Small field dosimetry, an example of what a Medical Physicist does (& some more examples)

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MEDICAL PHYSICIST
What is a Medical Physicist?

- Medical physics – application of physics concepts to medicine
  - Work in radiation oncology (ROMPs), diagnostic imaging (DIMPs), nuclear medicine, radiation safety
  - A majority of the workforce is clinical
  - Radiation oncology is the largest specialty
  - Approx. 700 across Australia, 14 in Radiation Oncology at Cancer Care Services, RBWH
  - ROMPs need a post-graduate education (MSc / PhD) and are trained clinically in a 4 year accreditation program
  - Accreditation program demands a publication
What is a Medical Physicist?

- Radiation oncology medical physicists are responsible for:
  - Quality assurance – routine checks that equipment works as expected
    - Most importantly that the dose delivered matches the dose planned
  - Radiation safety and protection
  - Innovation – service development and research
  - It involves lots of equipment
Radiation Oncology Basics

- Radiation therapy is the therapeutic use of radiation
- Radiation causes damage
  - We want to maximise the dose to the tumour / target
  - We want to minimise the dose to healthy tissue
- Commonly delivered with linear accelerators – “external beam radiation therapy”
External Beam Treatment Chain

**Diagnosis and consultation**
Radiation oncologist will have a prescription and treatment period in mind

**Patient imaging**
CT acquired with patient in treatment position, with immobilisation equipment set up

**Volume delineation**
Target volume and organs-at-risk contoured on CT image
Margins added for unseen expansion and delivery tolerances

**Treatment planning**
Arrangement of radiation beams selected to meet objectives
Iterative optimisation

**Setup verification**
Patient set up for treatment delivery with lasers and x-rays

**Treatment delivery**
Patient remains still while treatment is delivered
Beam on < 10 minutes
Treatment summary

- Machine rotates about patient and delivers radiation fields
- Field shape matches treatment volume along that axis
- “Target volume” includes
  - Tumour as seen in CT data
  - Margins for uncertainty in
    - defining the tumour from CT
    - patient setup on couch
    - movement of anatomy
What are small fields?

- Linear accelerators can produce beams up to 40 x 40 sq. cm
- Conventional treatments will cover areas of 5 x 5 to 20 x 20 sq. cm
  - Fields cover the size of the tumour with margins added
- 3 x 3 sq. cm fields (or smaller) are considered small
- 0.5 x 0.5 sq. cm is practical limit for common systems
Why small fields are useful

Treatment of smaller targets

Stereotactic radiosurgery
- Brain mets
- Meningiomas
- Trigeminal neuralgia
- Arteriovenous malformations

More conformal treatments

Stereotactic body radiotherapy
- Lung, liver, abdomen, spine, prostate, and head and neck
- The focus of a number of trials being proposed by Trans Tasman Radiation Oncology Group
- In development at RBWH
Why small fields are problematic

Treatment delivery
- Smaller margins mean that more precision is needed
- Solutions:
  - Patient immobilisation
  - Image guidance radiotherapy
  - 4D imaging / gating (next slide!)

Dosimetry
- Difficult to measure radiation output accurately
  - Time consuming
  - Special dosimeters needed
  - Complicated corrections
- Need accurate values for the sake of both the patient and to allow correlation with outcomes data
4D imaging

- Patients move during beam delivery
  - Periodic – respiration, heartbeat
- Worst case scenario
  - CT acquired while patient inhaling, and treatment planned for that
  - Beam delivered while patient exhaling
- Solution: obtain multiple CT images, at different points in the respiratory cycle
- First patient treated last week!
- Development of gating: turning beam on/off with respiratory cycle
Dose measurements?

- Planning systems use dose measurements to determine how much radiation to deliver
- Want measurements to meet national standards
  - 1 unit of dose (Gray) here to match 1 unit everywhere
- Measurements made in a water tank - dosimeter travels across beam in sub-mm steps, recording dose
- Tolerance should be <0.5%
Problems with dose measurements

- If you aren’t careful the same small field measurement done twice can differ by 20%
- Measurement devices have various issues:
  - Need corrections
  - Too large
  - Noisy signal
  - Expensive
  - Involve dangerous chemicals
Overcoming problems

