Treatment Machines: Special Architectures

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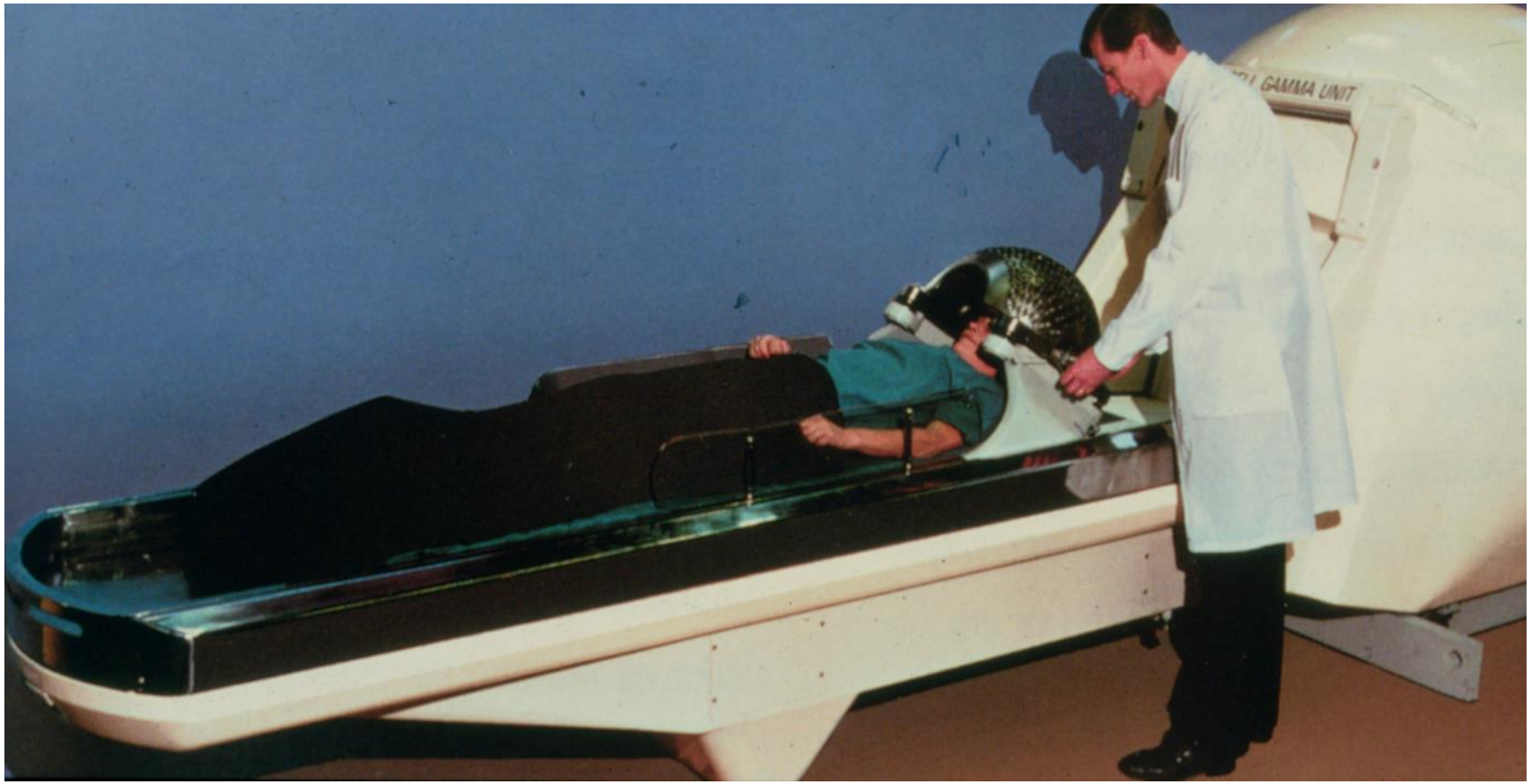
15.2STEREOTACTIC IRRADIATION

