So you want to be a medical physics researcher…

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Four questions for you…

- Are you willing to make less money to be a researcher?
- Are you willing to have reduced family time and free time to be a researcher?
- Is research something you would "like" to do, or something you "must" do?
- Are you burning to try your own ideas and to pilot your own ship?
- If the answer to any of these is "NO," *turn back now!*

The good news: "You can make a difference!"

- Math and modeling is becoming more important to medicine all the time
- Imaging is becoming more quantitative: despite the advances of molecular biology, the image says a lot about the instantiated phenotype
- Physicists are superheroes of the mind -- we can do amazing things with the tools we have.

There are lots of open questions!

- Radiotherapy is yet to be optimized
- Practical issues still need to be addressed, such as data organization
- Scientific issues such as radiobiological models for optimization
- Image-based biomarkers need to be developed to personalize medicine

Lots of opportunities for physicists in emerging areas of medicine

- "Big Data" analysis
- Radiomics
- Systems biology
- Systems Immunology
- Image guided surgery
- Quantitative pathology (computational pathology)

Medical physicists as research enablers

- Medical physicists are able to bridge the gap to some of the most exciting emerging areas of science and technology
  - systems analysis/networks
  - Computer vision
  - Machine learning

HOW?

- The Education of a MP researcher
- The Virtues of a MP researcher
- The Classic Career Trajectory
- Key Decisions
- Navigating the NIH
- Mistakes and Vices to Avoid
- Some Good Advice

The Education of a MP researcher

- Start with an in-depth PhD that heavily develops your math, engineering, and scientific writing skills.
- Lack of programming experience is a liability in the future: learn to script, but get a taste of what modern software design is about.
- Pursue a broad understanding of areas that are not your focus, but which are crucial for understanding and following developments in medical science:
  - Molecular biology
  - Statistical modeling principles
  - Machine learning
  - Radiation biology

Biology

- Aspire to at least a beginner's understanding of molecular biology and cellular functions
  - Learn some basic terminology.
  - Don't zone out when listening to the molecular biology component of a medical talk -- try to pick up something.
  - Don't be embarrassed: biology is too complicated for the biologists! (Let alone the physicians!)
- This will enable you to understand the motivation for many potential physics projects!

Radiation biology

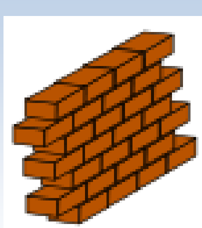
- Learn the basic concepts by reading and understanding the best published studies.
- Much of the dogma of radiation biology is, in my opinion, wrong.
- There is still much we do not understand!

Learn some statistical modeling principles

- Listen to youtube lectures about basic statistical tests, e.g., Khan Academy excellent lecture on the Chi-square test.
- Beware of overfitting.
- Beware of "mining for surprises."
- Understand power calculations
- Know what the "multiple testing correction" is all about
- There are many excellent books.
- In the era of Big Data, statistical ignorance is a Big Problem. There are excellent books on Statistical Modeling
- Learn the basic ideas behind Machine Learning.

The Past:
Outcomes = physics or biology

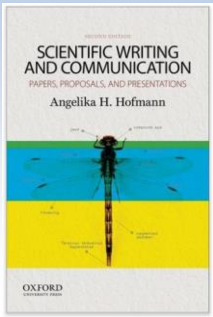
Outcomes determined by physics: prescription dose, normal tissue volume effects

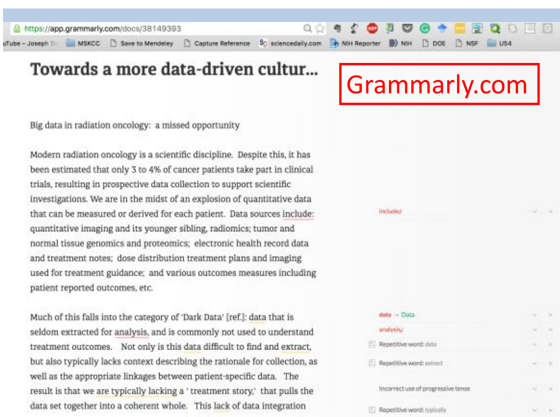


Outcomes determined by clinical radiobiology factors: stage, grade, fractionation, hypoxia, radiosensitivity, proliferation

JOD

Work on your writing skills!





Towards a more data-driven cultur...

Big data in radiation oncology: a missed opportunity

Modern radiation oncology is a scientific discipline. Despite this, it has been estimated that only 3 to 4% of cancer patients take part in clinical trials, resulting in prospective data collection to support scientific investigations. We are in the midst of an explosion of quantitative data that can be measured or derived for each patient. Data sources include: quantitative imaging and its younger sibling, radiomics; tumor and normal tissue genomics and proteomics; electronic health record data and treatment notes; dose distribution treatment plans and imaging used for treatment guidance; and various outcomes measures including patient reported outcomes, etc.

