“New” Brachytherapy and Radiotherapy Techniques - Radiation Protection Issues -

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Epiretinal Brachytherapy
The Patient’s Problem - Wet AMD

Normal retina

optic nerve (white disc)

Macula lutea (dark area)

Wet Age Related Macular Degeneration

Abnormal blood vessel growth → blood leaking under retina
Current Solution - “Lucentis”
1-3 monthly injections @ £761 per injection

“New” Solution - ionising radiation?
• 9 Gy will prevent cell division in blood vessels
• Retina can tolerate doses at least 25 Gy (in 2Gy fractions)
NOW - Epiretinal beta radiation therapy

- 24 Gy to centre of lesion
- Single fraction delivered in 3-4 minutes
MERLOT Trial
Vidion System, by NeoVista

Sr-90 / Y-90 source - 0.5 MeV / 2.3 MeV betas
370 - 555 MBq (Sr-90 29 y half-life)
2.5 mm length x 0.52mm diameter.
Reusable Delivery Module

Disposable Delivery Module

Bayonet Shutter Pin

Detent Pins

DA Shell

Cannula

Source Positioning Cross Mark

Cannula Tip

VIDION
For 24 Gy centre
\leq 4\text{Gy} \text{ @ 4mm radius}
Radiation Protection Issues (i)

- RSA93/EPR10
  - HDR but not HASS
  - Category 5 registration sufficient
  - Stored at Eye Hospital - theatre manager source custodian

- M(ARS) ARSAC
  - consultant oncologist obtained research ARSAC license.
• **IRMER**
  – Procedures written by Radiation Physics & Theatre Manager and ratified by Ophthalmic Business Meeting
  – Referrer - ophthalmic surgeon
  – Practitioner - ARSAC license holder (oncologist)
  – Operators - ophthalmic surgeon, nurse practitioner, physicists (other theatre staff in future)
  – Adequate training from NeoVista & in-house

• **CDG2009**
  – Reusable type A package
IRR99 - The RPA bits

- **2.3 MeV beta range**
  - 1 cm water
  - 10 m air
  - *(Will be less after attenuation by source capsule and cannula)*

- **Bremsstrahlung**
  - from capsule & cannula
  - from shielding
Beta particle dose

Very low $\beta$ risk from normal use

- Vitreous humour acts as beta shield
- Source deployed – max. finger dose
  - @ 4cm in air 1,400. mSv/h (0.4 mGy/s)
  - @ 4cm source in eye 0.7 mSv/h

(4cm is closest point of operator’s finger from deployed source)
Ready to deploy

ACRYLIC ROD ∅ 15 mm

DETECTOR (TLD)

microsieverts per hour

Courtesy of Rainer Pintaske & NeoVista
Not deployed

\[ \leq 6 \, \mu\text{Sv/h} \, @ \, 30 \, \text{cm} \]
\[ \leq 0.8 \, \mu\text{Sv/h} \, @ \, 100 \, \text{cm} \]

Fully deployed in eye

\[ \leq 24 \, \mu\text{Sv/h} \, @ \, 30 \, \text{cm} \]
\[ \leq 2.5 \, \mu\text{Sv/h} \, @ \, 100 \, \text{cm} \]
Typical Finger dose Scenario

1. Source ready to deploy
   - 792 μSv/h x holding 1 minute
   - 13 μSv
2. Transit dose from deploying
   - 100 μSv
3. Treatment dose
   - 670 μSv/h x 3.5 min
   - 39 μSv
4. Transit dose from deploying
   - 100 μSv
5. Cannula removed and end
   - 792 μSv/h x holding 1 min.
   - 13 μSv

Total finger dose
- 265μSv / patient
- 150mSv ≈ 566 patients
Effective dose

Physicist
- 0.038 mSv fingertips
- 0.006 mSv to body

Assistant (occupational)
- 0.020 mSv to fingertips
- 0.003 mSv to body

Circulator (occupational)
- 0.015 mSv to extremities
- 0.003 mSv to body

Surgeon (occupational)
- 0.260 mSv to fingertips
- 0.003 mSv to body

Patient (effective)
- 0.007 mSv to body

Physicist
- 0.038 mSv fingertips
- 0.006 mSv to body
Effective dose

- Highest predicted dose - Medical Physicist
- 6 μSv per patient
- If 566 patients/y → 3.4 mSv/y

i.e. surgeon finger dose is critical value

Our measurements, 4 patients

- Surgeon’s finger = 0.15 mSv
  - (Predicted 1.04 mSv)
- Physicist body = 0.01 mSv
  - (Predicted 0.024 mSv)
“Controlled area” - IRR99 Reg 16(1)

a) special procedures necessary to prevent significant exposure

b) likely to receive $E > 6$ mSv in a year ($H_{\text{eye}} > 45$ mSv/y, $H_{\text{skin}} > 150$ mSv/y)

Risk assessment shows b) not likely unless >566 patients per year

(20 in trial)
ACOP para 248 & 249 elaborated on a)

