HOW TO ESTABLISH AN ADEQUATE SYSTEM FOR EYE LENS DOSE MONITORING: A PROPOSAL FOR TYPICAL WORKPLACES

Robert Kollaard, chairman NCS subcommittee

EURADOS Winterschool Florence, 30-1-2020

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2. Legal requirements for eye lens monitoring
3. Proposal for adequate system for eye lens monitoring
4. Adequate monitoring for typical worker groups
5. Discussion
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1. INTRODUCTION – EYE LENS

- Last decade:
  New insights on the sensitivity of the eye lens
- Estimated dose threshold: 0.5 Gy
- Eye lens dose limit: 150 mSv ⇨ 20 mSv/year
- European BSS: 2013 ⇨ national legislation: 2018
- Old 150 mSv dose limit:
  Little attention for radiation protection and dosimetry of the eye lens
- New 20 mSv dose limit:
  Eye lens dose may be limiting the exposure for some worker groups!

Patient with cataract

1. INTRODUCTION – THE NCS

- Netherlands Commission on Radiation Dosimetry (https://radiationdosimetry.org/)
- Dutch/Belgian network providing recommendations for radiation protection and dosimetry, mostly in the medical sector

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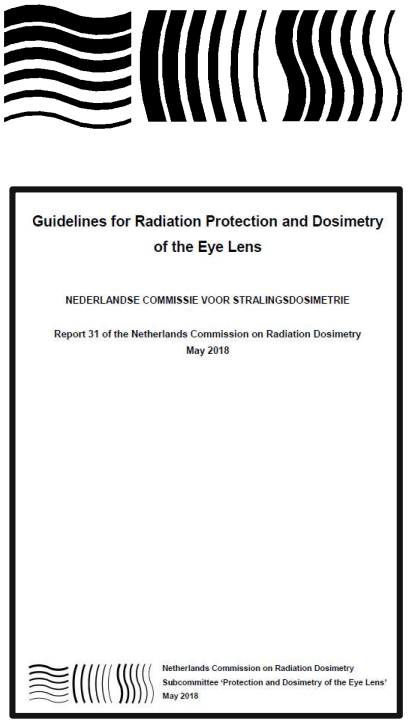
- Netherlands Commission on Radiation Dosimetry (https://radiationdosimetry.org/)
- Dutch/Belgian network providing recommendations for radiation protection and dosimetry, mostly in the medical sector
- Published a report in 2018 on radiation protection and dosimetry of the eye lens
- This NCS report considers typical workplaces



2. LEGAL REQUIREMENTS FOR EYE LENS MONITORING

EU BSS art. 41: When category A workers are liable to receive a significant exposure of the lens of the eye, an adequate system for monitoring shall be set up to ensure that the dose remains under the dose limit.

TERMINOLOGY ⇨ NEEDS INTERPRETATION!

2. INTERPRETATION OF THE LEGAL FRAMEWORK

EU BSS art. 41: When category A workers are liable to receive a significant exposure of the lens of the eye, an adequate system for monitoring shall be set up to ensure that the dose remains under the dose limit.

Liable:

Refers to prior risk assessment (calculate expected worker dose)

Include regular and potential exposures

2. INTERPRETATION OF THE LEGAL FRAMEWORK

EU BSS art. 41: When category A workers are liable to receive a significant exposure of the lens of the eye, an adequate system for monitoring shall be set up to ensure that the dose remains under the dose limit.

