Innovating in Medical Devices: The Medical Physics Sandbox

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Modern Expectations of Healthcare

- Patient-specific, Customized Therapy
  - Personalized Cancer Medicine
- High Performance, Minimally-invasive Interventions
  - Success in terms of disease control and minimal toxicity
- Zero Tolerance for Errors/Mistakes (6σ)
- Efficient Execution within the System
- Customer Satisfaction/Patient-Centred Care
- Accountability/Access/Metric Reporting
- Access/Management of Personal/Family Health Record
- Rapid Evaluation/Adoption of Novel Methods
- Continuous Learning and Adaptation

The Conflict

Our own expectations of healthcare

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The growing technological opportunity and the rate of uptake in other industries

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Healthcare as we know it is being delivered today

This shortfall highlights the need for innovation.

What is Innovation?

2011 Innovation Summit – The Lisbon Council

Constraints on Innovation in Healthcare

- Complexity of the healthcare process
- The need for evidence for novel therapeutics
- Regulatory factors
- Momentum/lack of resources
- Skills development and human resources
- Safety and maintaining quality
- Cost of deployment
- Poorly developed technology

Healthcare systems are not designed to change.

Medical Devices

An instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related article, including a component part, or accessory which is:

- Intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, in man or other animals
- Intended to affect the structure or any function of the body of man or other animals, and which does not achieve any of its primary intended purposes through chemical action within or on the body of man or other animals and which is not dependent upon being metabolized for the achievement of any of its primary intended purposes

Source: FDA

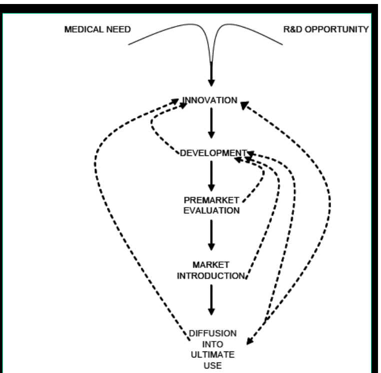
Compared to Pharma the Technology 'Pipeline' is a mess.

Pharma: Long, but 'straight'.

Devices: It depends

Medtech Product Lifecycle

3-7 yrs, $10-$100M in capital



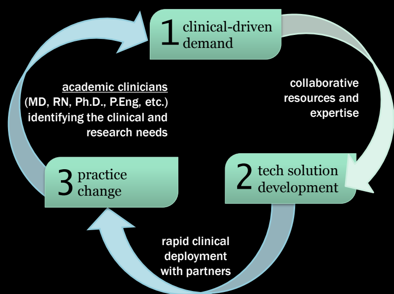
Source: William W. Lowrance, *New Medical Devices* (Washington, DC: National Academy Press, 1988).

Devices vs. drug technologies

Different Technologies, Culture and Perspectives

	Medical devices	Drugs
Disciplines	Engineering, materials; Engineers	Biology, chemistry; Scientists
R&D model	Technology development; Systemic, rapid product dev	Research; Slow, trial & error product dev.
User interface	Device-user-patient	Drug-patient
Effecting Outcome	User knowledge and skills	Active ingredients
Domain of impact	Local effects	Systemic effects
Lifecycle	Development – short (3-7 years; $10-$100M) Use - short	Development – Long (>10 years, $1-$2B) Use - Long
Risk	Lower – Proof point occurs at later stage ie, clinical validation, proven regulatory pathway	High – first proof point occurs at Phase 1
Maintenance	Essential	Nominal
Facility Planning Technical support	Critical	Minimal
Recurrent Operation Budget	Essential for durable devices	Nominal

The Lifecycle for Health Technology Innovation



Though users play a central role in invention in many industries (Shah and Tripsas 2006), they are particularly important to health technology.

‘User as Innovator’

- Though users play a central role in invention in many industries (Shah and Tripsas 2006), they are particularly important to medical devices.
- Users account for 80% of all medical device innovations. *
- 3M has enjoyed commercial success from incorporating user-based innovation into its corporate strategy. (von Hippel, Thomke et al. 1999)
- Identify the ‘last long feedback loop: The one from the ultimate user community back to the start of the whole process’ as the ‘most neglected step in the innovation scheme’. *

* New Medical Devices: Invention, Development, and Use. (1988) Washington, D.C., National Academy Press.

