The Future of Medical Physics Research and Education

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My favorite quote

If you don’t like change, you are going to like irrelevance even less.

*General Eric Shinseki, Secretary of Veterans Affairs*
Transformational changes in healthcare

- Changes in how patients access care.
- Changes in how organizations are reimbursed for providing care.
- Changes in how hospitals are organized.
- Changes in cancer research priorities.

What’s driving cancer research?

- GOOD NEWS
  - Death rates for the four most common cancers (prostate, breast, lung, colorectal), and all cancers combined, continue to decline.
  - The rate of cancer incidence has declined since the early 2000s.
  - Length of cancer survival has increased for all cancers combined.
- BAD NEWS
  - Incidence rates of some cancers are rising including melanoma, non-Hodgkin lymphoma, childhood cancer, leukemia, thyroid, pancreas, liver, testis.
  - Death rates for pancreas, esophagus, thyroid, and liver are increasing.

- Cancer treatment spending continues to rise.
- Research funding is flat from all sources!
- Few cures...
What is happening at NIH/NCI?

• While many institutes at NIH and other organizations fund research, I will focus today mainly on the NCI since they fund most of the imaging and radiation oncology research.

• Dissolution of the otherwise successful National Center for Research Resources in 2011 was an omen for changes to come in how NIH approaches research.

• The leadership at NCI (Harold Varmus, M.D., Ph.D.) wants to focus on fundamental approaches to curing cancer.
  – This approach is echoed by many leaders in the cancer research community, including MDACC President Ron DePinho, M.D. who launched a $3B Moonshots program focused on 6 cancers in 2012.
  – Individual and team research are competing for resources.
Changes in research funding priorities

• Much more **impact** focused.
  – So it’s a great idea. If it is successful, what will be the impact on patient mortality and morbidity?

• Biology orientation
  – *For cancer, that’s really genomics!*

• Instrumentation development will need a very well defined outlet.
  – Difficult to get funding for platform technologies or incremental advances.

**WHAT IS THE FUTURE OF MEDICAL PHYSICS RESEARCH IN A GENOMIC WORLD?**
The omics of cancer

Genomics
Proteomics
Blood biomarkers
Toxicity
Pathology

ANATOMY
PHYSIOLOGY
METABOLISM
PROTEINS
GENOME

ANATOMICAL IMAGING
FUNCTIONAL IMAGING
MOLECULAR IMAGING

Sustaining proliferative signaling
Resisting cell death
Evading growth suppressors
Inducing angiogenesis
Activating invasion and metastasis
Enabling replicative immortality

Hanahan & Weinberg, Cell 57-70, 2000
Emerging Hallmarks

- Deregulating cellular energetics
- Avoiding immune destruction
- Genome instability and mutation
- Tumor-promoting inflammation

Enabling Characteristics

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**Imaging the hallmarks of cancer**

- **Normal**
- **Altered metabolism & hypoxia**
  - ^18^F-FDG-PET
  - ^11^C-PET
  - ^18^F-FDOPA PET
  - ^18^F-FET PET
  - ^18^F-fluorinated pyruvate PET
- **Angiogenesis**
  - PDE-5 PET
  - DCE-CT
  - DCE-MRI
- **Proliferation**
  - FDG-PET
  - ^18^F-fluorodeoxyglucose PET
  - ^18^F-fluorouracil PET
- **Apoptosis**
  - ^99^Tc-Annexin V
  - Diffusion MRI
- **Metastasis**
  - Lymphography
  - Vertebral body
  - Soft-tissue bone scan
  - ^18^F-FDG PET-CT etc.

- Existing symptoms
- Self-sufficiency in growth signals
- Insensitivity to anti-growth signals
- Evasion of apoptosis
- Sustained angiogenesis
- Evolutionary and metastatic potential
- Increased glucose uptake & metabolism
- Increased proliferation & metastasis
- Increased invasiveness and neovascularization
- Invasion and metastasis
- Stabilized angiogenesis
- Acquisition of new metastatic efficiencies

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Hanahan D, Weinberg, Cell 646-671, 2011

Padhani A R , Miles K A Radiology 2010:256:348-364
Cancer Metabolism & Tumor Biology by Hyperpolarized 13C/15N MRSI: Prospects for Translation to Clinic Research

Haining Zhang*, Marvin Loscalzo†, Quanhua Liu*, Nicholas Darby‡, Abdelaziz Shehata‡, Gary Koldobsky*, Jim Tutt*,†, and Laurence Clarke*†

Summary

Hyperpolarized [13C]urea and [15N]ammonium are now routinely available in the clinic. The hyperpolarized agents have the potential to substantially improve our understanding and detection of cancer. In this report, the authors will briefly summarize recent advances in employing hyperpolarized 13C/15N techniques for understanding tumor biology and potential translation to clinical imaging.

