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Technical knowledge and skills in undergraduate radiation therapy: The University of Newcastle experience

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Abstract Radiation therapy (RT) technologies and the technical skills required have undergone an extended period of change and advancement. The University of Newcastle's RT curriculum has met this challenge by developing a technologically layered curriculum that not only retains the basic fundamental concepts underpinning RT, but also reflects current and emerging technology, as well as the associated skill developments.

This paper outlines how past, current and future RT technical approaches and technical skills are integrated into the current undergraduate RT curriculum.

Keywords: clinical skills, curriculum, radiation therapy, technical skills, technology, undergraduate

Introduction

Radiation therapy (RT) clinical practice has undergone major technological change over the past decade. The basic conventional approach to RT simulation, planning and treatment, has been mostly replaced by advanced approaches such as three dimensional conformal RT (3DCRT), and more recently by emerging approaches such as intensity beam modulation (IMRT) and motion sensitive RT (MSRT).[1,2,3]

In the conventional approach to RT, clinical practice was underpinned by knowledge and skills in basic techniques such as: volume measurement from simulation films and volume transfer to manually collected outlines; planning dose calculation including the use of tables and ISL calculations; and the use of shielding, physical wedges or the manual setting of field sizes for photon and electron therapy.

The advanced and emerging approaches to simulation, planning and treatment are supported by automated and computer generated and controlled functionality, and many of the foundation skills are now not required. For example, the use of simulation films for volume definition has been replaced with CT voluming; manual dose calculation has been replaced by computer generated doses and monitor units; and shielding construction and design including templates has been replaced with MLCs for beam shaping and dynamic wedging.

In educating students for current and future practice, one of two options are available; you can either include the basic science and clinical skills, which have been derived from past technology and form the basis for newer planning and treatment methods, or you can simply educate students in current practice and disregard the past science.

It is the authors' belief that there are basic 'first principle' concepts that still need to be taught so that the more complex techniques can be incorporated into the student's theoretical framework in subsequent years. It is also the authors' contention that implementing a curriculum that only educates for current practice results in a significant loss of the foundation science of professional practice to the future professional body. This can result in the shift of the responsibility for this knowledge and skill set to other groups, such as medical physicists.

This being said, there is a competing need to ensure currency in RT programs. To do this, it does mean that occasionally some past methods must be deleted to make way for new educational and professional practice needs. The big question, when faced with these two competing issues, is what basic science to keep in the program and what basic science to delete?

This paper presents a review of the teaching program for the basic, to advanced, to emerging technologies, as well as the associated professional technical skills within the University of Newcastle's undergraduate Radiation Therapy Program. It should be noted that while there are many other components to the RT curriculum, such as patient care and patient assessment skills, clinical methods, or research skills etc., this review only focuses on the teaching of RT technology and RT technical skills.

The basic to complex clinical paradigm

The idea that there is a hierarchy of clinical procedures from basic procedures to complex procedures is highlighted in the International Commission of Radiological Units Report 50 and 62. When discussing dose evaluation for reporting RT treatments, the ICRU reports[4,5] describe three levels of increasing complexity:

Level 1
Basic techniques – the determination of dose at the reference point and its variation along a central beam axis,

Level 2
Advanced techniques – the dose distribution can be computed for volumes in one or more planes using data sets of information,

Level 3
Developmental techniques – the dose distribution can be computed for 3D volumes, with coplanar and non-coplanar beams, with dose/volume assessment.

Table 1 Correlating ICRU complexity level to examples of treatment and technical skills

Level 1 Basic techniques: conventional RT approaches	
Treatment examples:	Palliation / Low dose curative
Knowledge and skills:	• Simulation, use of films • Planning, manual methods, use of isodose charts and curves, dose calculation • Treatment, use of templates, manual shielding, port films
Level 2 Advanced techniques: conformal approaches	
Treatment examples:	Pelvic RT
Knowledge and skills:	• CT simulation and CT data sets • Planning, computer planning, PTV & OAR volume determination • Treatment, MLCs, EPIs
Level 3 developmental techniques: IMRT, MSRT	
Treatment examples:	Dose escalated treatments
Knowledge and skills:	• CT/MRI/PET simulation • Planning, fused data sets, full and partial volumes, DVH plan evaluation • Treatment, dynamic MLCs, gated RT

Although the ICRU reports reference these complexity levels in relation to plan evaluation, the described complexity of plan evaluation relates directly to plan development and treatment complexity, which in turn is linked to the RT technical knowledge and skills needed to perform the task.