Medical Physicists

- Definition:
  - Medical Physics is an applied branch of physics concerned with the application of the concepts and methods of physics to the diagnosis and treatment of human disease. American Association of Physicists in Medicine
- Funding:
  - Radiation Therapy: 1 FTE/ 300 cases/yr
  - In Canada: ~20% allocation for R&D
- R&D:
  - Patient-specific Innovation
  - Technology/Process Innovation

University-Industry Constructs

- Corporate Contributions
  - Undirected
  - Fellowship
  - Directed
- Industrial Procurement of Services
  - Education and Training
  - Contract Research
  - Patents
- Cooperative Research
  - NSF-funded industry/SBIR/STTR
- Privately Funded Research Centers
  - Uni-, Multi-corporate
  - Long-term Contracts (Monsanto-Harvard)
  - University Controlled Companies
  - I.P. Brokerage Companies

Biotechnology: The University-Industrial Complex, Martin Kenney, Yale Press, (1986)

'User as Entrepreneur'

Strategic Entrepreneurship Journal
Strat. Entrepreneurship J., 1: 123–140 (2007)
Published online 16 November 2007 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/sej.15

THE ACCIDENTAL ENTREPRENEUR: THE EMERGENT AND COLLECTIVE PROCESS OF USER ENTREPRENEURSHIP

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"…define <u>user entrepreneurship</u> as the commercialization of a new product and/or service by an individual or group of individuals who are also users of that product and/or service."

Shah and Tripsas, Strat. Entrepreneurship J., 1: 123–140 (2007)

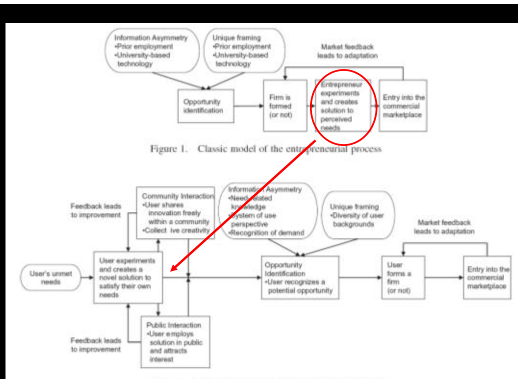


Figure 1. Classic model of the entrepreneurial process

Figure 2. Model of the end-user entrepreneurial process

SHAH and TRIPSAS, Strat. Entrepreneurship J., 1: 123–140 (2007)

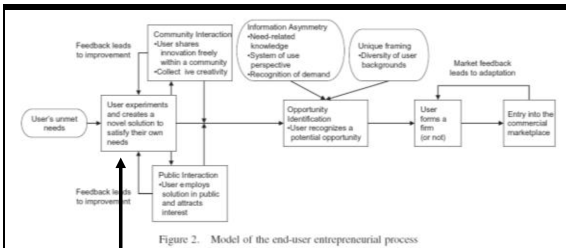


Figure 2. Model of the end-user entrepreneurial process

What elements are good to have in this mix?

(Hospital-based Researcher + Academic) + Industry Partner

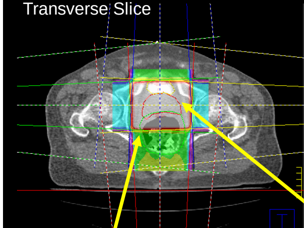
Example: Cone-beam computed tomography (CT) for image-guided radiation therapy (IGRT)

Rationale: Increasing the geometric precision and accuracy of radiation therapy delivery will increase control rates, allow dose escalation, and reduce toxicity.

~50% of cancer patients receive Radiation Therapy during the course of their care.

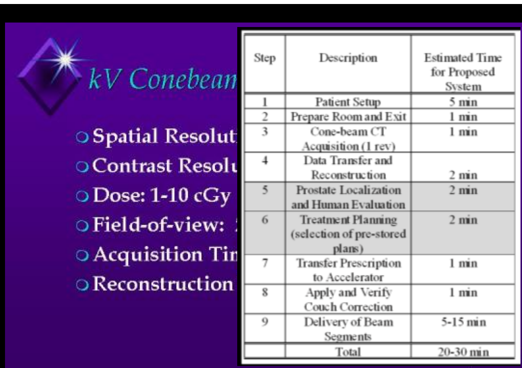
Radiation Therapy for Prostate Cancer Example of an Image-guidance Problem