15.2.5 Radiosurgical techniques

- Leksell Gamma Knife (older model)



Gamma Knife – since 1968


ELEKTA
icon

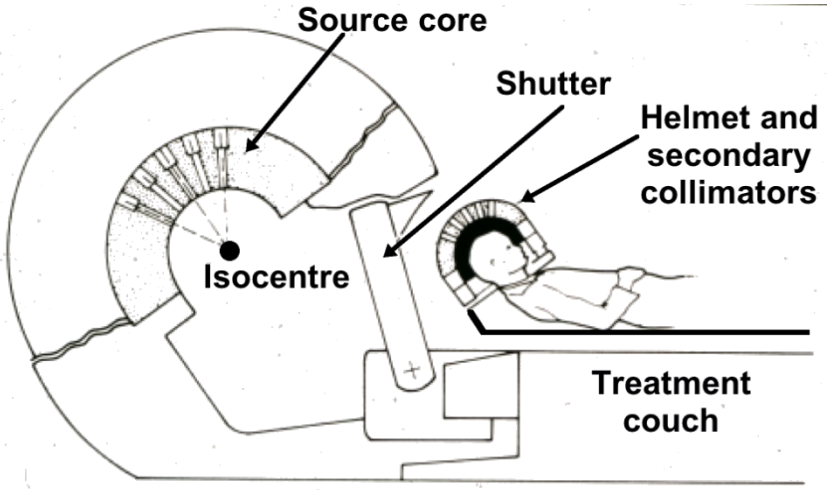
Gamma Knife

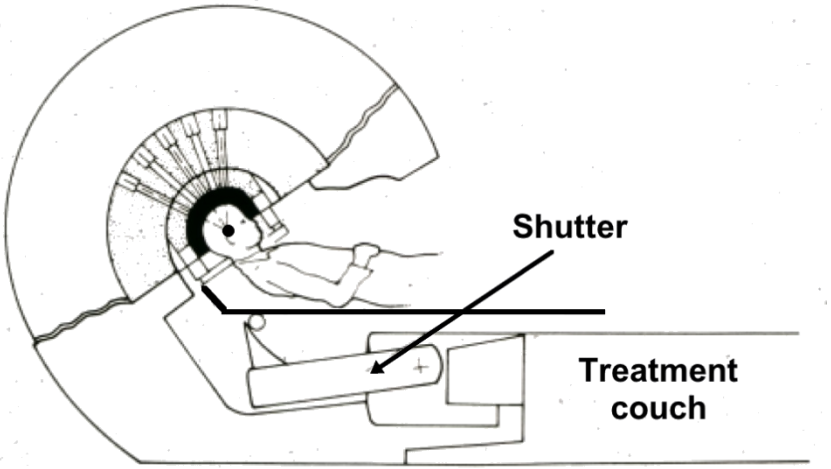
- 192/201 individual Co-60 sources, each source with an activity of 1.1 TBq
- Brain only – brain mets, AM, trigeminal neuralgia, acoustic neuromas, pituitary tumours …
- SAD = 40 cm
- Very accurate, < 1 mm
- Very popular with neurosurgeons

15.2STEREOTACTIC IRRADIATION

15.2.5 Radiosurgical techniques

- Main components of the Gamma Knife:
  - Source core
  - 201 cobalt-60 sources
  - Shutter mechanism
  - Helmet and secondary collimators
  - Treatment couch





