Global Radiotherapy Investment: Cost, Benefit, and Action

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Atun et al., Lancet Oncology 2015

NCPF Workshop 2016
Acknowledgements

• Members of the Global Task Force for Cancer Control
Predicted Global Cancer Cases

Source: WHO GloboCan
Grand Convergence in Health

Jamison et al., Lancet 2013
Radiotherapy: A missing but essential component of effective cancer control.
"What is the investment needed to close the gap between what exists today and reasonable access to radiotherapy globally?"
Dr. Tabaré Vázquez
Honorary Chair:
Radiation oncologist and President of the Oriental Republic of Uruguay.

Task Force
Members from over 35 Countries

Rifat Atun
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Harvard TH Chan School of Public Health

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Task Force Functionality

**Burden and Demand**
- Global Burden of Cancer
- \# of patients needing RT
- \# of RT treatments (fractions) required

**Outputs**
- **Outcomes**
  - Survival benefit of radiotherapy

**Health Systems Readiness**
- **CORE INVESTMENTS**
  - Facilities
  - Equipment
  - Personnel
- **ENABLING SERVICES**
  - Pathology
  - Radiology
  - Surgery
  - Primary Care
- **CONTEXTUAL READINESS**
  - Infrastructure
  - Finances
  - Awareness

**Investment Framework**
- Top ten cancers (75%) and benefits
- Scale by Total Cancer Burden
- Group countries by GNI
- Costs + benefits of treating cancer populations each year
- Accounting for increasing burden, based on IARC projections

**Demand (#fx/yr)**

**Cost to Build Capacity and Treat ($/fx)**

**Survival (5yr)**

**Year**
- 2015
- 2020
- 2025
- 2030
- 2035

**Coverage**
- 0%
- 20%
- 40%
- 60%
- 80%
- 100%

**Total Lives Gained (Thousands)**
- 2011
- 2020
- 2025
- 2030
- 2035

WG#1&3

WG#2
Key Broad Assumptions

1. Radiation therapy will continue to be part of cancer control in 2035

2. The cost of radiotherapy equipment and resources will not change substantially over the next 20 years

3. There is sufficient health system and societal infrastructure in place to enable radiation therapy
Combined Working Group 1 & 3: Burdens and Outcomes

*Authors: M Barton, M Yap, T Hanna, J Shafiq, F Bray, J Ferlay

*On behalf of Working Group 1
Objectives & Methods

Objectives

1. Number of cases requiring RT at least once by country in 2012
2. Average number of RT fractions per country in 2012
3. Local control and survival benefit from RT (top 10 cancers) in 2012
4. Objectives 1, 2, & 3 projected to 2035

Methods

1. Cancer numbers and distribution from GloboCAN (IARC)
2. RT Utilisation Approach (CCORE)
3. RT Fractions (Fx)
4. Published RT local control and survival benefit
5. Projections to 2035 from IARC
Global Demand and Benefit

2012

7 million indications
119 million fractions
1.5 million local controls
580 000 lives

2035

12 million indications
204 million fractions
2.5 million local controls
950 000 lives
Global RT Coverage Map: Variation

Atun et al., Lancet Oncology 2015
Global RT Coverage: Variation

Atun et al., Lancet Oncology 2015
Results for Input to Investment Framework

• 5-yr survival benefit for 10 highest incidence of cancer for use in detailed Markov Model

• Number of fractions/yr to deliver optimal use

• All broken down by non-disputed countries (184 in total)
Working Group #2: Core Investment Work Group

*Authors: Jake Van Dyk, E.H. Zubizarreta, Y. Lievens, D. Jaffray, T. Lui

*On behalf of Working Group 2
WG #2 Objectives

1. Definition of RT delivery model
   - Facilities, equipment, staffing, operations
2. Estimate current treatment capacity
3. Quantify current needed vs available
4. Determine operating cost per fraction
   - OpEx – US$/Fraction delivered
5. Determine investment required to generate a new fraction of capacity
   - CapEx – US$/fraction/yr
Costing: Components

**CapEx:** Upfront costs to develop a new facility

- investment in construction
- investment in equipment
- human-resource training costs

**OpEx:** Operating costs to deliver treatments

- human resources
- maintenance
- consumables
- overhead
- amortisation costs of equipment and facilities
Radiotherapy Costs per Fraction: OpEx and CapEx

<table>
<thead>
<tr>
<th></th>
<th>High-income countries</th>
<th>Upper-middle-income countries</th>
<th>Lower-middle-income countries</th>
<th>Low-income countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating cost per fraction</td>
<td>235</td>
<td>86</td>
<td>65</td>
<td>60</td>
</tr>
<tr>
<td>Upfront cost per fraction</td>
<td>803</td>
<td>357</td>
<td>349</td>
<td>352</td>
</tr>
</tbody>
</table>

Estimated on the basis of the activity-based model. Data are cost in US$. Operating cost = cost / fractions delivered. Upfront cost = one-off cost required to create the capacity, after which operating costs are incurred.
What resources will be needed to deliver the 204M Fx/yr in 2035?