- We’ve collaborated with other centres (in Brisbane, Sydney, Saskatoon!)
- Co-authored publications in the field
- Including a recent how-to paper in the national college journal
- Measurements take a lot of time to do carefully (a full day on a machine)
- An error in small field planning system dose data means an error for every patient receiving a small field
Water tank measurements

- MSc student Pat Stevenson helped with 8 hour long measurements (on a weekend!)
- Results will be evaluated against literature and independent mathematical simulation
- These measurements will be used to the commission a dose calculation system in the planning system – service development!
Dose in the planning system

- Verifications
  - examine dose calculations for simple fields in water
  - examine dose calculations in patients
  - verify existing QA procedures, or develop new ones
  - volunteer for dose audits

This will help enable planning studies, participation in trials and improved patient outcomes.
Air gap diode caps

- Those measurements used diode dosimeters
- Which overestimate dose in small fields – need correction
- Small pockets of air (e.g. 1 mm) can result in lower dose
  - Bad news for measurements, where you need to avoid bubbles or cavities
  - Good news – phenomenon can be exploited to cancel out over response
- MSc student Ben Perrett 3D printing caps with air cavities
Problem: we tell the accelerator to deliver a 1 x 1 sq. cm field,
  - Field edge may be 1.2 or 0.8 cm
  - Significant variation
Solution: have dozens of systems deliver this field size, and see what they get
Collaboration with Princess Alexandra Hospital, Genesis Cancer Care Queensland
460 pieces of radiosensitive film will be irradiated
**Other physics research**

- **Collaboration with QUT**
  - 2 of our physicists have appointments at QUT
  - Involved in the supervision of 6-12 month MSc research projects
  - Involved in the supervision of PhD candidates
  - Physicists planning on starting part-time PhDs

- **Collaboration with other centres**
  - Our college (ACPSEM) has a very active state branch
  - Monthly research chats
  - Quarterly research updates (presentations and round-table discussion)
  - Yearly symposium with invited speakers
Local projects

- **Gel dosimetry**
  - Provides 3D dosimetry data – excellent for verifying patient treatment plan dose
  - RBWH is one of few clinical centres in Australia investigating it
  - Commissioning the system
  - Projects underway include investigation of dose in treatments of spinal mets
  - We also have strong ties with QUT physicists and chemists
Local projects

- **Use of moulding materials in vaginal brachytherapy**
  - **Fricotan** – an ear moulding material source from audiologists
  - Repurposed for radiation delivery
  - Example of service development (solving a local problem) becoming published research
  - Now doing radiological modelling using data obtained from mass spectrometry at QUT
QUT collaborations

- Andre Asena, PhD candidate
  Investigating dose distributions near high-density materials (temporary tissue expanders in breast patients).

- Johnny Morales, PhD candidate
  Modelling of stereotactic radiosurgery system at RPAH, Sydney.

- Shadi Khoei, Post doc
  Development of education material

- Orrice Dancewicz, PhD candidate
  Novel 3D dosimetry technique for TomoTherapy using optical fibre and radiosensitive gel.

- Shaun Smith, PhD candidate
  Development of a safe-to-mix and safe-to-handle gel dosimeter.

- and more!
State collaborations

- **3D printing of dosimeter holders**
- Used with check sources - radioactive sources with a known output, so that dosimeter response can be checked
- Collaboration with Princess Alexandra Hospital radiation oncology
State collaborations

- **3D printing of patient phantoms**
- Collaborating with Radiation Oncology Mater Centre and Genesis Cancer Care Queensland
- Pictured: lungs containing tumours
- Printed components have varying density, approximately designed to match patient tissue
State collaborations

- Monte Carlo dose simulations
  - Collaborating with Princess Alexandra Hospital, Radiation Oncology Mater Centre, Genesis Cancer Care Queensland
  - Setting up clinical implementation of patient dose simulation

- Evaluation of pre-treatment quality assurance measurement processes
  - Treatment beams
  - Collaborating with Princess Alexandra Hospital, Genesis Cancer Care Queensland
  - Currently have analysed data from 1,265 QA measurements
  - Near completion
Conclusion

- **Strong research profile**
  - 13 publications involving current CCS ROMPs so far in 2015
    - plus 7 more submitted
    - plus more being drafted
  - PI on ARC Discovery grant application

- **What works for us**
  - Supervision of student research
  - Access to equipment after hours
  - Involvement in multi-centre studies
  - Regular research meetings, both locally, and with neighbouring centres