Comparison: Gamma Knife versus isocentric linac

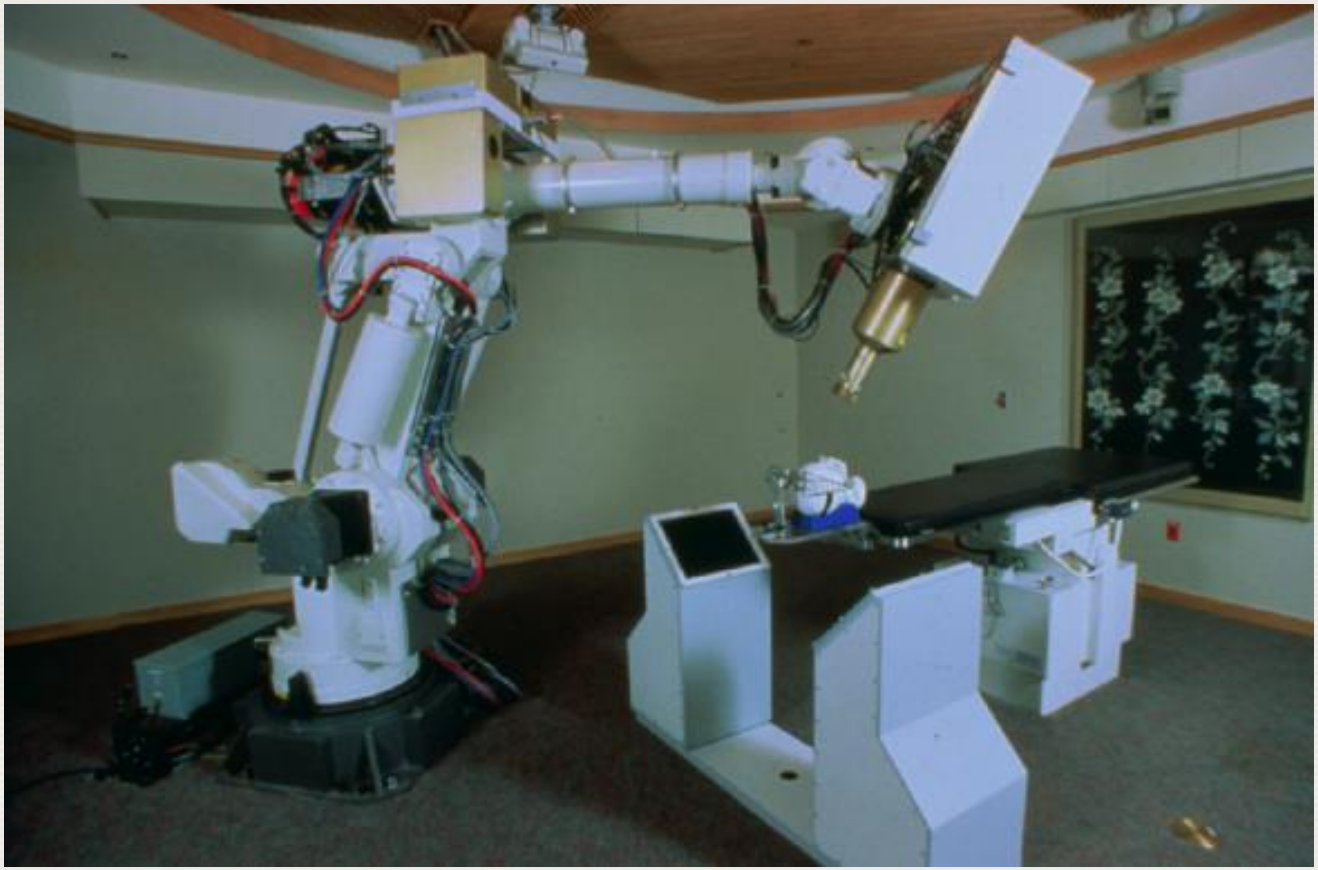
	Gamma Knife	Isocentric linac
Radiation quality	201 cobalt sources	x rays (6 – 18 MV)
Radiation beam	Stationary	Stationary or moving
Dose rate	Up to 350 cGy/min	Up to 600 cGy/min
Fields	Circular	Circular or irregular
Field diameters	4, 8, 14, 18 mm	5 mm – 40 mm
Irregular fields	Not available	Produced with microMLC
Operation	Dedicated	Used for standard RT