Much of this falls into the category of 'Dark Data' [ref.]: data that is seldom extracted for analysis, and is commonly not used to understand treatment outcomes. Not only is this data difficult to find and extract, but also typically lacks context describing the rationale for collection, as well as the appropriate linkages between patient-specific data. The result is that we are typically lacking a ' treatment story,' that pulls the data set together into a coherent whole. This lack of data integration

The Virtues of a MP Researcher

“Go to the sea by the streams, not directly”
– Thomas Aquinas

In other words, think things through in detail. Know the primary literature in your area of expertise. Don’t accept summaries you do not understand or agree with.

”Work on big problems!"
- Rock Mackie

They are often easier to solve than small problems.
And they matter more!

"We the unwilling, led by the unqualified, have been doing the unbelievable with so little, for so long, we now attempt the impossible with nothing "

I got this from Marcus McEllistrem, but goes back to Konstantin Jireček

"What can I do today that will impact the future of radiotherapy?"

Larry Marks, MD

"Be persistent, but be polite"

Hermann Suit and John Cameron

"If we are going to do a scientific study, we should do it right"

Soren Bentzen

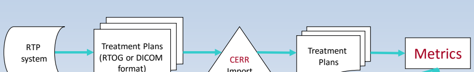
Don't fall in love with your own ideas!

It is your job to bury the good ideas in order to grow great ideas!

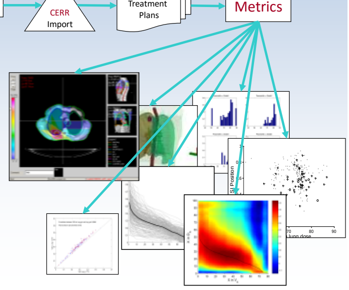
Be Open Source

- Open source code: algorithms
- Open source results and data
- Open source challenges

The Computational Environment for *Radiological* Research (CERR)



- Custom software extracts dose, volume, and structure data <u>automatically</u>



- http://cerr.info

(slide courtesy A. Hope)

The Classic Career Trajectory

- Obtain high-end skills under an outstanding research mentor. Look for an active group.
- If you have not already been working in medical physics, do a serious postdoctoral stint *in medical physics*
- Research only vs. clinical career -- not an easy decision.
- If choosing a research career, look at residencies that set aside serious time for building or charging your research career.

Postdoc then residency or postdoc plus residency

- A postdoctoral fellowship is a necessity
- Separate post-doc from residency
  - Pro: greater flexibility
  - Con: moving overhead
- Integrated (hybrid) residency
  - For example, MSK 2+2 structure.
  - Pro: less overhead, more efficient
  - Con: need to find the right place

First faculty post

- “Don't go to an intellectual desert” – Jack Fowler
  - As measured by past research productivity
  - Postdoctoral fellows, papers, grants
- Look for the right mentor
- Negotiate a good startup package
  - Time to do research is more important than all other things
  - Computing support (hardware/programming)
  - Postdoctoral fellow/technician support.
  - Timeframe for acquiring grant money.
  - Soft landing if it does not work out.

Be a leader! Why not?

- Physicians are constantly leading when they don't know the science.
- We can do that! Possibly better!
- Write protocols
- Propose/offer to organize symposia
- Organize interest groups, mailing lists, other ways to communicate

Vices to avoid

- Learn to listen carefully about advice before deciding what to do with it.
- Don't be an amateur, doing many different things.
  - Establish an identity and direction
  - Establish some depth.
  - Go beyond what others are doing.
  - Not "Me too." But showing the way.

The "Gold Brick" phenomenon

- Researchers will often overlook a promising research topic, not matter how exciting/important/impactful it could be.
- They often simply do not stop to realize they are walking past a *golden opportunity*
- Why does this happen?
  - Psychological devotion to what they are already doing.
  - Equivalent to throwing good money after bad.
- Don't get too busy to notice an extremely good opportunity

Time scales

- "It takes at least 10 years for anything to happen in medicine." -- Michael Goitein
- But...they shelf life of medical knowledge is only about 5 years.
- Expect to work in some area for at least a decade.
- The medical world is not Silicon Valley (e.g., Theranos)!

Navigating NIH

- Start small!
- Internal grants
- Industry grants
- A list of 10 grants totaling 100K is better than 1 grant x 100K.
- Early career: American Cancer Society, other foundation grants.
- Go for training grants if possible (K99)

Focused is beautiful!

Build a team!

- Despite what you have heard science is a social activity
- Build a track record of collaborations
- New rules reward multi-PI grants
  - Covers expertise
  - Increased credibility
  - Ameliorates lack of experience

You need a team to do data-driven research in radiation oncology

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Get feedback and guidance early. Use it!

- Present R01 ideas to others who have been awarded NIH funding.
- Discuss ideas with NIH program officers
- Take feedback to heart. Give the reviewers the grant they want!
- Send draft application to mock-reviewers. Make changes they suggest.
- Write applications that can be speed-skimmed, so the organization and main points are very apparent.

You want your reviewers to say:

- "This research will have a last and significant impact in this area of basic or translational research"
- "The problem being addressed is highly significant.
- "The PI team has an extremely good background and track record to conduct the project."
- "The methods are appropriate with some truly innovative elements."

Good luck!

The people of the Earth need great medical physics researchers!