Fixed-beam radiotherapy systems for more cost-effective treatment

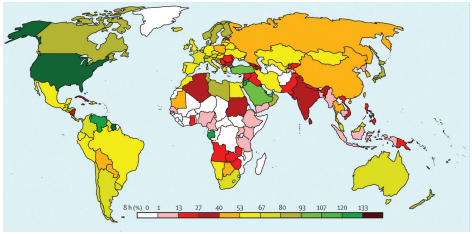
SYDNEY VITAL

ACRF IMAGE X INSTITUTE

THE UNIVERSITY OF SYDNEY

1

Global radiotherapy access



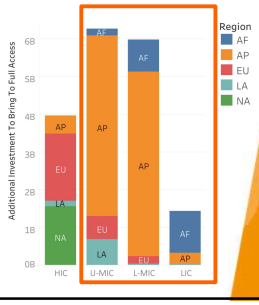
Global shortage in radiotherapy facilities and accessibility

ACRF IMAGE X INSTITUTE Source: Atun et al 2015

2

Need for investment

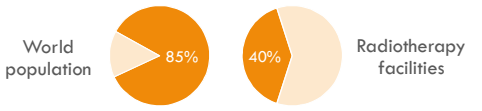
- High cost of equipment
- High cost of infrastructure
- Shortage of expertise
- Estimated $14 billion investment for full access in low/middle income countries



ACRF IMAGE X INSTITUTE Source: Zubizarreta et al 2016

3

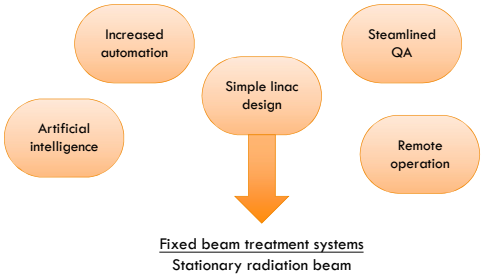
Low/middle income countries



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

ACRF IMAGE X INSTITUTE Source: IAEA Radiotherapy in cancer care 2017

4

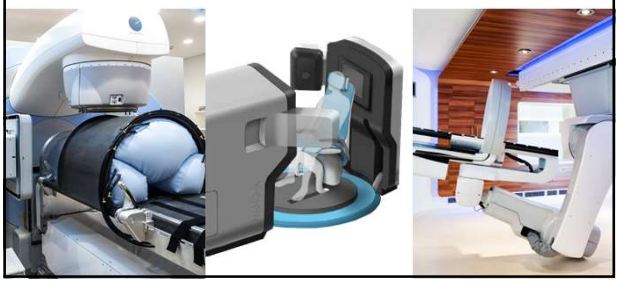


Fixed beam treatment systems
Stationary radiation beam
with target translation and rotation

ACRF IMAGE X INSTITUTE

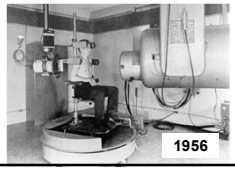
5

Horizontal treatments | **Upright treatments** | **Robotic patient positioning**



6

Fixed beam linear accelerators



ACRF IMAGE X INSTITUTE

7

Upright rotation systems

THE UNIVERSITY OF TEXAS MD Anderson Cancer Center
Making Cancer History®
THE GRADUATE SCHOOL OF BIOMEDICAL SCIENCES GSBS

- Seated, standing or kneeling patient with horizontal radiation beam

ACRF IMAGE X INSTITUTE Source: McCarroll et al 2016

8

Upright rotation systems

- Potential clinical benefit for lung patients
- Upright systems would require upright imaging for treatment planning

ACRF IMAGE X INSTITUTE Source: Yang et al 2014

9

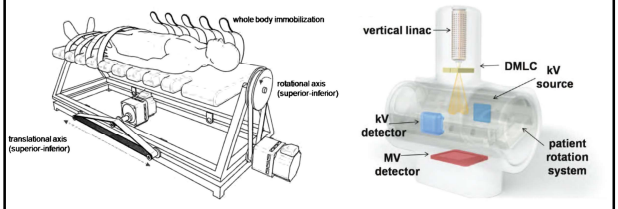
NanoX linear accelerator

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

ACRF IMAGE X INSTITUTE Source: Eslick and Keall 2014

10

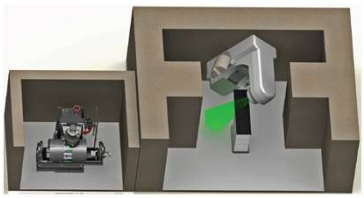
NanoX concept



ACRF IMAGE X INSTITUTE Source: Eslick and Keall 2014

11

NanoX bunker Conventional bunker



	Footprint	Concrete required
Conventional	54 m^2	102 m^3
Nano-X	17 m^2	35 m^3

ACRF IMAGE X INSTITUTE Source: Eslick and Keall 2014

12

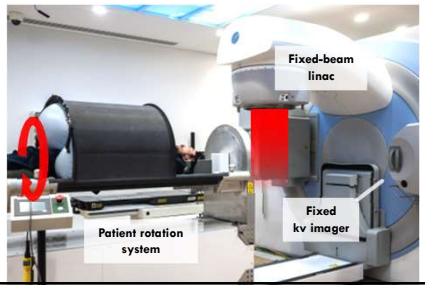
NanoX concept summary

Benefits	Challenges
• No gantry to rotate	• Organ motion during rotation
• More robust with fewer moving parts	• Patient acceptance of rotation
• Smaller footprint	• Patient safety
• Less shielding required	

