Radiation exposure to patient & therapist – damage limitation

Phil White

phil.white@ncl.ac.uk

STATEMENT OF INTERESTS:

Consultancy work with Microvention for education & Stryker Global Advisory Board

Chief Investigator randomised controlled PISTE, STABILISE, TOPSAT 2 trials

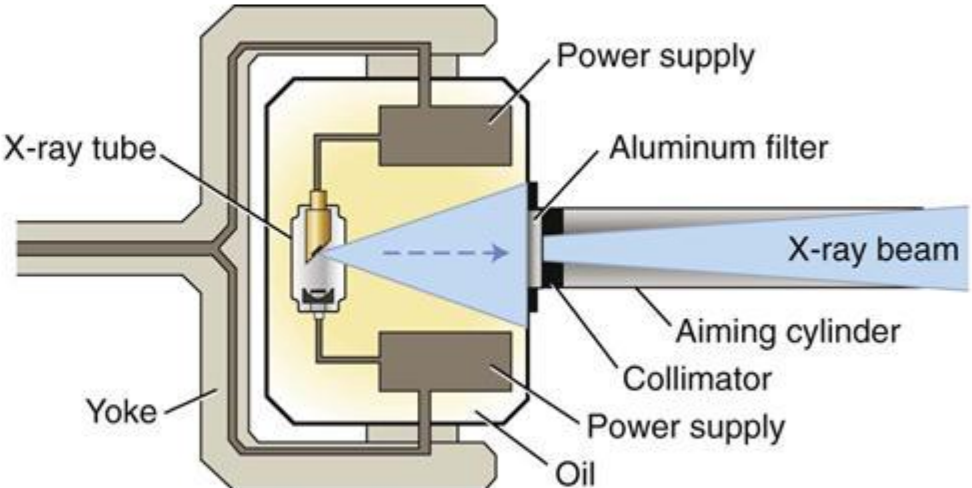
Research funding from: Codman, Covidien, Microvention, Stryker, IBEX Innovations

Key learning points

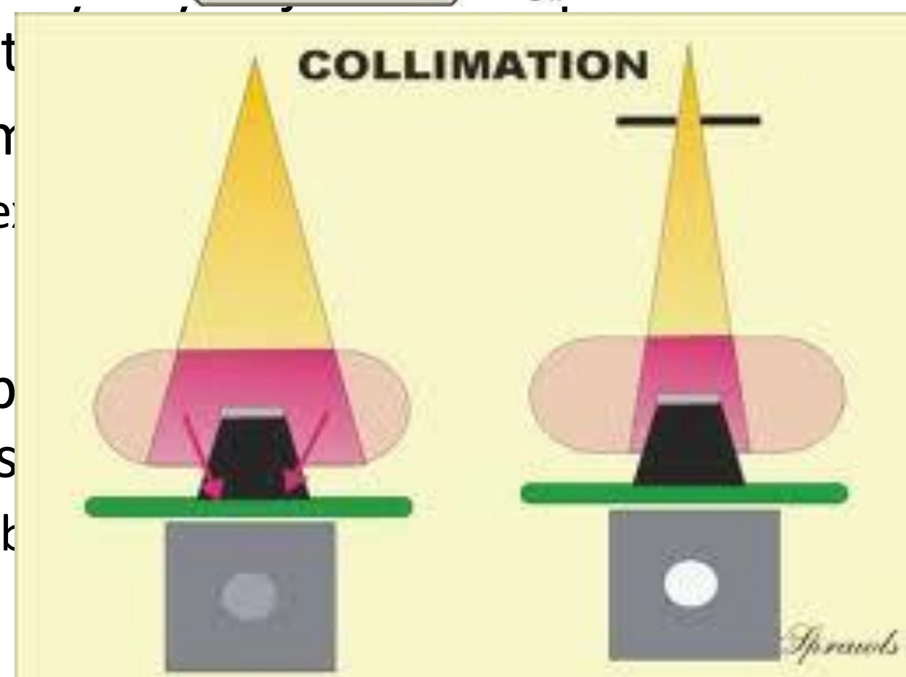
1. ALARA principle
2. Stochastic & Non-stochastic radiation effects
3. Inverse square law
4. Important dose saving techniques/equipment
   - Specific to
     - Neuroangio suites
     - INR practice/patients/staff

Important terminology

- **Direct exposure**
  - The X-Ray dose from the tu
    patient to obtain a medical
    - Primary beam