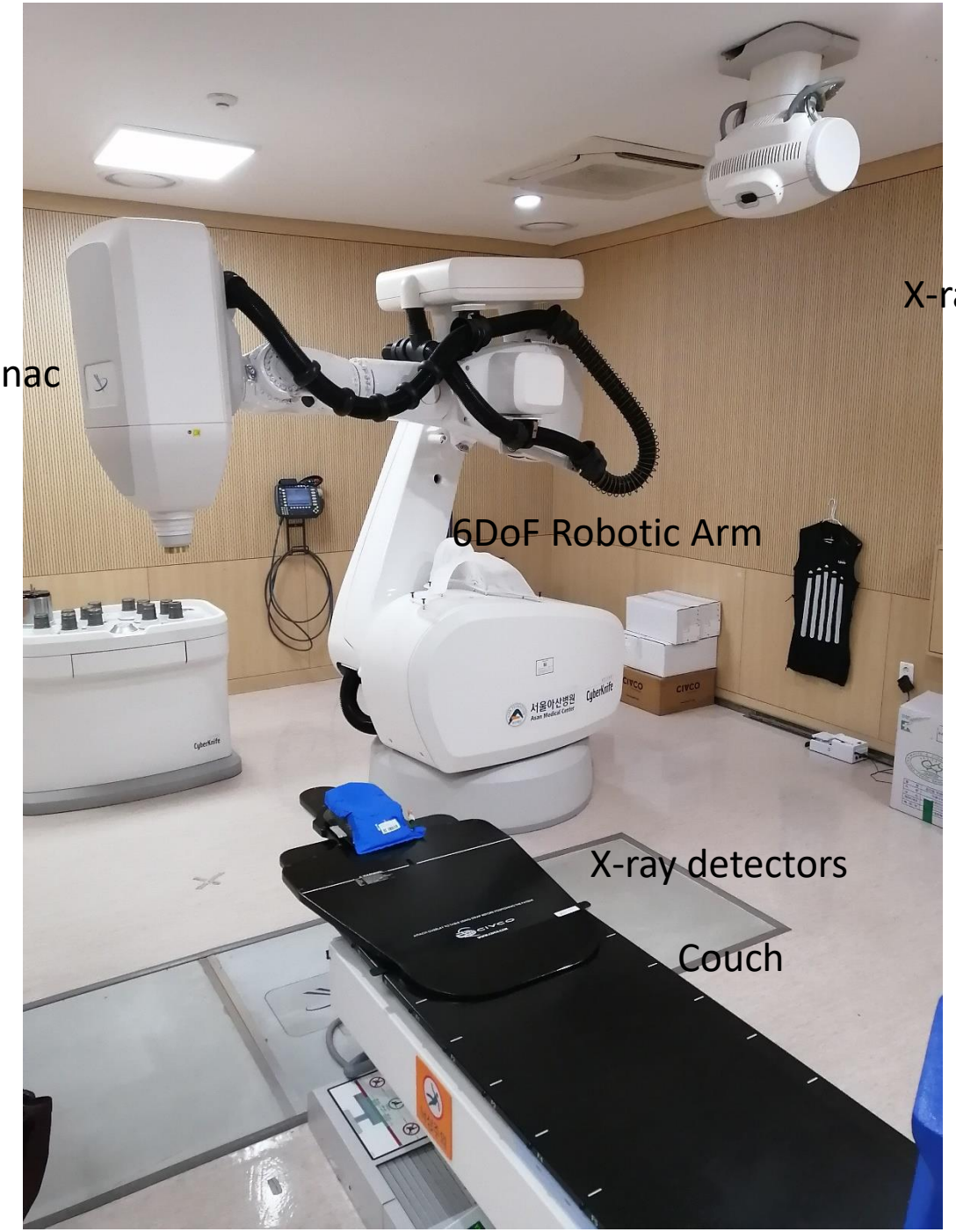
- General consensus among radiation oncologists and medical physicists is that:
  - Linac-based radiosurgery with regard to treatment outcome is equivalent to that provided by a Gamma Knife
  - Linac-based radiosurgery, in comparison with Gamma Knife radiosurgery, is considerably more complicated but has a much greater potential for new and exciting developments.
- General consensus among neurosurgeons is that Gamma Knife radiosurgery is superior to that practiced with isocentric linacs.