ACRF IMAGE X INSTITUTE

13

NanoX prototype



ACRF IMAGE X INSTITUTE

14

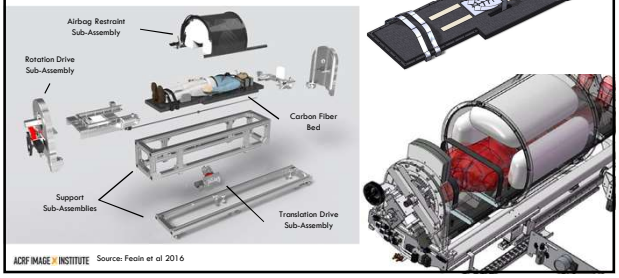
Prototype development roadmap

Hardware	Basic treatment system	Advanced treatment system
• Elekta Synergy	• Control software	• IMRT/VMAT delivery
• Patient rotation couch	• kV imaging	• Imaging with motion compensation
	• Treatment delivery	• KIM
	• Commissioning	• MLC tracking

ACRF IMAGE X INSTITUTE

15

Patent rotation system



ACRF IMAGE X INSTITUTE Source: Feain et al 2016

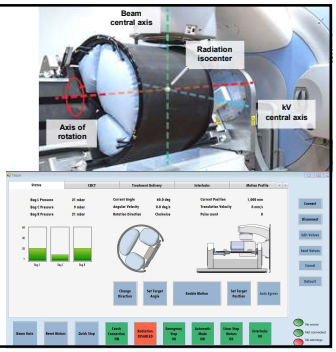
16

NanoX prototype

17

Prototype development

- Geometric alignment
- Interlock and emergency stop integration
- Control software
- Fixed beam kV imaging

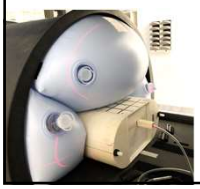


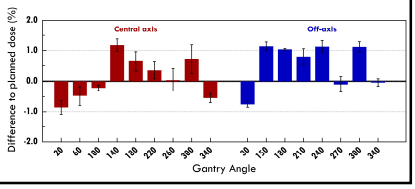
ACRF IMAGE X INSTITUTE

18

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

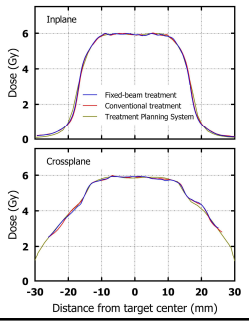




19

Dosimetric equivalence

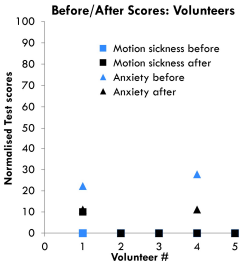
- Dose distribution delivered on NanoX prototype agreed with planning system and conventional treatment
- 100% pass at 2%/2 mm gamma



20

Patient acceptance and comfort

Healthy volunteers rotated on Epley Omnimax

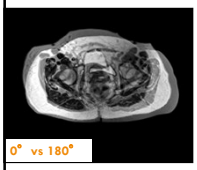


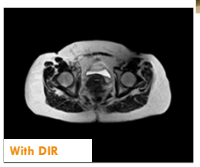
ACRF IMAGE X INSTITUTE Source: Whelan et al 2014

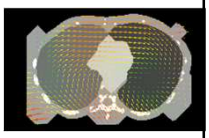
21

Organ deformation

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







ACRF IMAGE X INSTITUTE Source: Whelan et al 2017, Buckley et al 2019

22

Prototype development roadmap

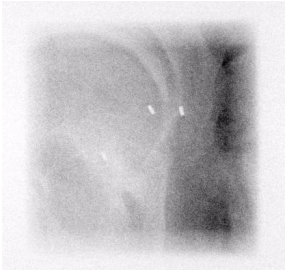
Hardware	Basic treatment system	Advanced treatment system
• Elekta Synergy	• Control software	• IMRT/VMAT delivery
• Patient rotation couch	• kV imaging	• Imaging with motion compensation
	• Treatment delivery	• KIM
	• Commissioning	• MLC tracking

ACRF IMAGE X INSTITUTE

23

Kilovoltage Intrafraction Monitoring (KIM)

- Tracks the target position based on markers as target rotates rotates
- KIM algorithm has been used to over 100 patients in clinical trials for prostate cancer

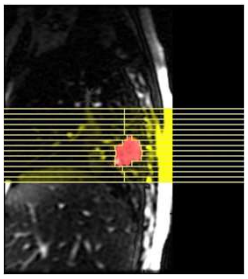


ACRF IMAGE X INSTITUTE

24

Beam shifts and MLC Tracking

- Based on target position, new leaf positions are calculated
- Static aperture shifts and real-time MLC tracking have been tested with a rotating target

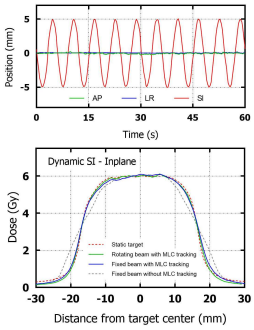


ACRF IMAGE X INSTITUTE

25

Dynamic phantom motion

- Phantom moved sinusoidally along SI axis (amplitude 5 mm and periodicity 6 s)
- With MLC tracking, 98.9% pass (2%/2mm) compared to conventional delivery
- Without MLC tracking, pass rate would be 90.1%



26

Summary

- 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 addressed

ACRF IMAGE X INSTITUTE

27


Thank you!
THE BRIGHT
NELUNE
NSW GOVERNMENT Health
SYDNEY VITAL
TRANSLATIONAL CANCER RESEARCH
NORTHERN SYDNEY CANCER CENTRE
ide
Australian Government
Australian Research Council
Australian Government
National Health and Medical Research Council
ACRF IMAGE X INSTITUTE
THE UNIVERSITY OF SYDNEY

28