Significant exposure:

Eye lens dose of ≥ 15 mSv (minimal interpretation)

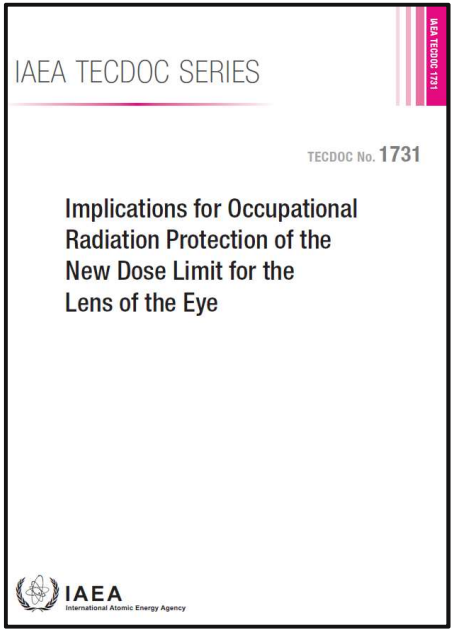
15 mSv = dose limit for public exposure (BSS art. 12)

2. INTERPRETATION OF THE LEGAL FRAMEWORK

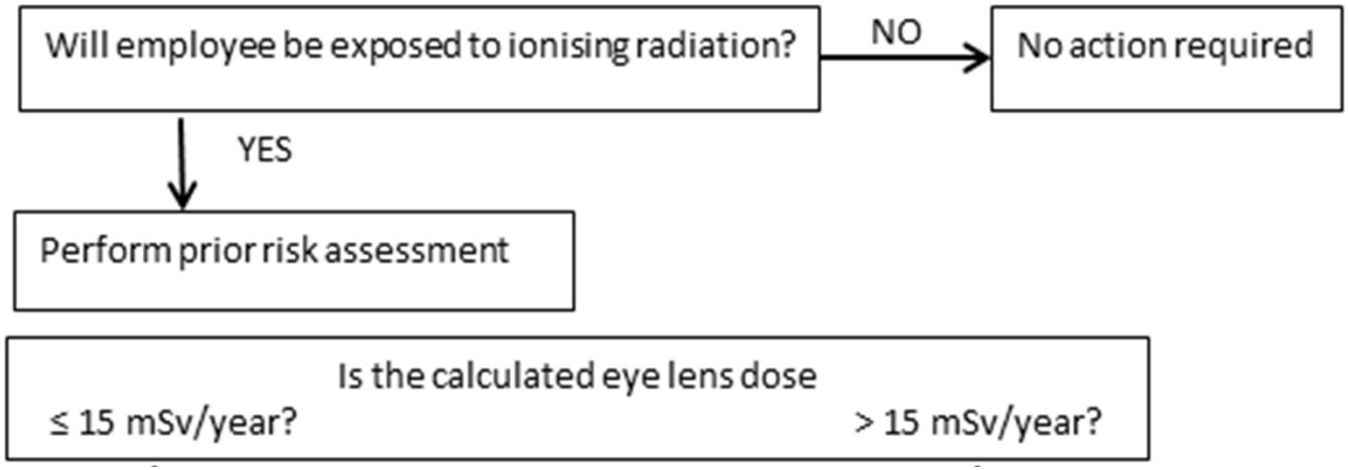
EU BSS art. 41: When category A workers are liable to receive a significant exposure of the lens of the eye, an adequate system for monitoring shall be set up to ensure that the dose remains under the dose limit.

Adequate system for monitoring:

- depends on exposure situation
- NCS: use IAEA TECDOC 1731 as guidance



2. LEGAL FRAMEWORK – SUMMARY FROM WORKER PERSPECTIVE



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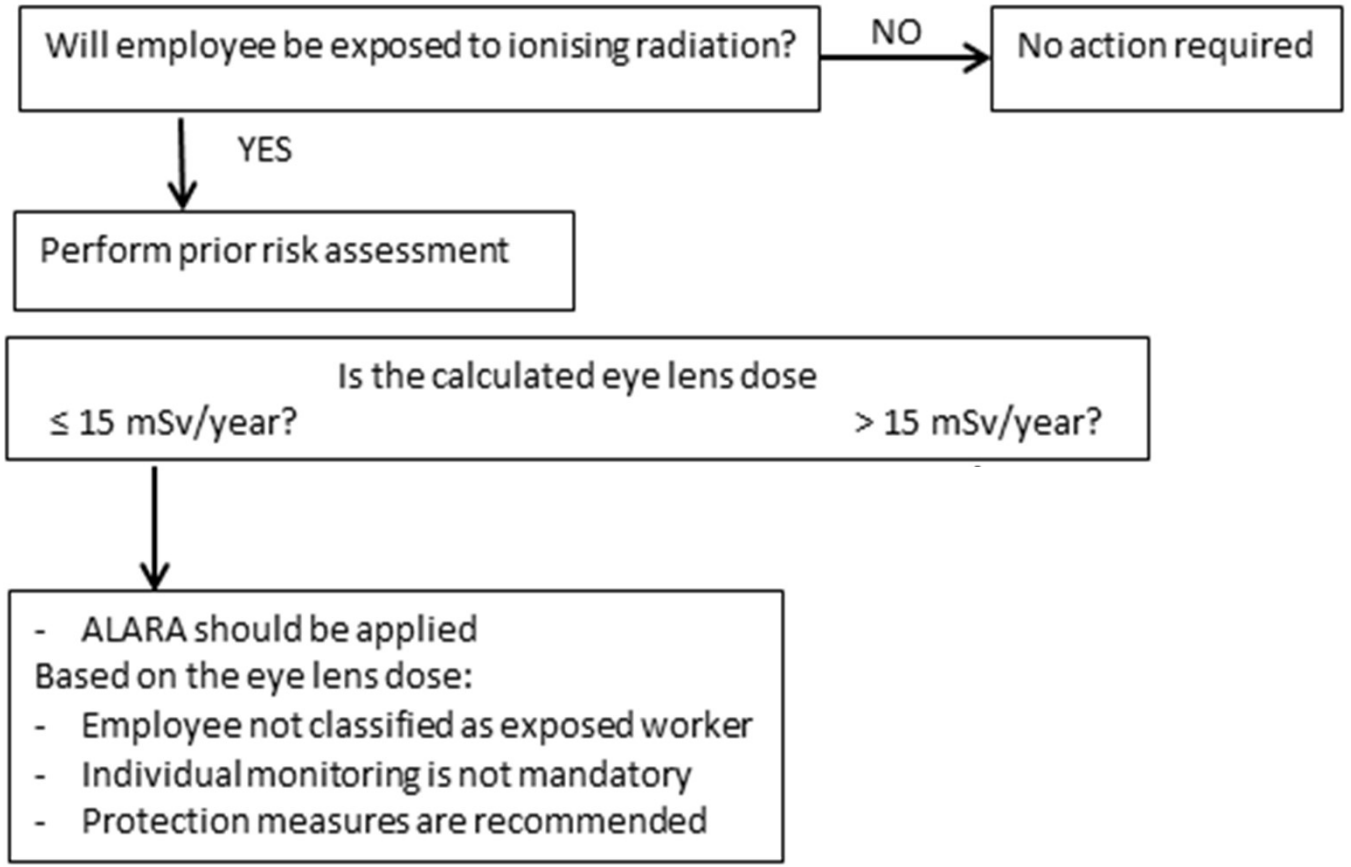