Transverse Slice



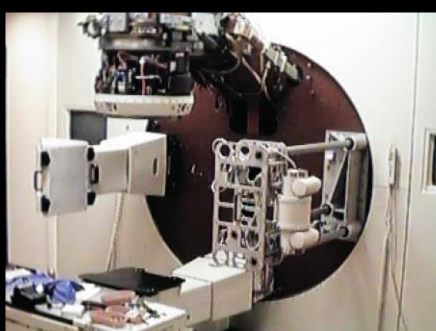
Rectal Wall (Avoidance Volume)

Prostate Gland (Targeted Volume)



Step	Description	Estimated Time for Proposed System
1	Patient Setup	5 min
2	Prepare Room and Exit	1 min
3	Cone-beam CT Acquisition (1 rev)	1 min
4	Data Transfer and Reconstruction	2 min
5	Prostate Localization and Human Evaluation	2 min
6	Treatment Planning (selection of pre-stored plans)	2 min
7	Transfer Prescription to Accelerator	1 min
8	Apply and Verify Couch Correction	1 min
9	Delivery of Beam Segments	5-15 min
	Total	20-30 min

RT machines treat ~30 patients/day → 5 min more = 2.5 hrs

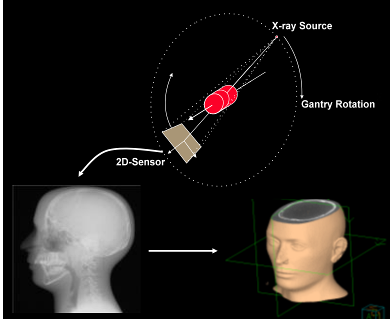


Grants and Publications

- 1994 - Industrial Collaborations (Elekta)
- 1997 - U.S. Army Prostate Cancer Research Program – New Investigator Award – ‘On-line Tomographic Guidance for RT of the Prostate’
- 2001 – NIH/NIA – RFA – ‘High-precision Radiation Therapy of the Prostate’ – R21/R33
- 2001 – NIH/NCI/NIBIB – ‘Flat-panel Cone-beam CT for Image-Guided Radiotherapy’ – R01
- 2002 – Phase II U.S. Army Grant – ‘On-line Tomographic Guidance for RT of the Prostate’
- 2002+ - Industrial Collaborations (Elekta)

Siewerdsen, Wong, Yan, Martinez, Sharpe, van Herk, and many more!

kV Cone-Beam CT for Guiding Radiation

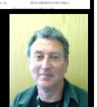



Prototype (1997)


Product (2005)

Cone-beam CT for IGRT : Collaboration Model

- Driven by clinical need (< 1997).
- No existing solutions, developed prototype (1999).
  – Grant funding, industrial partner
- Intellectual property position (USPTO)
- Convinced industrial partner to initiate prototype construction (2001).
  – Licensing of technology (respecting relevant contributions)
  – Peer-review grants (NIH/PCRP) are valuable in this step
  – Innovative alpha/beta approach – depends on manufacturer
- Research Group (peers) worked with alpha units (2004).
  – Matured requirements for clinical release (Beta)
- Full release (2005)


K. Brown - Elekta

Research Platform Model: A Tool for Translation


Christie Manchester


Beaumont Royal Oak


Princess Margaret Toronto


NKI / AvL Amsterdam

"From the point of ignition
To the final drive
The point of the journey is not to arrive

Anything can happen..."

Lyrics from "Prime Mover", Hold Your Fire, 1987 Rush

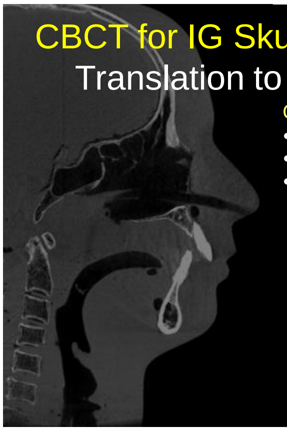
Cone-beam CT: Continued Research and Development

- Unique Perspective (continued R&D)
  - Additional industrial partners engaged on these new/peripheral problems (surgical applications)
  - Continued Collaborative Research for past 5 years
  - Commercialization of Arising Solutions
- Education/KT Demands
  - Established an education program to share experience
  - Arising IP: Course content