- **Scatter radiation**
  - Results from X-Rays scatter
    beam → unnecessary irradiat
  - Most is generated where prim
    - Main source of staff radiation e
- **Collimation**
  - Use of adjustable "metal diap
    to only expose area of interes
    - Image sharpened by focussing b



Dose terminology

- **Dose & image quality are inextricably linked**
- **Detector dose** - Kinetic energy released in matter (KERMA) after patient directly in front of image receptor – measured in μGy
- **Entrance dose** – air Kerma in front of patient excluding back-scatter; measured directly in μGy
  - DAP is derived from it: ED multiplied by collimated area
    - e.g. if ED = 1mGy & collimation of 42cm FPD at 20 x 20cm, DAP = 400
    - For same ED if don't collimate DAP = 1764!
- **Doserate** – approximates to skin dose. Includes scatter dose as well as direct exposure. **Estimated** value
- **Effective dose** – patient risk measure. Takes into account absorbed dose, tissue type & radiation type
  - Recorded in [milli]Sieverts

ALARA Principle

- As Low as Reasonably Achievable
- Principle of practice with ICRP & EU legislative basis
  - Justification/optimisation/local rules
- Comprehensive safety principle & regulatory requirement
- Minimising patient doses = minimises your dose
  - Trade off dose vs image quality *(MOSTLY)*
- Factors used in ALARA
  - Collimation of field
  - Magnification– smallest mag (largest flat panel size) providing adequate detail *[younger eyes]*
  - Pulse & frame rate
  - Kv versus mA
  - Screening time
  - Number of runs & whether all biplane
  - Use of software tools to reduce dose- 3D roadmap, automotion correct etc.
- Skin dose – switch between planes & use of >1 WP

ALARA

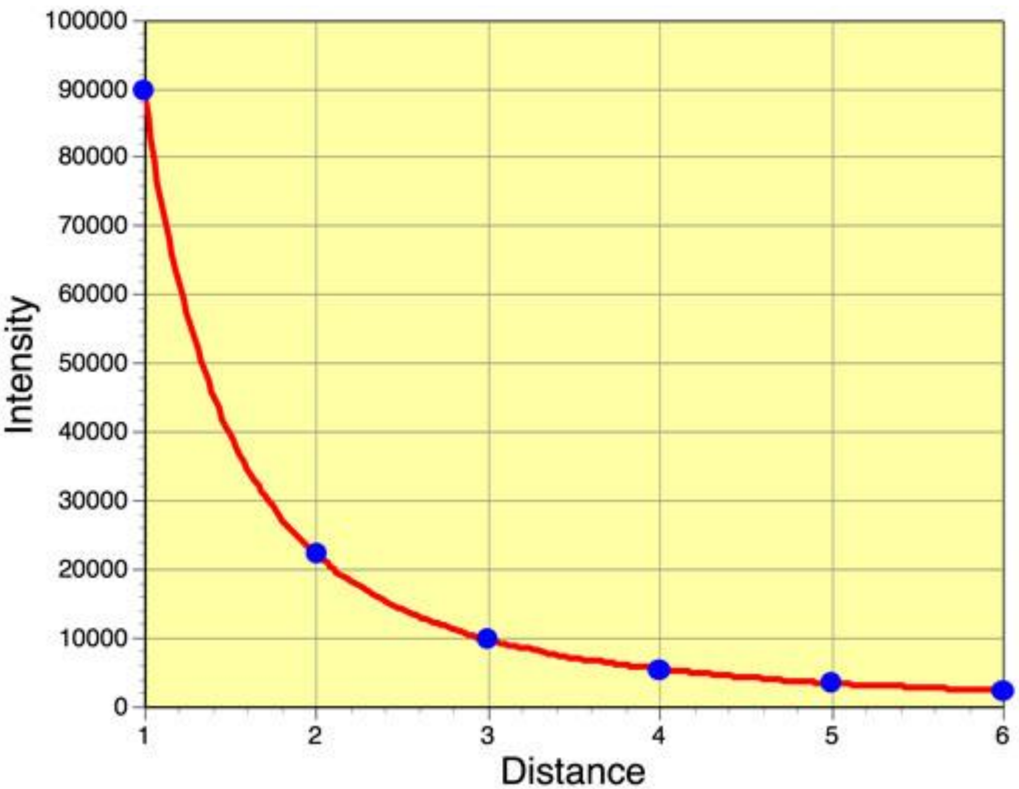
- Use of all reasonable methods to minimise radiation doses
- In medical imaging implemented via practice operating round:
- **Justification**
  - There must be a clear rationale for exposing the patient to ionising radiation in every X-Ray based imaging examination. Auth
- **Optimisation**
  - Every effort must be made to ensure that the exposure t results in diagnostically useful information (at minimum
- **Local rules**
  - Must exist, all relevant staff must be familiar with them
    - Signage/warning lights; room & equipment shielding; controlled access doors
    - Radiation dose monitoring patients & staff; personal protection equipment etc.
    - *Not time to go into all these aspects in this 30 min talk*