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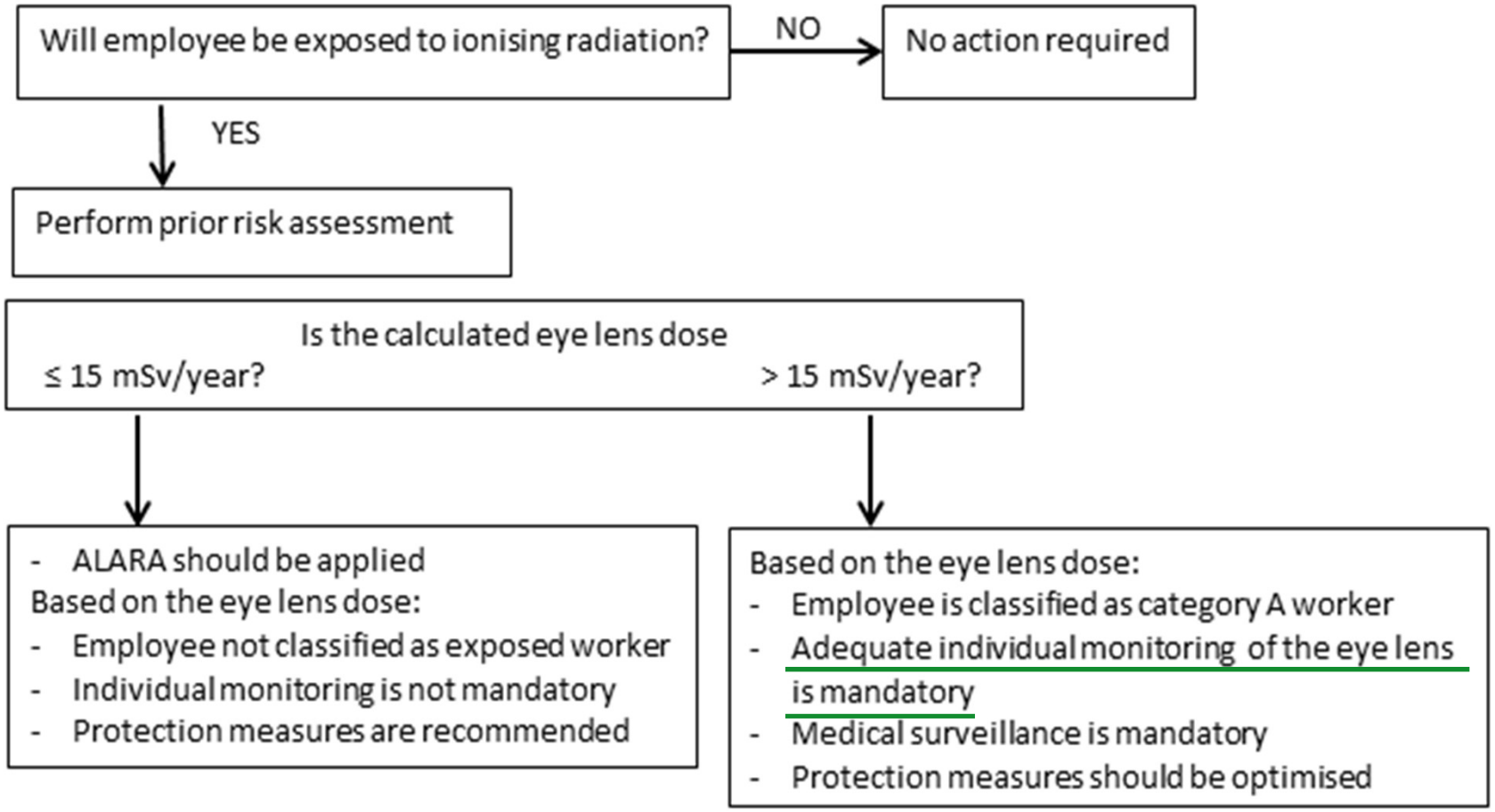


3. PROPOSAL FOR ADEQUATE SYSTEM FOR MONITORING

- NCS decided to adopt the methodology in IAEA TECDOC 1731
- This publication provides flowcharts with recommendations on:
  - Wearing position
  - Dose quantity
- Based on:
  - Particle type
  - Energy and angle
  - Geometry [homogeneity of field]
  - Protective equipment