<table>
<thead>
<tr>
<th>2035</th>
<th>High-income countries</th>
<th>Upper-middle-income countries</th>
<th>Lower-middle-income countries</th>
<th>Low-income countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fractions</td>
<td>76 424 000</td>
<td>77 014 000</td>
<td>40 974 000</td>
<td>13 268 000</td>
</tr>
<tr>
<td>Radiotherapy departments</td>
<td>4600</td>
<td>3700</td>
<td>2000</td>
<td>600</td>
</tr>
<tr>
<td>Megavoltage machines</td>
<td>9200</td>
<td>7400</td>
<td>3900</td>
<td>1300</td>
</tr>
<tr>
<td>CT scanners</td>
<td>4600</td>
<td>3700</td>
<td>2000</td>
<td>600</td>
</tr>
<tr>
<td>Radiation oncologists to be trained</td>
<td>15 500</td>
<td>16 800</td>
<td>9 900</td>
<td>3 300</td>
</tr>
<tr>
<td>Medical physicists to be trained</td>
<td>17 200</td>
<td>12 500</td>
<td>7 200</td>
<td>2 400</td>
</tr>
<tr>
<td>Radiation technologists to be trained</td>
<td>51 900</td>
<td>45 300</td>
<td>24 900</td>
<td>8 100</td>
</tr>
</tbody>
</table>

Atun et al., Lancet Oncology 2015
Investment Framework

Authors: Danielle Rodin, Rifat Atun
How much to invest and what are the economic returns?

• Investment framework: A “formalized, structured, and numerically based” approach to decision-making and resource allocation.


• Choosing the investment scheme.
• Platform to compare competing health priorities to guide future spending.
Modeling Approach (1/2)

• Cancer site-specific Markov models
  – Simulate the remaining lifetime following diagnosis

• Period of analysis: 2015-2035
  – Each year defined as a “cohort”, with given cancer population and RT coverage level

• RT coverage of each cohort year simulated in “scale-up” and “no scale-up” scenarios
Global RT Coverage Map: Current

Atun et al., Lancet Oncology 2015
Linear Investment Scenario

Coverage

Year

2015 2020 2025 2030 2035

0% 20% 40% 60% 80% 100%

UMIC LMIC LIC

Union for International Cancer Control
www.uicc.org
Modeling Approach (2/2)

• Model outcomes
  – Discounted life years (LYs), economic benefits (measured through GDP per capita), and costs

• Analysis
  – Each cancer and cohort year separately modeled
  – Stratified by World Bank income group regions
    • Low-income [LIC], lower middle-income [LMIC], upper middle-income [UMIC]
  – Sensitivity analysis
Translating lives saved into economic benefits

• Human Capital Approach
  • Benefits from labour force participation and productivity as a result of deaths avoided from cancer.

• Full Income Approach
  • “Value in a particular country or region of a 1-year [potential] increase in life-expectancy”

• Both calculated through effects on GNI-specific gross domestic product (GDP)
A Linear Investment in RT Coverage: Cost and Benefits in non-HIC

Atun et al., Lancet Oncology 2015

Full Income Benefits
Human Capital Benefits
Costs-Efficient
Costs-Nominal

Total Cost:
$184.0 Bn
$96.8 Bn

Atun et al., Lancet Oncology 2015
Linear increase in RT Capacity in LMICs: Net Benefits