Optimisation

- Correct patient & examination!
- Careful choice of exposure parameters
  - Think about collimation, FOV, pulse & fluorography rates, KV, filtration, single vs biplane vs shifting WP
  - X-Ray tube at maximum achievable distance from patient with flat panel as close as possible to patient
  - Choose FOV for stage of procedure & anatomy/location/type of pathology
- Don’t expose/irradiate unnecessarily *(take your foot off the pedal if not looking at screen!)*
- Make full use of dose reduction capabilities of equipment
  - Digital zoom can be a great aid
- Don’t ignore alarms/warning systems

Inverse square law

- Intensity α 1/distance^2
  - Radiation exposure decreases with squar
    distance from 1m to 2m = ¼ of exposure
  - More realistically, shuffle back before DSA



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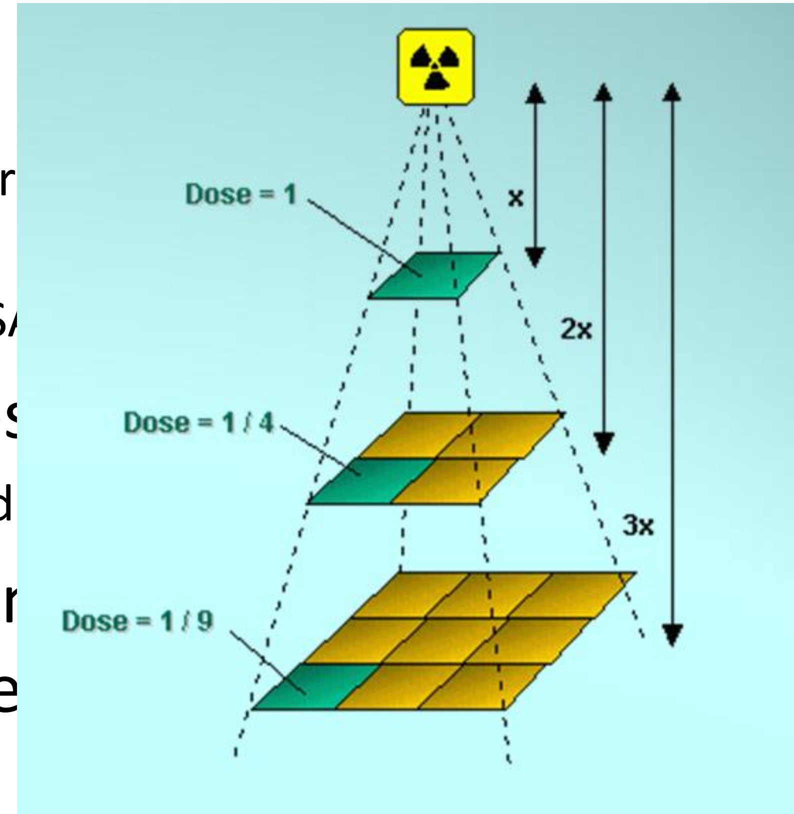
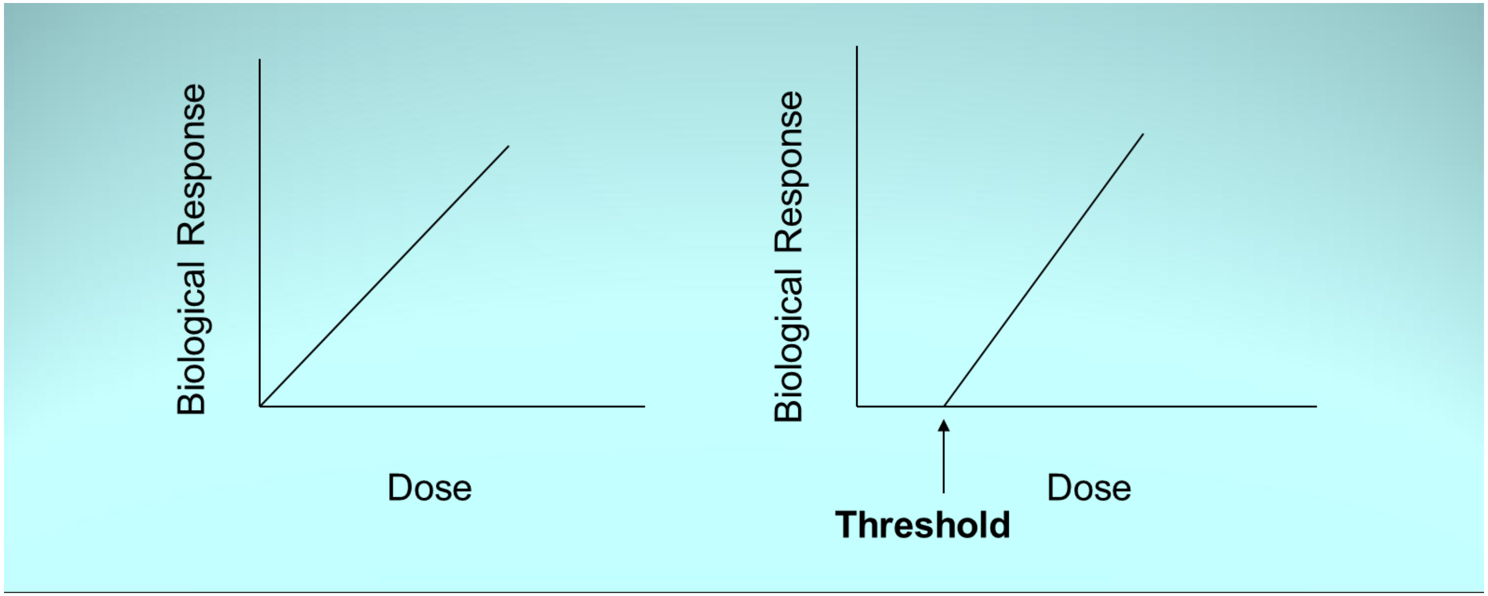