CyberKnife

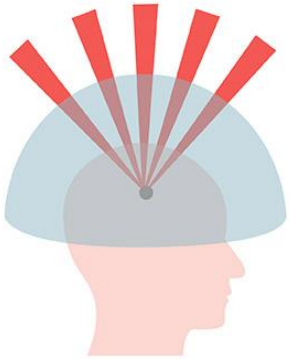
- Fully robotic radiation delivery system
- 6 MV linac mounted on a robotic arm

- Miniature linac mounted on a robotic arm (CyberKnife)




X-ray camera
Linac
6DoF Robotic Arm
X-ray detectors
Couch

Gamma Knife



200 angles of treatment
Limited to 1 treatment session

vs

CyberKnife

1400 angles of treatment
1 or 2-5 treatment sessions

- Not limited to head only
- No frame
- Image guided
- Possibility of motion tracking

- Very expensive

Tomotherapy

- The very first paper on tomotherapy was published by Mackie in 1993.
- The first clinical unit was completed in 2001
- It is essentially a CT scanner, but with a linac beam replacing the X-ray beam

- Dose delivery is done helically, moving slip-ring gantry

Tomotherapy

- 6 MV linac rotates around patient like a CT scanner
- MLC - Tomotherapy uses a 64-leaf binary MLC
- Table moves while beam is on
- Can acquire an MV CT
- Planning systems use a common beam model

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The concept and challenges of TomoTherapy accelerators

Claude J Bailat, Sébastien Baechler, Raphael Moeckli, Marc Pachoud, Olivier Pisaturo and François O Bochud

Radiation characteristics of helical tomotherapy

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MR-Linac

- Viewray MRIdian
- 0.35 T, 6 MV
- However, they declared bankruptcy in July 2023

MR-Linac

CE approval obtained in 2018, over 100 orders by now

- Beam energy: 7 MV FFF
- SAD 143.5 cm
- Max FS: 22x57.4 cm
- Step & Shoot IMRT
- 425 MU/min
- Gantry rotates at 6 rpm

Why?

- 1) Adaptive radiotherapy
- 2) Superior imaging
  - Machine learning, gated treatments, better soft tissue contrast

For example: Prostate, oligomets, liver

- Prostate: ability to adapt to account for variable bladder/rectal filling
- Motion monitoring
- Margin reduction possible

- However: longer treatments leads to bladder filling during treatment

Oligomets

- Able to visualize and optimize around OARs
- Motion monitoring

- But: bowel shows up better in T2, targets show up better on T1

Liver

- Better visualization than CBCT
- But motion may be a problem

- Integration of a 7 MV linac and full field MLC
- 1.5 T Philips MRI

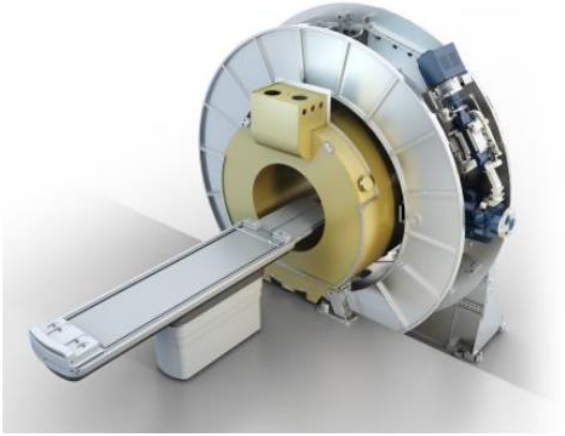
- Linac unaffected by MR
- MR unaffected by linac

- But many challenges to get there!!