Impact factor	Comment		
A (Energy and angle)	Is the mean photon energy below about 40 keV?		
	If yes ↓ $H_p(0.07)$ may be used but not $H_p(10)$ (see Fig. 6 in Ref. [65] and Fig. 1 in Ref. [66])	If no ↓ Is the radiation coming mainly from the front or is the person moving in the radiation field?	
		If yes ↓ $H_p(0.07)$ or $H_p(10)$ may be used (see Fig. 1 in Ref. [66])	If no ↓ $H_p(0.07)$ may be used but not $H_p(10)$ (see Fig. 1 in Ref. [66])
B (Geometry)	Are homogeneous radiation fields present?		
	If yes ↓ Monitoring on the trunk may be used.	If no ↓ Monitoring near the eyes is necessary.	
C (Protective equipment)	Is protective equipment such as lead glasses, ceiling, table shields, and lateral suspended shields in use?		
	If used for the eye ↓ Monitoring near the eyes and below the protective equipment or below an equivalent layer of material is necessary. Otherwise, appropriate correction factors to take the shielding into account should be applied.	If used for the trunk (e.g. a lead apron) ↓ Monitoring below the shielding underestimates the dose to the lens of the eye as the eye is not covered by the trunk shielding. ↓ Separate monitoring near the eyes is necessary.	

3. ADEQUATE OPERATIONAL DOSE QUANTITIES

Photons:

- Mean energy > 40 keV → Hp(10) provides suitable estimate of Hp(3) when photons enter mainly from the front
- Hp(0.07) provides overestimate of Hp(3), especially at lower energies

Betas:

- Beta energy < 0.7 MeV: monitoring not needed
- Beta energy ≥ 0.7 MeV: only Hp(3) is adequate

Mixed photon/beta fields:

- When beta energy ≥ 0.7 MeV: only Hp(3) is adequate

Neutrons:

- Add Hp(10) neutron dose to Hp(3) photon/beta dose

3. ADEQUATE WEARING POSITION

Homogeneous fields:

- Monitoring on the trunk is adequate
- Situation may occur for photon and neutron fields

Inhomogeneous fields:

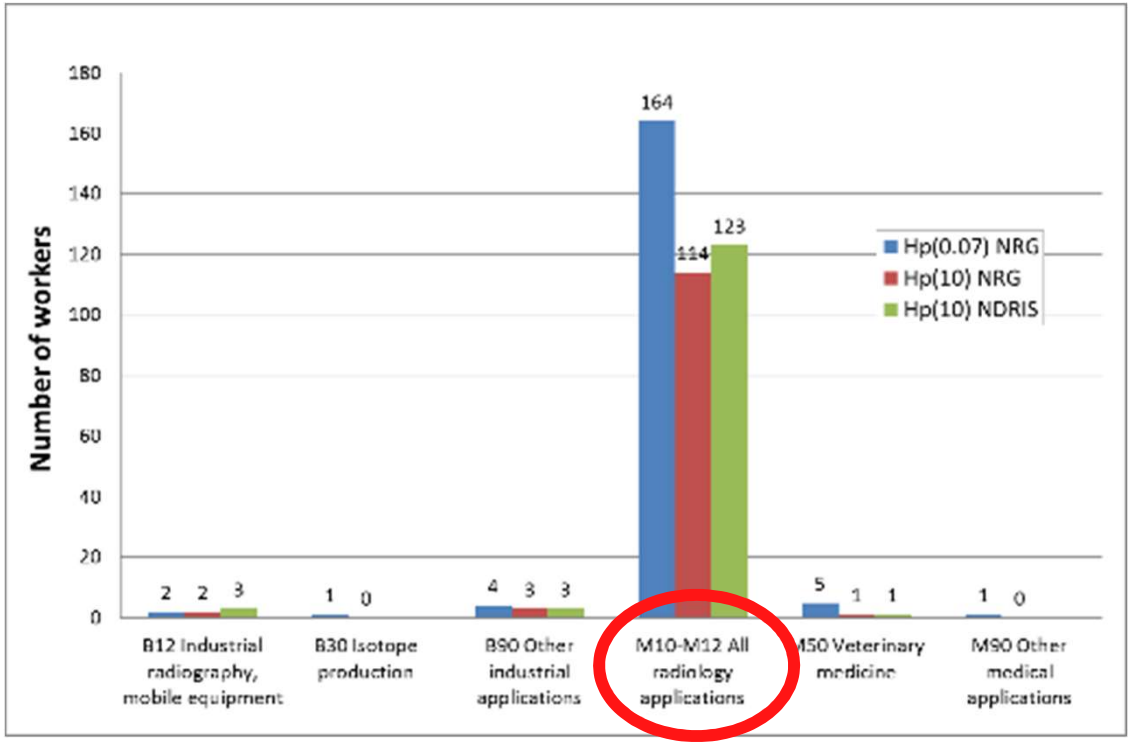
- Monitoring near the eye lens is most adequate

When considered inhomogeneous?