<table>
<thead>
<tr>
<th></th>
<th>Low-income countries</th>
<th></th>
<th>Lower-middle-income countries</th>
<th></th>
<th>Upper-middle-income countries</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nominal</td>
<td>Efficiency</td>
<td>Nominal</td>
<td>Efficiency</td>
<td>Nominal</td>
<td>Efficiency</td>
</tr>
<tr>
<td>Net monetary benefit (US$, billions)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human-capital approach</td>
<td>-14.9</td>
<td>-2.4</td>
<td>-18.7</td>
<td>10.7</td>
<td>50.5</td>
<td>95.9</td>
</tr>
<tr>
<td>Full-income approach</td>
<td>0.265</td>
<td>12.8</td>
<td>38.5</td>
<td>677</td>
<td>239.3</td>
<td>284.7</td>
</tr>
<tr>
<td>Return on investment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human-capital approach</td>
<td>-0.56</td>
<td>-0.17</td>
<td>-0.3</td>
<td>0.32</td>
<td>0.53</td>
<td>1.94</td>
</tr>
<tr>
<td>Full-income approach</td>
<td>0.01</td>
<td>0.91</td>
<td>0.62</td>
<td>2.03</td>
<td>2.52</td>
<td>5.77</td>
</tr>
</tbody>
</table>

Net monetary benefit = cost of investment - economic return. Return on investment = net monetary benefit / cost of investment. Costing models are described in the text and include both operational and capital costs.
Call to Action

Action 1: population-based cancer control plans
Radiotherapy must be incorporated into population-based comprehensive cancer plans in all countries with explicit targets for scaling up radiotherapy capacity to expand coverage.
Target: by 2020, 80% of the countries should have cancer plans that include radiotherapy.

Action 2: expansion of access to radiotherapy
We urge immediate action to establish additional radiotherapy capacity by creating at least one cancer centre in each low-income and middle-income country by 2020. In addition to providing treatments, these new centres should be used to train the radiotherapy workforce to enable further expansion of radiotherapy coverage.
Target: an increase of 25% in the 2015 radiotherapy treatment capacity by 2025.

Action 3: human resources for radiotherapy
We call for new approaches to train radiotherapy professionals globally, with the creation of new core curriculums, innovative learning methods, and international credentialing to expand the radiotherapy workforce. Training should become part of the mandate of each national radiotherapy centre to self-propagate the required skills, enabling national expansion of cancer therapies and providing the ability to replace staff as they leave or are recruited out of country.
Target: 7500 radiation oncologists, 20,000 radiation technologists, and 6000 medical physicists to be trained in low-income and middle-income countries by 2025.

Action 4: sustainable financing to expand access to radiotherapy
Domestic and international financing will be needed to expand radiotherapy capacity with substantial upfront investment. International development banks and the private sector should work in partnerships with countries to finance investments in infrastructure and radiotherapy services.
Target: $46 billion of investment by 2025 to establish radiotherapy infrastructure and training in low-income and middle-income countries.

Action 5: align radiotherapy access with universal health coverage
We call for inclusion of radiotherapy coverage in each country's universal health coverage plans to prevent catastrophic out-of-pocket expenditures and treatment abandonment.
Target: 80% of low-income and middle-income countries to include radiotherapy services as part of their universal health coverage by 2020.
Objective: Bring safe, high quality radiotherapy to the 12.5M cancer patients that will need it by 2035.

- Cost – not a problem.
- Value – not a problem.
- Methods – a problem.

*We know what we need to do, we don’t know how to do it.*
Objective: Bring safe, high quality radiotherapy to the 12.5M cancer patients that will need it by 2035.

- Financial,
- social,
- and technological..

Encourage us to step back and take a ‘multi-scalar view’.
The design of a radiotherapy treatment machine affects the entire system.

- Embark on the design of the machine as a global optimization problem.
- The operating costs, the capital costs, the financial benefit (and their limiting derivatives wrt time).

“The Devil is in the details, but so is salvation.”

— Admiral H.G. Rickover, USN
BOX 1.2  FOUR REVOLUTIONS THAT WILL TRANSFORM HEALTH AND HEALTH SYSTEMS

There are four revolutions currently underway that will transform health and health systems. These are the revolutions in: a) life sciences; b) information and communications technology; c) social justice and equity; and d) *systems thinking to transcend complexity*.


*Italics added for emphasis.*
Cancer Care in Developed Nations is Very Complex

Diagnosis
Staging

3D imaging
Target volume
Organ localization

Prescription
Segmentation

Dose calculation
Beam optimization

Beam shaping

QA of Plan

Plan Transfer

Treatment verification
Delivery

Follow-up

Monitoring
Clinical Response

Clinical Response in Developed Nations is Very Complex
Burden of Complexity

Things should be made as simple as possible, but not simpler.

Albert Einstein
The Steam Engine

James Watt (1736-1819)
Mr. Watt believed that throttling a steam valve by a human being was not the best way to maintain a constant speed of the steam engine.

The beginning of modern automatic control began, when James Watt in 1788 developed a mechanical device the flyball governor.