ube in choice of WP

minimise frontal tube scatter

X-Ray risks in perspective

- **Linear hypothesis**
  - Every radiation dose of any magnitude can produce some level of detrimental effect with cumulative effects as mutations or cancer
  - Effect is increased in proportion to dose
  - *No-threshold* – used in regulatory assumptions



Impact of radiation on INR patients

- Deterministic (non-Stochastic) effects – can occur >1Gy
  - Hair loss (rare on modern kit with attention to dose reduction facilities)
  - Skin erythema →→ necrosis
  - GI symptoms for spinal angiography/intervention
  - **Cognitive impairment**
    - Reported that 0.5 Gy can produce cerebrovascular damage with potential for CI [ICRP]
    - Doses in INR certainly often exceed that – see Sanchez RM et al AJNR 2014
- Stochastic effects – less important in most of the adult population with serious conditions meriting INR - but NB in incidental lesions in <60y!
  - *Genetic mutations*. Cancer – risk = 5% per Sv. Long lead time 15-20y+
  - Cumulative – so risk from angio/coil/control & recoil with EDE of 30 mSv+ = ~1:600 but with medium risk tissue allowance more likely ~1:1000

X-Ray risks in perspective

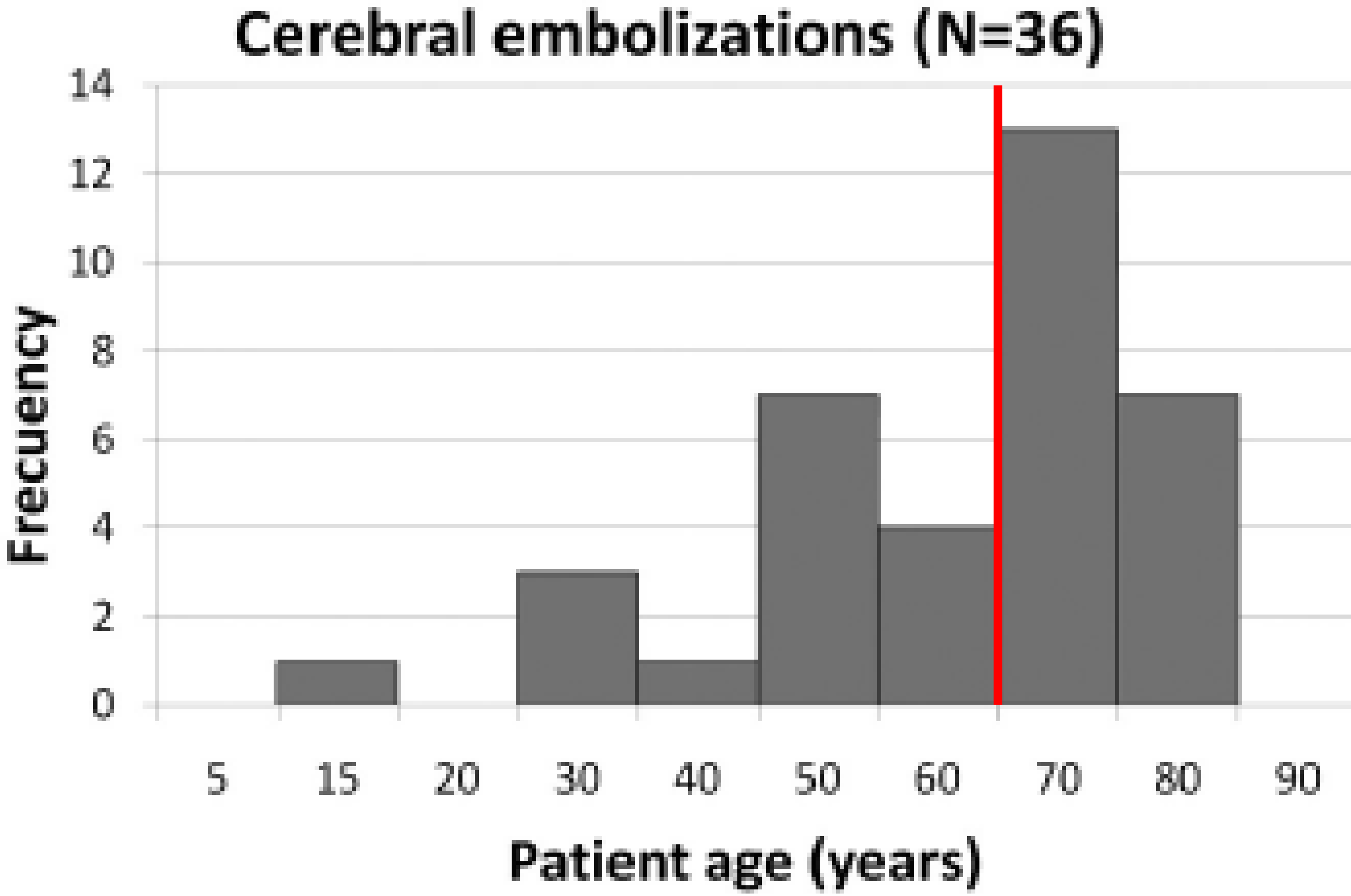
- Dose is low[ish] for most one-off examinations
  - e.g. CT Head ~2 mSv ≈1y background exposure in UK
- However repeat/cumulative doses can be substantial
