Delivery and verification

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- Historical milestones
- Delivery systems
- LINAC – the workhorse
- Respiration controlled delivery
- Verification approaches
- The use in clinical routine
- Current IGRT approaches
- Clinical Examples
## Historical milestones

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>1895</td>
<td>Discovery of x-rays - called Röntgen-Rays - by W. C. Röntgen</td>
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<td>1896</td>
<td>First treatment of a bathing trunk nevus by Prof Freund, Wien</td>
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<td>1898</td>
<td>First application of x-rays for the treatment of skin tumors</td>
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<td>1914</td>
<td>First full-rotation treatment</td>
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<td>1930</td>
<td>Development of the first linear accelerator by R. Wideröe in Zurich</td>
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<td>1948</td>
<td>First clinical use of a Betatron (Electron cyclotron)</td>
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<td>1949</td>
<td>First clinical use of a linear accelerator</td>
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<td>1952</td>
<td>First use of a cobalt unit</td>
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Delivery approaches

1. X-ray unit
2. Cobalt unit
3. Linear accelerator
4. Intraoperative unit
5. Brachytherapy unit
6. Radioactive implants
X-ray units I: First systems

Siemens Stabilivolt, 1919

Philips RT 250, 1953

Siemens Dermopan, 1967
X-ray units II: Modern systems

Gulmay XStrahl 100 & 300

WoMed T300
Cobalt unit

MDS Nordion Theratron Phoenix (1980)

MDS Nordion Theratron Equinox (2006)

UJP Teragam K01 (2003)
Ring accelerator/Cyclotron

Siemens Betatron (1956)

BBC Asklepitron (1962)
Linear accelerator

Siemens Mevatron, 1974

Varian Clinac, 1978
A modern linear accelerator (LINAC)

Varian Clinac EX
Intraoperative unit I

Zeiss Intrabeam
Intraoperative unit II

Accent Xoft

X-Ray Tube

HV Cable
HDR Afterloading

Sauerwein Gammamed Ir (1989)

Bebig Curiotron Cs (1983)

Bebig Multisource Ir,Co (1991)
A modern HDR afterloading unit

Varian Gammamed Plus
Radioactive implants

Ruthenium-106

Iodine-125 for Prostate LDR
Precision and stability of a LINAC

- 0.7 Sek. min beam activation time
- High dose rate: up to 1000/Min
- Fast & accurate beam steering
- Optimized movement controls
- Ergonomic
- Beam/dose stability
- Integrated system
Visible parts of a LINAC

- **Gantry**
  - accelerating section

- **Modulator stand**
  - Electronics, Klystron

- **Analog indicator for collimator rotation**
  - collimator position 0-360°

- **Accessory tray**
  - Electron appl., blocks and compensator

- **Collimator**
  - variable positioning of jaws and MLC

- **Digital position indications**
  - showing gantry parameters/visual control

- **PVI arm**
  - Remotely retractable arm

- **PortalVision Kassette**
  - Digital cassette for digital port films

- **Manual table control**
  - Direct

- **Patient couch**
  - 4 axes (3 translation, 1 rotation)
Possible movements of a LINAC

- Gantry rotation (360°E) IEC scale
- Table rotation (360°E) IEC scale
- collimator rotation (360°E) IEC scale
- Vertical (Z)
- Lateral (X)
- Longitudinal (Y)
Components of a LINAC
A look into more detail

- Beam/Bending Magnet
- Target
- Standing wave accelerating section
- Electron gun
- Energy switch
- Asymmetric blades
- Multileaf collimator
- Monitors chambers
- Flattening filters and scatter foils
- Carousel
- Real time Beam steering

COPYRIGHT ©2000 VARIAN MEDICAL SYSTEMS
Clinac® 23EX Interior
Components

- **Digital dose rate control**
  - Highly precise: electrons are injected puls controlled, i.e. only when HF wave is stable.

- **Energy switch**
  - Selection between two photon energies.

- **Standing wave accelerating section**
  - Electrons are linearly accelerated on a HF wave.
  - Hollow wave guide, ultra high vacuum. Series of hollow cylinders = cavities.

- **Target**
  - Electrons hit target: production of Bremsstrahlung radiation (photons)

- **Real-time beam steering**
  - Symmetry and intensity are stabilized.

- **Beam/Bending Magnet**
  - Beam bending, energy control.

- **Caroussel**
  - Holds flattening filter and scatter foils

- **Unvented monitor chambers**
  - Energy-, dose- and symmetry control

- **Flattening filter and scatter foils**
  - Broadening of the beam.

- **Asymmetric jaws**
  - Field size definition, EDW
Accelerating section
Clinac 600 (Single energy-CLINAC)

- Accelerating section with gun and target
- HF-Generator
- Magnetron
- Standard head
Standing wave acceleration
Beam monitoring

- Beam stability control
  - Underdose
  - Overdose
  - Energy per pulse

- Beam Flatness and Symmetry control

- MLC Position control.
  Beam off, if leaf deviation 1mm from defined position
Dose and symmetry control I

1.) Energie Detector
2.) Vertikal Abweichung
3.) Transversal Abweichung
4.) Dosis Anzeige am Monitor
5.) Dosis Anzeige am Monitor
Dose and symmetry control II

Im Strahlengang nach hinten gerichtet

Im Strahlengang nach vorne gerichtet

Transversal rechts

Transversal links

Target

A

B

C

D

E

F

G

H
Multileaf collimator (MLC)

- 2 x 40 leaves = 40 x 40 cm field size
- 1 cm leaf width at isocenter
- 1.5cm/sec leaf speed for dynamic treatments
- Add-on completely integrated and verified
MLC vs. block

Dose distribution
Multileaf field

Dose distribution
Cerrobind block

Transmission
Multileaf field

Transmission
Cerrobind block
120-leaf MLC

- 5 mm leaf width around isocenter for 20 cm
- 40x40 field, 120 leaves, 80 @ 5 mm & 40 @ 10 mm
- All leaves are additionally backed up by the primary collimator
- All leaves can be moved over the field center (for IRMT).
Linac with MLC

Collimator blades $X_1, X_2$

Collimator blades $Y_1, Y_2$

MLC

Monitor chamber
**MLC-80 measurements**

- LINAC: 2300 CD
- Photon energy: 6 MV
- Target film distance: 100 cm
- Water depth: 5.0 cm
- Leaf width: 1.0 cm x 1.0 cm
MLC-120 measurements

- LINAC: 2300 EX
- Photon energy: 6 MV
- Target film distance: 100 cm
- Water depth: 5.0 cm
- Leaf width: 0.5 cm x 0.5 cm
Enhanced dynamic wedge (EDW)

- same functionality as conventional hard wedges
- only possible with upper jaws
- integrated and verified
- Similar approach: Siemens Virtual Wedge