- In case of high dose gradients
- Typical situations:
  beta radiation / short distances / partial shielding of source

4. TYPICAL WORKER GROUPS

1. Interventional procedures in radiology and cardiology
2. Nuclear medicine
3. Industrial radiography
4. Veterinary medicine
5. Nuclear industry
6. Isotope production



Workers in The Netherlands with WBD > 15 mSv/year

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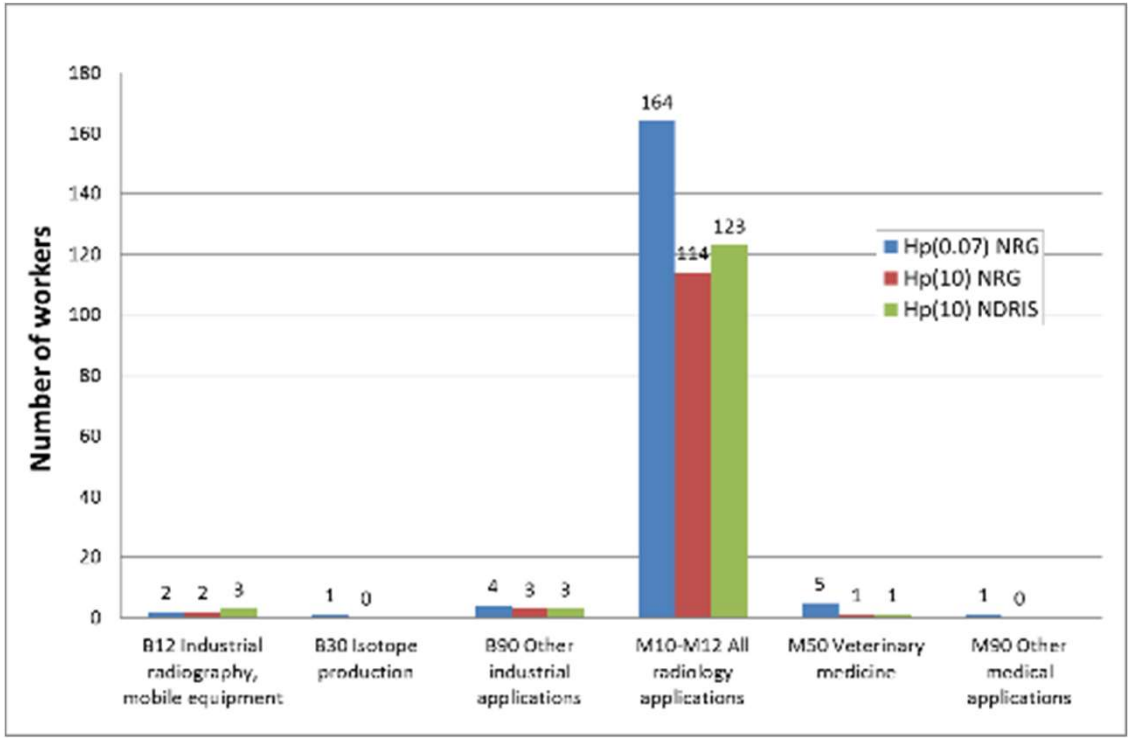