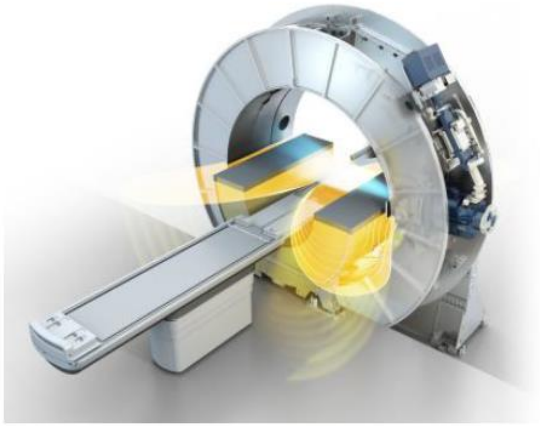
- Philips modified design of MRI component
- Elekta modified linac design
- RF cage integral to the scanner was designed to remove mutual interferences.

- But, no third party QA tools
- Reimbursement a major problem!!

- The very strong magnetic field influenes charged particle motion due to Lorentz force, resulting in changes to out-of-field dose compared to conventional linac.



MRI magnet integrated inside the gantry of the linear accelerator



Cross-section of magnet showing simultaneous radiation beam and magnetic field

Elekta Unity successfully integrates a next-generation linear accelerator technology with a high-field (1.5T) diagnostic-standard MRI system in one device. It is powered through intelligent software that offer adaptation to plans while the patient is on the table, creating a personalized plan every time you treat depending on the tumor at that moment in time.

