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 ($6\sigma$)
• 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
≠
Healthcare as we know it is being delivered today

This shortfall highlights the need for innovation.
What is Innovation?

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
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

Devices vs. drug technologies
Different Technologies, Culture and Perspectives

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

1. Clinical-driven demand
2. Tech solution development
3. Practice change
4. Collaborative resources and expertise
5. Rapid clinical deployment with partners

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’.


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’

...define user entrepreneurship 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.


Model of the 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.
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’
- 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!
**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
  - Matured requirements for clinical release (Beta)
- Full release (2005)

**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

- CT Agent: iohexol (MW. 1626.2)
- MR agent: gadoteridol (MW. 558.7)

Zheng et al., Investigative Radiology, Volume 41, Number 3, March
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.
Leverage the Quality Agenda

The Quality – Innovation Relationship

Quality

Innovation

What gets measured, gets fixed.

Fresh Thinking on Innovation and Quality

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 Baldrige National Quality Award.

ASQ 2010
Innovating is Collaborative

Successful Collaboration Always Comes Down to Committed Individuals

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.