Figure 9.8 The Biology of Cancer (© Garland Science 2007)
NCI provocative questions project

- How does obesity contribute to cancer risk?
- Are there ways to objectively ascertain exposure to cancer risk using modern measurement technologies?
- What are the molecular and cellular mechanisms by which patients with certain chronic diseases have increased or decreased risks for developing cancer, and can these connections be exploited to develop novel preventive or therapeutic strategies?
- Why do certain mutational events promote cancer phenotypes in some tissues and not in others?
- Can tumors be detected when they are two to three orders of magnitude smaller than those currently detected with in vivo imaging modalities?
- Are there definable properties of a non-malignant lesion that predict the likelihood of progression to invasive or metastatic disease?

Figure 10.5a  The Biology of Cancer (© Garland Science 2007)
Figure 16.44c  The Biology of Cancer (© Garland Science 2007)

beginning of AP23573 treatment

5 days of treatment

54 days of treatment
What is the impact of these changes on AAPM?

- The shortest term impact will be on the types of research being funded by NIH/NCI.
  - NIH/NCI funding is currently a “zero sum” game.
  - Fundamental instrumentation related research is less likely to be funded as a stand-alone project. Most instrumentation research will likely be linked to applications of the technology to a specific cancer problem.
- The intermediate impact will be on what the educational profile should be for a medical physicist.
  - What are the evolving core competencies that will be needed to be competitive for peer-reviewed research grants in the future?
- Ultimately, this could change the face of cancer care and the role of the medical physicist in delivering that care.
  - What will be the role of the medical physicist in 10 years if the science of cancer care evolves significantly, but medical physics does not?

What is *medical physics*?

- According to Wiki
  - Medical Physics is generally speaking the application of physics concepts, theories and methods to medicine/healthcare.
  - Biophysics is an interdisciplinary science that uses the methods of, and theories from physics to study biological systems.

- According to AAPM (from Vision statement)
  - ...medical physics, a broadly-based scientific and professional discipline encompassing physics principles and applications in biology and medicine.
How should AAPM move forward?

• Do we continue to focus in the sciences and practices of radiation physics, radiological imaging physics and nuclear medicine physics as they apply to whole humans?
• Do we expand the focus of AAPM to include a broader scope of science?
• What? Who? How?

— Work Group on the Future of Research and Education

Changes in research focus and funding will necessitate changes in education

• We must become more efficient in the use of research funding in developing the next generation of scientists.
• Our educational programs must be sustainable.
• While we should accommodate alternate pathways to becoming a Qualified Medical Physicist (QMP), we must first make sure that students entering medical physics graduate programs are afforded the opportunity to become QMPs.
What kinds of medical physicists do we need?

- **Qualified Medical Physicists**  90%
  - Clinical practitioners
    - Get the job done
  - Academic QMPs
    - Teaching
    - Advanced technology implementation
    - Some science
- **Research scientists**  5%
  - Academics who derive their income primarily from grants
  - Industrial research
- **Regulatory and other**  5%

Sustainable educational programs

- Graduate programs have been relatively homogeneous in educating medical physicists.
  - Ph.D. programs have been expected to develop clinical, academic and research medical physicists using basically the same curriculum.
  - Special M.S. programs were developed to meet the manpower needs for clinical medical physics, but are often abbreviated Ph.D. programs.
  - Stipends for all these trainees often comes from research grants & contracts.
- The preparation for medical physicists who only want to practice clinical medical physics needs to evolve into a financially sustainable model.
  - Professional degree program where students pay for education.
  - Model after medical, dental and veterinary school.
Sustainable educational programs

• Academic medical physicists that have both research and clinical effort, that are expected to publish and to teach, will be educated in much the same way as the past.
  – Ph.D. degree with stipend from research grant or contract.
  – Traditional two-year residency. There are currently 67 residency programs graduating approximately 100 trainees per year.

• Medical physicists whose goal is to be at the forefront of research and achieve principal investigator status should be educated in the sciences important for research of the future.
  – More forward looking with advanced curricula.
  – Extended hybrid residency/post-doctoral research fellowships to bridge research momentum from graduate school to independent investigator status.
Summary

• Some reasonably obvious opportunities.
  – Quantitative imaging
  – Some challenges
• Continuing to define and refine who we are, and more importantly who we want to be, is critical in developing a strategic vision for the future in research.
• The AAPM’s role is to provide a framework and infrastructure for addressing these challenges and opportunities, and to organize our efforts to achieve our goals in patient care, research and education.

From a research perspective, how many hallmarks with links to cancer development/metabolism have been identified?

A. 4
B. 5
C. 7
D. 8
E. 10
Death rates for the following cancers have increased in the last decade with the exception of:

A. Pancreatic  
B. Liver  
C. Breast  
D. Endometrial

As of April 2013, the number of CAMPEP-accredited residency programs, both therapy and diagnostic, in medical physics is:

A. 37  
B. 47  
C. 57  
D. 67  
E. 77