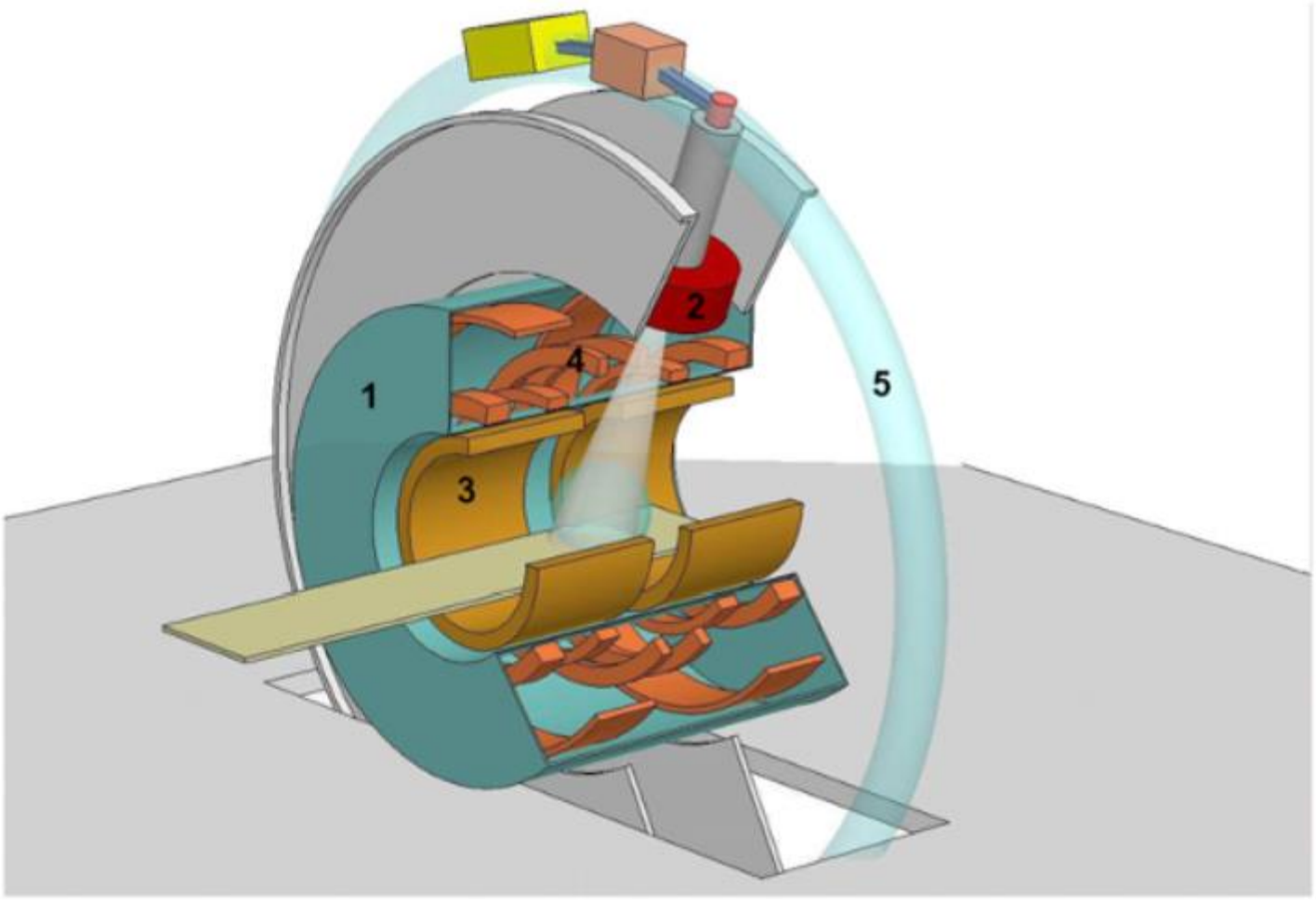


Figure 1. Sketch of the MRI accelerator concept. The 1.5 T MRI is shown in blue (1), the 6 MV accelerator (2) is located in a ring around the MRI. The split gradient coil (3) is shown in yellow and in orange the superconducting coils (4) are shown. The light blue ring around the MRI indicates the low magnetic field toroid (5) in the fringe field.

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Letter

First patients treated with a 1.5 T MRI-Linac: clinical proof of concept of a high-precision, high-field MRI guided radiotherapy treatment

B W Raaymakers[1,3], I M Jürgenliemk-Schulz[1], G H Bol[1], M Glitzner[1], A N T J Kotte[1], B van Asselen[1], J C J de Boer[1],

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Phys. Med. Biol. **54** (2009) N229–N237
doi:10.1088/0031-9155/54/12/N01

NOTE

Integrating a 1.5 T MRI scanner with a 6 MV accelerator: proof of concept

B W Raaymakers[1], J J W Lagendijk[1], J Overweg[2], J G M Kok[1], A J E Raaijmakers[1], E M Kerkhof[1], R W van der Put[1], I Meijsing[1], S P M Crijns[1], F Benedosso[1], M van Vulpen[1], C H W de Graaff[1], J Allen[3] and K J Brown[3]

Upright radiotherapy

- Lung: increased lung volume and reduced motion when upright
- Prostate: early data suggests reduced toxicity to surrounding organs
- H&N: Study from 1982 shows improvement in intra- and inter-fraction motion when comparing seated to supine.
- Breast: could well be more reproducible upright