- By 2005 medical imaging → 50% population radiation exposure in USA
  - CT alone will account for 2% of all US cancers from 2025
  - Medical exposures continue to rise
    - Germany dose is 500% that in UK & 140% that in France
- Pregnancy & females of childbearing potential:
  - Additional care/precautions
  - Additional clinical justification for exposure

Do patient doses really matter?

- YES

>50 nanogrammes of Polonium 210
(assassination not accident)

AJNR Sanchez RM et al 2014



AJNR Constantinou paper 2014

- Doses up to 1.7 Gy delivered!
- In 34% of all procedures & in 60% of embolisations 0.5 Gy dose level was exceeded
- Author conclusions:
  - Dose delivered in INR may produce radiation side effects
  - Dose must be minimised & exposure optimised
  - Dose must be monitored using DAP & AK and included in the clinical report
  - In complex interventions individual dose calculation to brain/lens/skin may be needed esp in higher risk groups
  - QA programme for patient doses

Impact of radiation on INR staff

- Here the main issue is cumulative dose
  - Main deterministic issue is eye lens dose (cataract risk)
  - Stochastic cancer risk is important over whole career
- Important message is don't ignore radiation protection procedures & use facilities for dose minimisation on modern equipment
  - Collimation
  - Shielding – angio mounted & personal
  - Attention to ALARA

Do staff doses really matter?

