Fixed-beam radiotherapy systems for more cost-effective treatment

Global shortage in radiotherapy facilities and accessibility

Global radiotherapy access

Need for investment

- High cost of equipment
- High cost of infrastructure
- Shortage of expertise
- Estimated $14 billion investment for full access in low/middle income countries

Source: Zubizarreta et al 2016

Source: Atun et al 2015
Low/middle income countries

World population: 85%
Radiotherapy facilities: 40%

- Lack of screening
- Low availability of surgical procedures
- 75% of patients have no access

Source: IAEA Radiotherapy in cancer care 2017

Fixed beam treatment systems
Stationary radiation beam with target translation and rotation

- Increased automation
- Simple isocentric design
- Steamlined QA
- Remote operation
- Artificial intelligence

Horizontal treatments
Upright treatments
Robotic patient positioning
Fixed beam linear accelerators

1956

Upright rotation systems


• Seated, standing or kneeling patient with horizontal radiation beam

Upright rotation systems

Source: Yang et al 2014

• Potential clinical benefit for lung patients
• Upright systems would require upright imaging for treatment planning
NanoX linear accelerator

- Fixed-beam linac with vertical central beam axis
- Horizontal patient rotation system
- Real-time beam adaptation to address tumor motion

Source: Eslick and Keall 2014

NanoX concept

Source: Eslick and Keall 2014

NanoX bunker Conventional bunker

<table>
<thead>
<tr>
<th></th>
<th>Footprint</th>
<th>Concrete required</th>
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<tbody>
<tr>
<td>Conventional</td>
<td>104 m²</td>
<td>102 m³</td>
</tr>
<tr>
<td>Nano-X</td>
<td>17 m²</td>
<td>33 m³</td>
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</tbody>
</table>

Source: Eslick and Keall 2014
NanoX concept summary

**Benefits**
- No gantry to rotate
- More robust with fewer moving parts
- Smaller footprint
- Less shielding required

**Challenges**
- Organ motion during rotation
- Patient acceptance of rotation
- Patient safety

NanoX prototype

Prototype development roadmap
Commissioning

- Geometric and dosimetric accuracy commissioned based on TG-142
- Commissioned for conformal treatments for a rigid target with 6 MV and 10 MV X-rays

Dosimetric equivalence

- Dose distribution delivered on NanoX prototype agreed with planning system and conventional treatment
- 100% pass at 2%/2 mm gamma

Patient acceptance and comfort

Healthy volunteers rotated on Epley Omnimax

Source: Whelan et al 2014
Organ deformation

- Volunteers imaged using MRI compatible rotation system
- Deformable registration used to account for deformation

Prototype development roadmap

Kilovoltage Intrafraction Monitoring (KIM)

- Tracks the target position based on markers as target rotates
- KIM algorithm has been used to over 100 patients in clinical trials for prostate cancer
Based on target position, new leaf positions are calculated.

Static aperture shifts and real-time MLC tracking have been tested with a rotating target.

With MLC tracking, 98.9% pass (2%/2mm) compared to conventional delivery.

Without MLC tracking, pass rate would be 90.1%.

Fixed-beam treatment systems have the potential to reduce linac size and cost.

Prototype NanoX system and demonstrated real-time image guided treatments.

Challenges regarding patient acceptance and organ deformation still need to be addressed.
Thank you!