These three levels of complexity can also be matched closely to terms used more frequently to describe RT methods, such as conventional RT, conformal RT or emerging approaches such as intensity modulated RT. Table 1 outlines the connection between ICRU complexity level descriptions and treatment type and skill set required.

Basic to emerging approaches in clinical practice

To quantify the use of the basic to emerging technical approaches to RT, a small clinical audit was conducted in NSW. The NSW Health Department, 2003 Radiotherapy Management Information System Report,[6] was reviewed. The statistics indicated that 43% of patients are still being treated palliatively using more conventional methods, while approximately 57% of patients are being treated radically using a combination of conventional, conformal and emerging approaches.

A second audit was undertaken where the caseloads at three NSW clinical centres for the past year were reviewed. Pooled results indicated that approximately 46% of the caseload from the clinical centres reviewed were palliative patients, with a large percentage of these being simulated, planned and treated using conventional methods. The remaining were curative cases using advanced clinical methods.

Therefore with respect to the current caseload in NSW, the teaching of the conventional to emerging methodologies appears justified and required.

Incorporating the model into the RT program

In teaching technology and technical skills, the undergraduate RT program at Newcastle has been designed on a layered model

Table 2 Technical approaches by year, semester and course code

Year of study Semester and course code	Technical and skill approach
Year 1	
Semester 1 – MRSC1000	Conventional
Semester 2 – MRSC1050	
Year 2	
Semester 3 – MRSC2200	Conventional, and introduction to Conformal
Semester 4 – MRSC2250	3D Conformal techniques
Year 3	
Semester 5 – MRSC3200	3D Conformal techniques, and Emerging (IMRT)
Semester 6 – MRSC3250	Emerging techniques

of increasing complexity. The program provides for this vertical integration over the three years and six semesters of the undergraduate program. Rather than referring to Level 1 complexity etc. as in the ICRU 50 Report, the program teaches technology and technical skills following the three matching RT descriptions:

(1) Conventional techniques
(2) Conformal techniques
(3) Emerging techniques

This layering of complexity and learning allows the student to grasp the basic underlying principles of clinical skills and patient management, before engaging with higher level learning. Table 2 shows the layering of the techniques by year and semester of study.

Conventional techniques

The Year 1, MRSC1000 and MRSC1050 MRS Professional Methods courses teach the technology and technical skills of conventional or basic methods. This allows the student to develop, early in his/her program, a solid framework of foundation knowledge and skills, from where they can begin to construct more complex concepts, techniques and skills. In Year 1 Semester 2 students learn to plan basic level cases (palliative spine, chest, hip) using manual isodosing methods as well as 2D planning computers. All calculations are done manually with all factors derived manually.

Many of these skills are used in the four-week clinical placement at the end of the first year of the program where clinical competency assessment is used to evaluate the students' ability to undertake a basic or low-level task. Normally, most students will be successful in obtaining a low level competency in planning and treatment, e.g. palliative spine, hip.

In Year 2 Semester 3 of the program, MRSC2200 consolidates the conventional approach by advancing the concepts to multifield isocentric treatment and planning, shielding requirements and construction, and the application of ICRU 50/62 to plan evaluation. Once again, manual or 2D computer planning, using CT data sets, is used and all calculations are derived manually. Students learn to plan and evaluate multi-beam treatments of the pelvis and abdomen. Students are also introduced to 3DCRT approaches and are introduced to 3D planning with students planning a 3D pelvic case. This is useful as students will experience conformal methods while on clinical.