- **Staff**
  - 72% IR had maximum annual eye doses higher than 5 mSv; 50% >15 mSv [Carinou E *et al* 2014 *J. Radiol. Prot.* **34** 729]
  - If doses exceed 3/10 of limits = become **classified**
  - EU lens dose limit ↓from 150 mSv/y to **20 mSv/y** from Feb 2018!
  - @ 6mSv/y this could impact most IRs & cardiologists!
    - End up as Cat A (classified) not B worker = strict dose limits
    - Offence to exceed dose limits
    - Much stricter monitoring/records & ultimately investigation & even restriction on work- NHS + private exposures shared
      - » *http://www.hse.gov.uk/radiation/ionising/faqs.htm*

Patient & staff doses

- All manufacturers address these issues but the 2 European OEMs stand out – Philips & Siemens
- Siemens: CARE/CLEAR systems
- Philips: CLARITY plus other software facilities

Equipment features for dose minimisation

- Take some time to familiarise yourself with them

"What fits your busy schedule better, exercising one hour a day or being dead 24 hours a day?"

Siemens: CARE+CLEAR tools

- Combined Applications to Reduce Exposure (CARE)
  - CAREposition: Last Image Hold- outline of the upcoming image is displayed on monitor, allowing you to move the table or C-arm without radiation
  - CAREvision: frame rate adjustment 0.5-30 pps
  - CAREfilter: during acquisition or fluoroscopy variable filtration is set automatically according to patient thickness & angulation of the C-arm. Can achieve up to 50% entrance dose reduction with minimal impact on contrast
  - CAREprofile: Using LIH as a reference enables radiation-free collimator adjustment and semitransparent filter position setting

http://www.healthcare.siemens.co.uk/angio/innovations-technologies/care-clear/dose-reduction

CLEAR

- CLEAR – automatically enhances image quality
  - CLEARpulse: ↓pulse length to optimise X-Ray spectrum (improve sharpness)
  - CLEARcontrol: correctly exposes the entire image = better vasc. visibility
  - CLEARmap: enhanced image quality in Roadmap
  - CLEARview: removes noise in low-dose images with multilevel decomposition & reconstructs sharper image
  - CLEARvessel: works automatically in real time to enhance the visibility of vessel edges
  - CLEARmotion: automatically detects fine structures and compensates for motion artefacts
  - CLEARmatch: keeps the live image while pixel-shifting the mask image in real-time to provide consistent image quality during Roadmap
  - CLEARchoice: customise image quality to your individual preferences independent of dose

