved by various methods. The first is modelling EBM as the foundation of an expert clinician. Learners, aspiring to clinical excellence, look up to their teachers as models of expert behaviour.[26] The second method addresses the disorganised nature of active learning by making EBM the focal point and returning to the available evidence when concluding an interactive session. Journal club meetings provide an ideal opportunity for this approach and should incorporate the principles of critical appraisal of evidence. Mobile applications like 'Read by QxMD' have also drastically enhanced our ability to practise and teach EBM. It allows learners to search specific topics in the training environment and follow a range of specialities, journals and keywords. It also allows teachers to provide a selection of notable articles in a collection that can be accessed by learners. Other resources include journals like *Bone and Joint 360* (currently provided by the SAOA), which provides an expert's summary of noteworthy publications in each sub-discipline. While this platform for EBM teaching lends itself to active and interactive participation, the method has to be employed in a learner- and patient-centred manner. This requires the learner to be engaged in a way that is relevant to them in clinical practice and this may be achieved through situated learning.

Situated learning describes the principle of making the learner part of the community of practice. This is achieved by the legitimate participation of the trainee in the clinical environment. We frequently hear clinicians saying: 'Students/registrars are not what they used to be.' While this may be true, the fault is not necessarily on the student's side. Gawande points out that trainees are currently a lot further removed from the actual care of the patient.[1] Consultants tend to make the decisions about treatment etc., which removes the trainee's sense of purpose and belonging to the team. The situated learning theory aims to address this issue through legitimate participation in the treatment process.[27] This not only reinforces theoretical knowledge but also provides the trainee with a sense of purpose and belonging to the team. While this can be achieved relatively easily through the student having to consult with patients in the clinic, on a ward round or while on call, independent interaction with the patient alone does not constitute complete inclusion of the learner. If the student presents the patient to the teacher who then prescribes the diagnostic procedures and treatment modalities to be employed, the value of the method is diminished. By insisting that learners provide their diagnostic and treatment plans (with reasoning) when presenting patients for discussion, this method focuses the trainee's assessment of the patient on solving the problem at hand, rather than on just being able to perform generic symptom and sign reporting during the case presentation. It forces the trainee to think beyond the symptoms and signs, and begin to integrate the problem list with the treatment options. The process ties in with the over-riding aim, which is to engender a culture of critical thinking. The situated learning theory also supports the concept of 'scaffolding' where the learner is temporarily supported by an expert tutor who places them in the so-called 'zone of proximal development' where the student is able to progress in problem solving through interaction with more capable peers.[6,28]

Although clinical acumen is essential, it is not all that is required of a competent clinician. The introduction of the CANMED principles into medical teaching recognises this.[29] This approach emphasises the acquisition of all the necessary competencies to be able to function as an effective:

1. Medical expert
2. Communicator
3. Collaborator
4. Manager
5. Health advocate
6. Scholar
7. Professional

The aim should be to incorporate these aspects into clinical training and there is some evidence that implementation of CANMED principles can improve clinical outcomes in surgery. Apart from the fact that trust in the physician may have a certain 'placebo' effect, strength in leadership may improve outcomes through the establishment of effective health care systems. Young *et al*. found that, when comparing surgical services with low and high complication rates, the difference was not in the training and experience of the surgeons but in the performance of the team as a health care system.[30] They recognised the role of the surgeon as a leader of the team, who should not only be proficient in terms of management and the administrative aspects of running a team (protocols, systems and coordination etc.) but also with regard to the human resource side of things (communication, motivation and empowerment). This, again, emphasises the requirement to train a surgeon as more than a mere 'technician'.

Assessment

Assessment of trainees forms a crucial part of supervision as it not only describes the progress of the learner, but also serves as a measurement of the efficacy and relevance of the training programme and the trainers. A recent study from the United Kingdom suggested that UK medical schools may be failing to ensure that medical students have acquired a basic competence in musculoskeletal medicine.[31] In fact only 21% of students passed the Freedman and Bernstein musculoskeletal cognitive examination.[32] The situation does not appear to be much better in South Africa, where a similar study (involving interns) found a 91% failure rate.[33] These results are worrying and indicate that we need to intensify efforts to improve education in musculoskeletal disease. Indeed, recent studies have emphasised the underrepresentation of orthopaedic surgery in undergraduate curricula.[34] While these studies illustrate the importance of training programme development and delivery it also highlights the need for appropriate assessment of learners. Assessment typically drives learning in students and therefore assessments should be designed to direct study in the relevant direction. The learning goals should therefore be considered when developing assessment tools to ensure that they remain relevant while not compromising quality. The challenge is that trainees must be assessed on the traditional competencies (knowledge and skills) but also on the other educational elements embodied in the CANMED principles.

At postgraduate level, the assessment of both aspects of cognition (knowledge and competence as referred to in Miller's pyramid) is challenging.[7] The evolution of single-best answer questions based on a clinical scenario appears to hold benefit as it promotes patient-centred analytical thinking. This format of assessment addresses several dimensions (remember, understand, apply, analyse and evaluate) of the revised taxonomy of educational objectives, as proposed by Krathwohl.[35] In terms of formative assessment of knowledge, open-ended essay-style questions may not necessarily be superior to the multiple-choice format.[36] However, it may still have an educational impact through its value as a driver for learning.

The assessment of skills has received some attention in recent literature. While the use of simulation is currently very prominent in orthopaedic literature, it is not always a realistic option in our resource-restricted environment. Furthermore, the cost efficiency of simulation-based assessments has been questioned. While OSATS (Objectively Structured Assessment of Technical Skills) was initially heralded as a reliable and valid tool, its validity has recently been called into question.[37] The problem is that evaluating a technical competency does not equate to an acceptable outcome in orthopaedics. Assessing drilling and screw insertion techniques does not measure adequacy of the fracture reduction, the level of stability that is achieved or the risk of non-union, for example. In order to achieve a more outcome-oriented approach, peer review may be implemented as part of the formative assessment. Both technical competency and surgical outcome can be assessed in this fashion. Surgical logbooks are useful additional formative assessment tools and can be used to assess if trainees have met the required milestones in terms of surgical exposure, in a similar way to what is prescribed by the Accreditation Council of Graduate Medical Education (ACGME), for example.[3] Assessing the learner's ability to communicate, manage and work in a team, as well as perform adequately as a scholar and a professional, is difficult. Even more challenging is the assessment of actual performance.

Although our ability to assess knowledge, competence and even performance has certainly improved, 25 years after Miller's article was published, his words still ring true: the action aspect of the clinical behaviour is still the most difficult to measure reliably and accurately.[7] The most important final outcome is the ability of the trainee to perform independently, and this is the most difficult level to assess. Many factors affect the trainee's performance outside of the artificial training or examination environment. Attitudes, personality traits, coping mechanisms and the working environment may all play a role. Some of the aspects involved are so subtle or complex that they are extremely difficult to capture in a checklist. Obviously, the best way to assess the trainees' ability to 'do' is to evaluate their performance in carrying out their normal clinical duties. The coaching method, as used by the AO foundation, is primarily formative in nature and experienced as a training opportunity in a realistic environment. The trainee's actions can be assessed by their 'coach', who (similarly to a sporting coach) is seen to be on their side (rather than a critical examiner). Improvement is then achieved through the trainee and the coach's combined 'post-match' analysis.

Conclusion

With the massively expanding curriculum and required skillset, exposure restrictions and litigious environment, we need to adopt safer and well-proven educational strategies to prepare our trainees for Orthopaedic Specialist practice.

Compliance with ethics guidelines

This article does not contain any studies with human participants or animals performed by any of the authors. For this study, formal consent was not required.

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