Table 3 Conventional or basic technology and technical skills

Year 1 – Semester 1 – MRSC1000	
Introduction to RT	• Linacs • Cobalt • Surface anatomy • Outlining/contouring • Simulation overview • Planning overview • Treatment overview • Beam modifiers, e.g. physical wedges
Year 1 – Semester 2 – MRSC1050	
Non-isocentric methods	• Taking and using simulation films • Determining magnification factors • Volume and field size determination • Equivalent square calculation • Manual isodosing and the use of percentage depth dose tables • Plan development and plan evaluation • Manual dose calculation, maximums, tumour doses, minimums, OAR (organs at risk) doses • Area factors, shadow tray factors, wedge factors
Year 2 – Semester 3 – MRSC2200	
Isocentric methods	• Application of all MRSC1050 learning to isocentric methods • Manual dose calculations using statistics and DAH / DVH (Dosearea histogram / Dose volume histogram)
Shielding and template design and construction	• LMA (Low melting point alloy) blocks, straight sided, divergent sided, daily placement vs. fixed blocks, block construction from simulation radiographs, hot wire cutters, QA (Quality assurance), OH&S (Occupation health and safety) • Template material, template use, template construction from simulation radiographs, QA
ICRU 50 / 62	• ICRU Reports 50 / 62 Prescribing, Recording and reporting • ICRU reference point, reporting of doses, standardisation of dose reporting, volume definitions, dose variations across volumes, OAR doses, full and partial volume doses
Introduction to 3DCRT (3D Conformal RT)	• Comparison of conventional/conformal approaches • The 3DCRT pathway

Table 4 Conformal technology and technical skills for pelvic sites.

Year 2 – Semester 4 – MRSC2250	
Pelvic RT Prostate Bladder Cervix Rectum Testes	• CT data sets versus orthogonal simulation films • 3D PTVs (Planning tumour volume), OARs versus multi-slice 2D volumes • Conformal beam shaping versus shielding methods • Asymmetric methods versus symmetric methods determination • Plan development and evaluation • Manual dose calculation, maximums, tumour dose, minimums, OAR doses • Area factors, shadow tray factors, wedge factors • ICRU reference point, concept of prescribing, recording and reporting of doses, standardisation of dose reporting, volume definitions, dose variations across volumes, OAR doses, full and partial volume doses

At the end of this semester, a five-week clinical placement allows students to apply these new developing skills. By the end of this clinical, students will have completed the low level (basic conventional) competency requirements and begin to undertake medium level (conformal) procedures. The conventional technical knowledge and skills included in these subjects are summarised in Table 3.

Conformal techniques

In Semester 4 in MRSC2250, students alternate between planning cases conventionally and conformally using 2D and 3D planning. All teaching in this semester focuses on the major RT sites within the pelvis. The reasons for this are that pelvic RT is associated with:

- major tumour sites being in close proximity to full and partial organs at risk volumes (OARs);
- the use of CT data sets at simulation and planning;
- multi-field treatments using highly shaped beams;
- multi-phased treatments with dose escalation;
- concomitant chemotherapy for some sites; and
- the availability of clinical practice guidelines that describe clinical methods for pelvic sites.

Treatment complexity is increased because of these issues and therefore, conformal approaches are required. Table 4 shows the range of clinical skills introduced in Semester 4. Once again, all

Table 5 Conformal RT approach for complex sites.

Year 3 – Semester 5 – MRSC3200	
Breast RT	• 2 field to 5 field breast treatments
Head and Neck RT	• Multi-phase head and neck
Chest / Thorax RT	• Small field versus wide field intra-thoracic treatments

dose calculations are being derived manually.

At the end of the semester there is a five-week clinical placement for Year 2 students to integrate their learning. At this time, students will normally gain treatment and planning competencies in medium to high level conformal methods.

In Year 3 in Semester 5 of the program, students focus on conformal approaches for the head and neck region, breast region and thorax (Table 5). The same skill sets are reinforced as in the previous semester, but in a more complex clinical situation.

There is a five-week clinical placement mid semester, where students will finalise all medium and high level conformal treatment and planning competencies.

Emerging techniques

To ensure that graduates enter the profession prepared for future practice, Semester 6 focuses on emerging and future RT techniques. Table 6 displays these topics, and the knowledge or skills that are developed.

While most of the topics are studied theoretically, the students develop IMRT plans for a range of sites. These are the only planning cases done across the three years where students use the computers to auto generate the required monitor units.

Towards the end of the semester the Year 3 students undertake a final four-week placement where all students finalise all outstanding competencies. In the past few years students have returned from these placements with IMRT competencies.