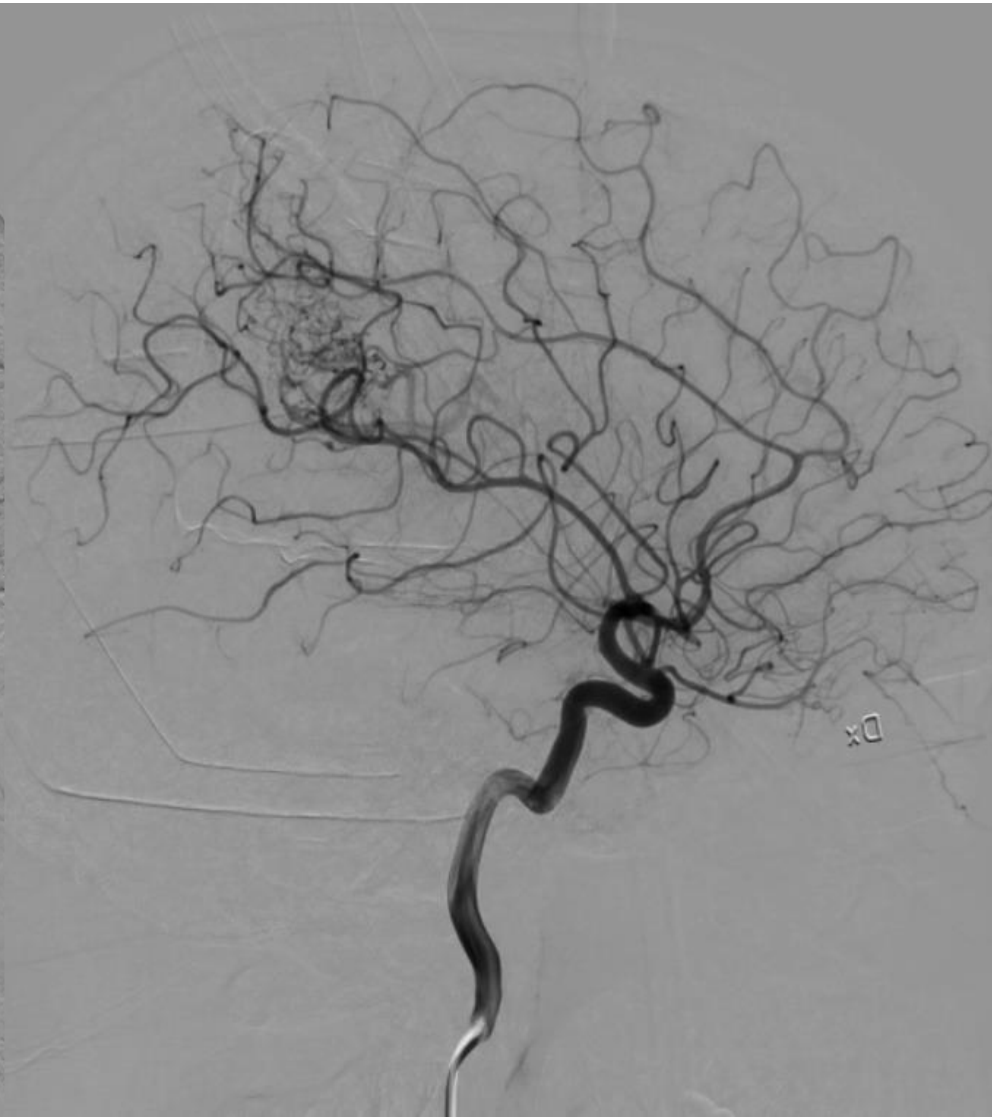
http://www.healthcare.siemens.co.uk/angio/innovations-technologies/care-clear/dose-reduction

ClarityIQ Dose Reduction

- Mostly post processing of digital imaging chain
  - Flat panel detector essential
  - Tweaked >500 parameters
- Greater Cu beam filtration
  - Filter out soft X-rays (contribute to dose not image quality) – reduce dose
- Shorter pulses
  - Reduce motion blurring – making temporal integration of fluoroscopy / fluorography more efficient & reduce noise
- Grid switch
  - Low dose steep pulses
- Smaller focal spot
  - Increase sharpness & reduce noise

Standard ALLURA Xper

ALLURA CLARITY



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Independent CLARITY data!

Presented on behalf of:

Dr Leesien Yap
Mrs N Hind
Dr Eva Dougeni

Medical Physics dosimetry

- Frontal plane before / after CLARITY upgrade
- **DSA –** substantial dose reduction (~**80%**)

Entrance Surface Doserate for 185mm Perspex Phantom with a focus to skin distance of 73.5 *(cm)*

Mode 1: Head Cereb 2fps grid in

field (cm)	kV	mA(s)	filter	dose / image (mGy)
48	80	23		1.78
31				
22	80	68		3.8
19				
15	80	100		5.1

Mode 1: Head Cerebral 2fps

field (cm)	kV	mA(s)	filter	dose / image (mGy)
48	75	7		0.43
31	75	9		0.58
22	75	14		0.77
19				
15	75	20		1.02

Summary of patient dose audit

- Reflects published experience
  - 60% dose reduction with Clarity in Karolinska 614 patient study
- Newcastle prospective study – **53.1% ↓ in 277 patient study**
  - Cerebral neuroangiography: ~68% reduction in DAP
  - Aneurysm EVT: 56% reduction in DAP
  - AVM/AVF: 29% reduction in DAP but only 3% of cases (9)
  - Tumour embo (9 vs 8): 69% reduction in DAP
  - Spinal angio (4 vs 6) : 68% reduction
- **Dose reduction excluding AVM/AVF: 56-69%**

Conclusions: radiation reduction

- Apply ALARA principle
- Remember & apply the Inverse Square Law
- Work on **optimisation** of your X-Ray exposures
  - Be aware of & utilise radiation minimisation equipment/techniques in your clinical practice
- Minimising patient dose minimises yours!
- Consider radiation issues in equipment purchasing

Any questions?

Thank you

NB 15th Brainstorm Interactive Course

Edinburgh, 1-3 June 2020

phil.white@ncl.ac.uk