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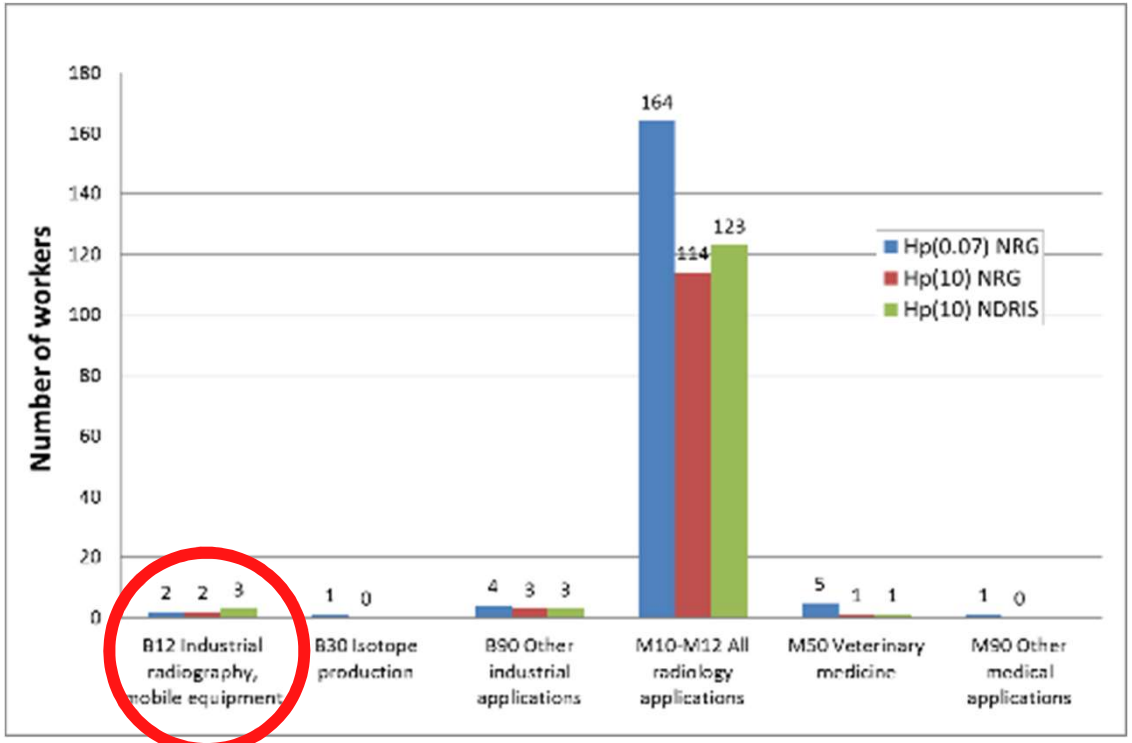

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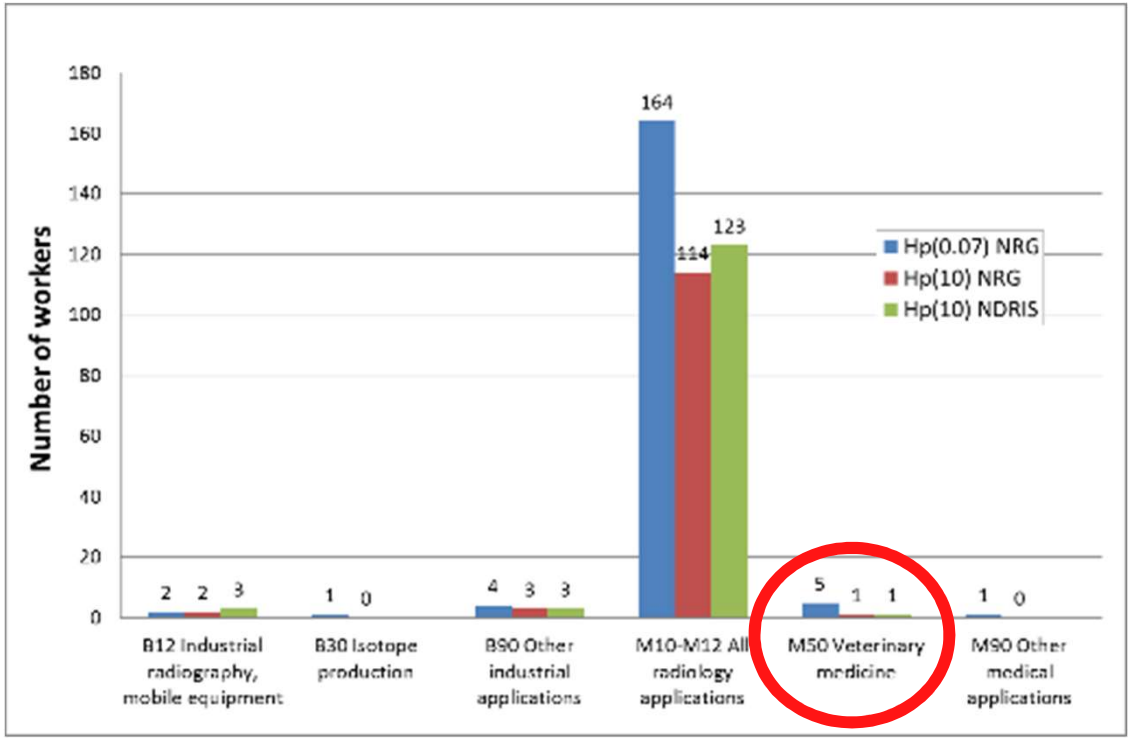