New Problem Exposure → Intellectual Property Arising

- Phantoms for QA
- Novel Calibration Methods - USPTO/License
- Dosimetry Systems - USPTO/License
- Contrast Agent Development – USPTO
- Advanced CBCT Methods - Patent Pending
- Small Animal RT Units - Licensing

CBCT for IG Skull Base Surgery: Translation to Clinical Trials



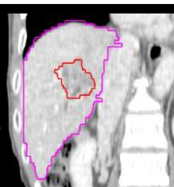
CBCT-Guided H&N Surgery

- IRB Approval (UHN) – Oct 2007
- ITA (Health Canada) – Nov 2007
- Trials Begin (UHN) – March 2008

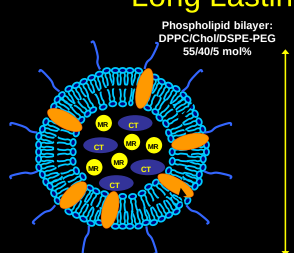
Image Quality in Cone-beam CT

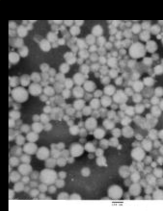
– Challenges
  - Scattered X-rays Reaching the Detector
  - Lower Detector Efficiency
  - Lower Projection Density
  - Artifacts due to Limited Field-of-View (Truncation Artifacts)
  - Motion artifacts

Prevent visualization of low contrast structures



Improving Contrast for IGRT: Long Lasting Agents





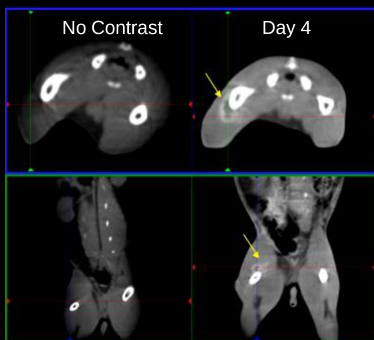
TEM of Extruded Liposomes – Uniform Sizing

CT — **CT Agent: iohexol (MW. 1626.2)**

MR — **MR agent: gadoteridol (MW. 558.7)**

Zheng et al., Investigative Radiology, Volume 41, Number 3, March

Visualization on CBCT



CBCT Guidance

Elekta Synergy – CBCT Linac

Innovating is Contagious

Infection: Building a Stream of Innovators

Training should include technology development and commercialization elements

- Trainees directly involved in development projects and play a key role in developing new technologies and influencing practice change
- Strong links with industry will be encouraged on projects, under appropriate conditions
- E.g. "BioDesign" model (Stanford)

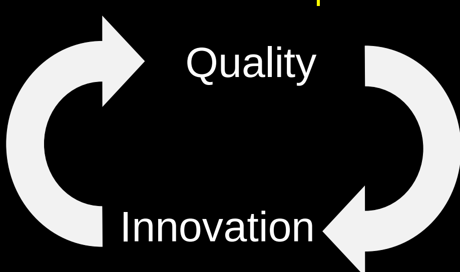
Model, mentor, and facilitate academic clinician-innovator practices

- All staff (i.e. physicians, surgeons, nurses, physiotherapists, etc.) should be encouraged to bring specific needs and new ideas forward
- Need role modeling for young clinicians, biomedical engineers, and applied scientists to learn the skills of innovation in the healthcare setting.

University of Toronto

Leverage the Quality Agenda

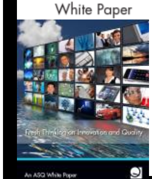
The Quality – Innovation Relationship



What gets measured, gets fixed.

Fresh Thinking on Innovation and Quality

An ASQ White Paper



The idea that innovation must embrace both the blue sky and the practical is neither new nor radical, yet we cling to our fascination with the home run.

It makes sense to manage innovation activities with the same management tools and approaches that are used in other major sectors of the business.

ASQ (American Society for Quality) is the world's leading authority on quality and sole administrator of the Malcolm Baldridge National Quality Award.

ASQ 2010

Innovating is Collaborative

Successful Collaboration Always Comes Down to Committed Individuals

VS

Summary

- Need and demand for innovation in health care.
  - Complexity and momentum
- Hospital-based medical physicists have a unique opportunity as ‘Users as Innovators’
  - Perspectives and Skills
- Innovation is a learned skill that once active, gives back over and over.
- Aligned with the ‘quality agenda’ that is central to medical physics practice.


TFRI'14