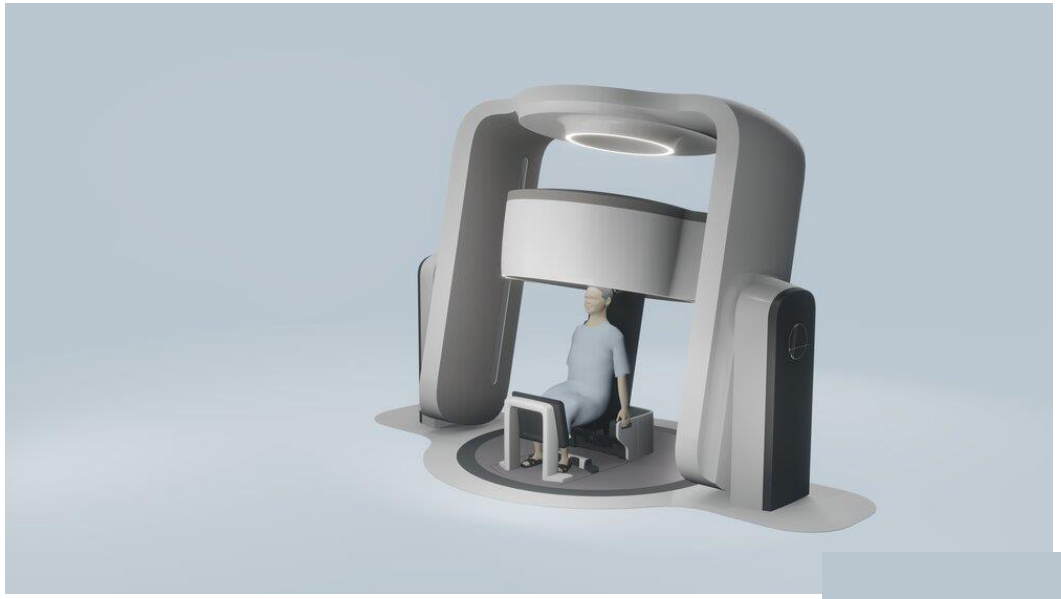
Leo Cancercare

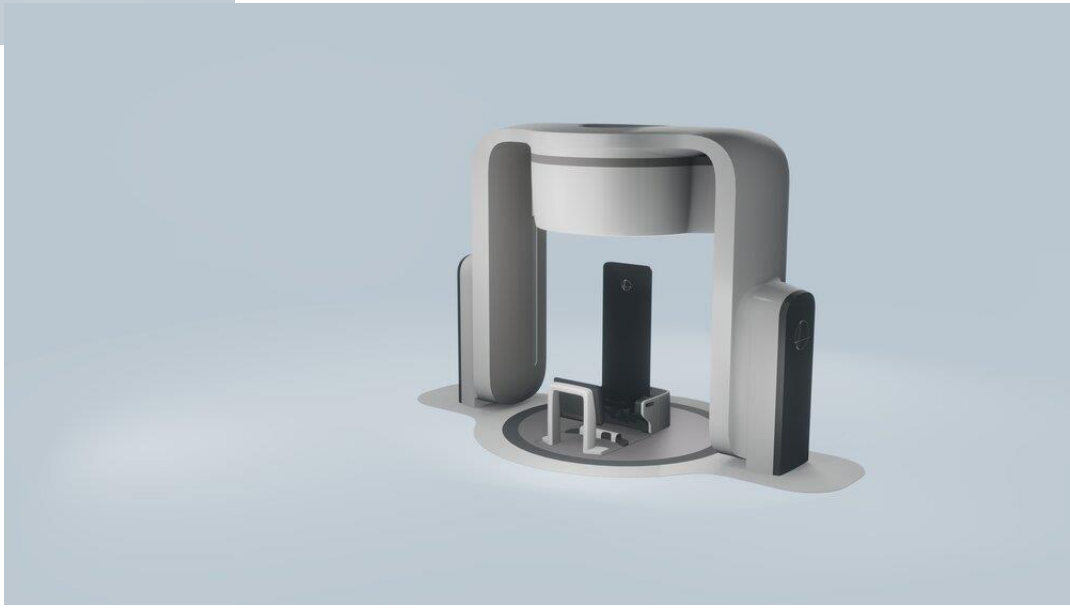

LEO
Cancer Care

- Real time image guided upright radiotherapy
- Delivers rotational IGRT
- Fixed horizontal beam → cheaper
- Potential for reduced shielding, or integrated shielding

- Upright CT?

“We have that”





- They even have plans for upright proton radiotherapy that will fit into a conventional bunker

- We covered:

- Gammaknife
- Cyberknife
- Tomotherapy
- MR Linac
- Upright radiotherapy

- Thank you!