- \( > 7.5 \, \mu\text{Sv/h} \) averaged over working day = 10 patients in a day on physicist’s dose
- \( H_{\text{hands}} > 75 \, \mu\text{Sv/h} \) averaged over working day = 2 patients in a day on surgeon’s hand dose
- Significant risk of contamination spread = none
- Liable to \( E > 6 \, \text{mSv/y} \) = 567 patient/y
- Dose rate \( > 7.5 \, \mu\text{Sv/h} \) over 1 minute and site radiography = no
- Dose rate \( > 7.5 \, \mu\text{Sv/h} \) over 1 minute and untrained staff = ?
• dose rate $>7.5 \, \mu\text{Sv/h}$ over 1 minute and untrained staff
  – Undeployed = $6 \, \mu\text{Sv/h} @30\text{cm}$
  – Deployed in eye = $24 \, \mu\text{Sv/h} @30\text{cm}$, $2.5 \, \mu\text{Sv/h} @1\text{m}$

• exclusion or supervision of untrained staff necessary
  – Physicist, surgeon, nurse practitioner trained in procedure
  – Some other theatre staff (*not anaesthetist yet!*)

➢ Controlled area (+ local rules + RPS) ?
➢ Maybe ... maybe not
Accuray Cyberknife

- 6 MVx unflattened beam
- 5 to 60 mm diameter field at 80cm from focus
- No fixed isocentre
- 50-200 fields per treatment
• Conventional linac - +/-180° rotation around isocentre - “donut” primary shielding OK

• CyberKnife linac - 2.5π sr beam - primary shielding in (nearly) all directions required
Hull & East Yorks. CL1 & CL2

- Add 28 cm
- Add 53 cm
- Add 23 cm
- Add 103 cm?
- Add 13 cm concrete (or 3.7 cm steel)

(Note: CyberKnife can only fire up at maximum of 22° to the horizontal)
• All barriers primary shielding, except
  – Ceiling - max. $22^0$ to the horizontal
  – can be programmed to limit beam directions
  – Many small fields $\rightarrow$ small USE FACTOR of 0.05 recommended
Use Factor = fraction of a primary-beam workload directed toward a given primary barrier.

- **Linac - IPEM 75**
  - floor $U=1$, walls & ceiling $U=0.25$
  - floor 0.42-0.58, ceiling 0.12, 0.2-0.23 walls

- **NCRP 151**
  - Cyberknife, $U = 0.05$
  - Determined by analysis by James Rodgers of 324 treatment sessions at Georgetown University Hospital
Secondary Shielding

- leakage predominates
- “IMRT”, so each beam on for a longer time  
  – “modulation factor” should be used
IMRT Factor

\[ C_I = (\text{MU for 1 Gy prescribed dose by IMRT}) \]

\[ C_I = (\text{MU for 1 Gy at 10 cm depth at isocentre}) \]

Modulation Factor, \( C_K \)

\[ C_K = \text{average MU per cGy delivered over all SAD's and tumour depths} \]

- High value, more beam on time per treatment
- No effect on primary or patient scatter barrier calculation
- Effects leakage shielding
- Linac IMRT, \( C_I \approx 2 \text{ to } 10+ \)
- Cyberknife, \( C_K = 15 \) recommended
Helical Tomotherapy

• vs traditional linac treatment
  – Unfiltered 6 MV X-ray beam
  – Slit beam (max 5 cm x 40 cm at 85cm isocentre)
  – 13 cm lead beam stop (Hi-Art II)
  – Long beam on time → more leakage
Intraoperative Radiotherapy (IORT)

One-shot radiotherapy 'success against breast cancer'

A single dose of radiation during surgery is just as effective as a prolonged course of radiotherapy for breast cancer, a study suggests.

Doctors have tested the technique, which involves a single shot of radiotherapy to a tumour site, in more than 2,000 patients.

It could save the UK £15m a year, the researchers said.

Cancer Research UK said The Lancet study could have a "huge impact."
Zeiss Intrabeam

- 50kV, 0.05mA, Au target
Intrabeam Radiation Protection

Parry, Sutton, Mackay et al (Dundee)

• No shielding - 10 mSv/h @ 1m
• Procedures take between 15 and 40 minutes.
• 2mm lead screens - 40 μSv/h @ 1m
  – Sufficient for operator & anaesthetist
• “local shielding at the treatment site is essential in order to reduce the dose rate in adjacent areas to acceptable levels.”
Intraoperative Electron radiation therapy

- IntraOp Mobetron
- Mobile electron beam linac
- Up to 12 MeV e⁻'s (6-7 cm range)
- IntraOp - "No room shielding is required"
- Jodi Davies et al 2001 - Depends on workload - scatter & leakage up to 18 μGy/1000Mu @ 2 m (more towards floor)
KV stereotactic radiosurgery

- iRay system (Oraya Therapeutics Inc)

- 100kV, 150mm focus-retina, 3 beams,
- 16-24 Gy, 4mm diameter target (90%),

Eric Chell et al, 2009
Some References & Useful Documents

• CyberKnife
  – Accuray Site Planning documents - www.accuray.com/Services/Site_Planning.aspx
  – CyberKnife Shielding Design, Jim Rodger, AAPM Summer School 2007
    www.aapm.org/meetings/07ss/documents/RodgersCyberKnifeShieldingpostmeeting.pdf

• Tomotherapy

• Intraoperative Radiotherapy (IORT)

• Kilovoltage stereotactic radiosurgery
  – see www.orayainc.com/articles.asp for this and papers