The flyball governor maintained the speed of the steam engine automatically by controlling the opening and closing of the steam valve.
Complexity Buried
Objective: Bring safe, high quality radiotherapy to the 12.5M cancer patients that will need it by 2035.

Exporting the cancer care that we can’t even afford is not the solution.
“Connectivity as the primary engine of creativity and innovation over the past 600 years.” – Steven Johnson

The report of the GTFRCC connects evidence-based practice, cost of care delivery, and financial benefit. This connectivity has the capacity to stimulate innovation.
Innovating for the Global Expansion of High Quality RT

- Key Messages to Drive Innovation
  - Overwhelming Need and Impact
    - >24M/yr cancers in 2035
    - >200M fractions of RT need to be delivered
    - >900,000 lives saved per year
  - Long-term Market
    - RT is an essential part of effective cancer control in 2035
  - Infrastructure, Technology, Skills, Finance
  - Significant Emerging Investment
    - $184B in LMICs in the next 20 years

Atun et al., Lancet Oncology 2015
Software systems that automate the treatment planning process AND improve plan quality.

>Planning from 4 hours to 4 min.

Purdie et al. - Int J Radiat Oncol Biol Phys. 2011

Migration to the Cloud will enable shared learning and lower infrastructure costs.

NanoX radiotherapy system design including fixed linac and patient rotation system.

>Significant construction cost savings.

Keall et al.

http://dx.doi.org/10.1594/ranzcr2014/R-0142

Opportunity to ‘bury the complexity’ of RT.
During the summer, the array’s output will be more than the Radiation Oncology Centre needs to run its two linear accelerators, a large bore CT system and the clinic’s IT technology, lighting and air-conditioning.
Innovation for Efficiency: Technology, Processes, Purchasing

<table>
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<tr>
<th>Operating cost per fraction: sensitivity analysis</th>
<th>Cost savings relative to base scenario</th>
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<tbody>
<tr>
<td>Automation: efficiency</td>
<td>High-income countries</td>
</tr>
<tr>
<td>Longer hours</td>
<td>25%</td>
</tr>
<tr>
<td>Bulk purchase</td>
<td>13%</td>
</tr>
<tr>
<td>Combination 3</td>
<td>8%</td>
</tr>
<tr>
<td>Combination 4</td>
<td>33%</td>
</tr>
<tr>
<td>Combination 5</td>
<td>19%</td>
</tr>
<tr>
<td>Combination 6</td>
<td>31%</td>
</tr>
<tr>
<td>Combination 7</td>
<td>37%</td>
</tr>
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</table>

The operating cost model allows for improved efficiency, longer treatment hours per day, and bulk purchasing savings. These factors can occur alone or in combination, resulting in seven different combinations. X shows the inclusion of a factor in the sensitivity analysis.

Table 3: Sensitivity analysis to determine operational costs

Capacity for significant savings while maintaining quality.
Health professionals have made enormous contributions to health and development over the past century, but complacency will only perpetuate the ineffective application of 20th century educational strategies that are unfit to tackle 21st century challenges.”

“Health professionals have made enormous contributions to health and development over the past century, but complacency will only perpetuate the ineffective application of 20th century educational strategies that are unfit to tackle 21st century challenges.”

Result: >215,000 RT Professionals to be Trained by 2035

Innovative Leadership and Stewardship

...a mentoring network of cancer professionals who work with local and regional in-country groups to develop and sustain expertise for better cancer care.

http://www.iceccancer.org/

...provide Medical Physics support with the goal of improving the effectiveness and safety in the use of physics and technologies in medicine, especially in LMICs.

http://www.mpwb.org/

...is a movement of young leaders to turn radiotherapy into a global health priority.

http://globalrt.org/
Financing Innovations

• Novel financing solutions for mobilising, pooling, channelling, and funding radiotherapy services
  • AIDS, tuberculosis, malaria, and children’s immunisation programmes

• Leverage scale for cooperative approaches to supply and manufacturing
  • Brazil will source 40% of the RT system parts, accessories and software from within the country.

• Innovative financing instruments
  • Commitments (GAVI), Bonds (Diaspora), or Guarantees (World Bank)

Summary

• Global data permits the accurate projection of cancer burden.
• Evidence based benefit of radiation therapy demonstrates the opportunity to impact 5-yr survival for 950,000 people per year by 2035.
• While significant investment is required, a net financial benefit is projected.
• Five Calls to Action identify targets
• Investment is not enough – we need innovation.