Student attitudes toward the technical curriculum

When discussing the teaching of basic to emerging RT methods with students, two distinct responses are given. Some students will tell you that they enjoy or respect learning the basic science that underpins the science of RT and their ongoing professional development. They learn from the fundamental conventional approach and can abstract this acquired knowledge and skills to more difficult situations with ease, through reflection and/or active experimentation. These students appear to have a deep approach to learning[7] and hold a higher conception of their own learning,[8,9] where personal meaning and understanding are prioritised as more important than the structural process of learning, i.e. how do I do this task?

In contrast, there are also students who only want to know how to operate current technology and only want to learn the current and computer assisted method. They have no interest in developing a deeper understanding of the origins of the technology or clinical practice, and have little time for manual or fundamental methods.

They want quick inputs and immediate outputs. This surface learning approach, focusing on structural learning and a conception of learning as utilisation of facts, often translates into difficulties when performing increasingly more complex tasks both at university and on clinical placement.

This is noted at university and on placement, where students who have a problem with a case they are doing cannot problem solve unfamiliar situations and they cannot reflect on prior learning.

Table 6 Emerging and future RT approaches

Year 3 – Semester 6 – MRSC3250	
IMRT (Intensity modulated RT) planning	• IMRT planning of breast – skill development • IMRT planning of head and neck – skill development • Inverse planning • Dose or fluence map verification • Linac based versus tomotherapy
IGRT (Image guided RT)	• EPI vs OBI • KVCT vs MVCT
Biological plan evaluation	• TCP – tumour control probability • NTCP – normal tissue complication probability • EUD – equivalent uniform dose
Motion Sensitive RT	• Real time tumour tracking • Gating • Assisted breathing
Functional Imaging	• In simulation vs. planning • PET vs. SPECT vs. MRI
Brachytherapy	• Manual vs. Remote after-loaders • HDR vs. PDR vs. LDR • Biological considerations • Clinical techniques

Conclusion

Radiation therapy professional practice comprises elements of patient care, clinical procedures, and technology assessment and implementation. Each of these three elements is underpinned by the knowledge and skills of their basic concepts leading to advanced practice. The practice of three elements all progress with time.

However, the change in technology and the required technical skills in RT over the past 10 years have been extreme and have forced major reviews of the technical aspect of RT curricula.

To stay current universities must educate for the new modalities and teach new skills. This places pressure on the retention of the basic science concepts. Most professions teach the basic or foundation sciences to underpin advanced concepts, and also as a way of keeping the profession, the guardian of their knowledge base.

In terms of technology and technical skills teaching, the University of Newcastle's undergraduate RT program reflects current and future clinical practice. It also provides students with access to foundation knowledge and skills as a means of bridging the gap to the automated world of RT.

References

1 Skala M, Berry M, Duchesne G *et al.* Australian and New Zealand three-dimensional conformal radiation therapy consensus guidelines for prostate cancer. *Australas Radiol* 2004; 48: 493–501.

2 van de Bunt L, van der Heide UA, Ketelaars M, de Kort GA, Jurgenliemk-Schulz IM. Conventional, conformal, and intensity-modulated radiation therapy treatment planning of external beam radiotherapy for cervical cancer: The impact of tumor regression. *Int J Radiat Oncol, Biol, Phys* 2006; 60 (1): 189–96.

3 Shirato H, Suzuki K, Sharp GC, Fujita K, Onimaru R, Fujino M *et al.* Speed and amplitude of lung tumor motion precisely detected in four-dimensional setup and in real-time tumor tracking radiotherapy. *Int J Radiat Oncol, Biol, Phys* 2006; 64 (4): 1229–36.

4 International Commission of Radiological Units. ICRU Report 50. Prescribing and Reporting Photon Beam Therapy. 1993.

5 International Commission of Radiological Units. ICRU Report 62. Prescribing

and Reporting Photon Beam Therapy (Supplement to ICRU Report 50), 1999.

6 NSW Health Department. 2003 Radiotherapy Management Information System Report (RMISR). North Sydney: Statewide Services Development Branch, NSW Health Department, 2003.

7 Marton F, Säljö R. On qualitative differences in learning: II. Outcome and process. *Br J Edu Psychol* 1976; 46: 4–11.

8 Säljö R. Learning in the learner's perspective: I. Some common-sense conceptions. *Reports from the Department of Education.* University of Gotborg 1979; 76.

9 Marton F and Säljö R. On qualitative differences in learning: II. Outcome as a function of the learner's conception of the task. *Br J Educ Psychol* 1976; 46:115–27.