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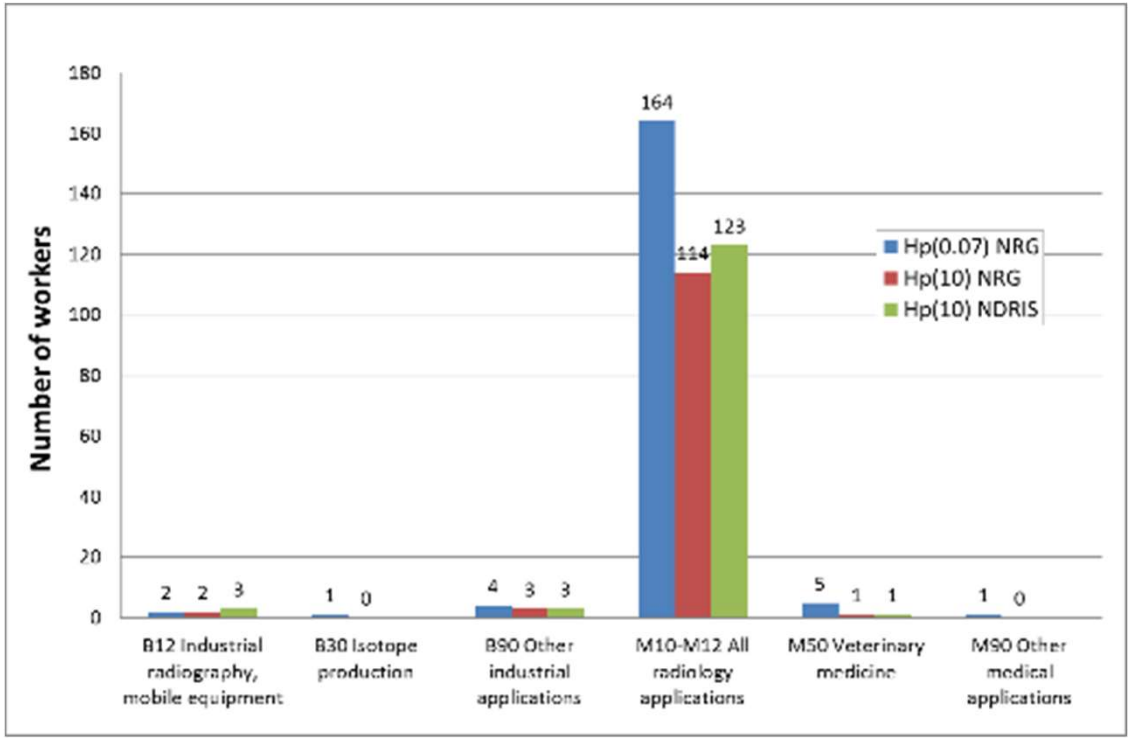

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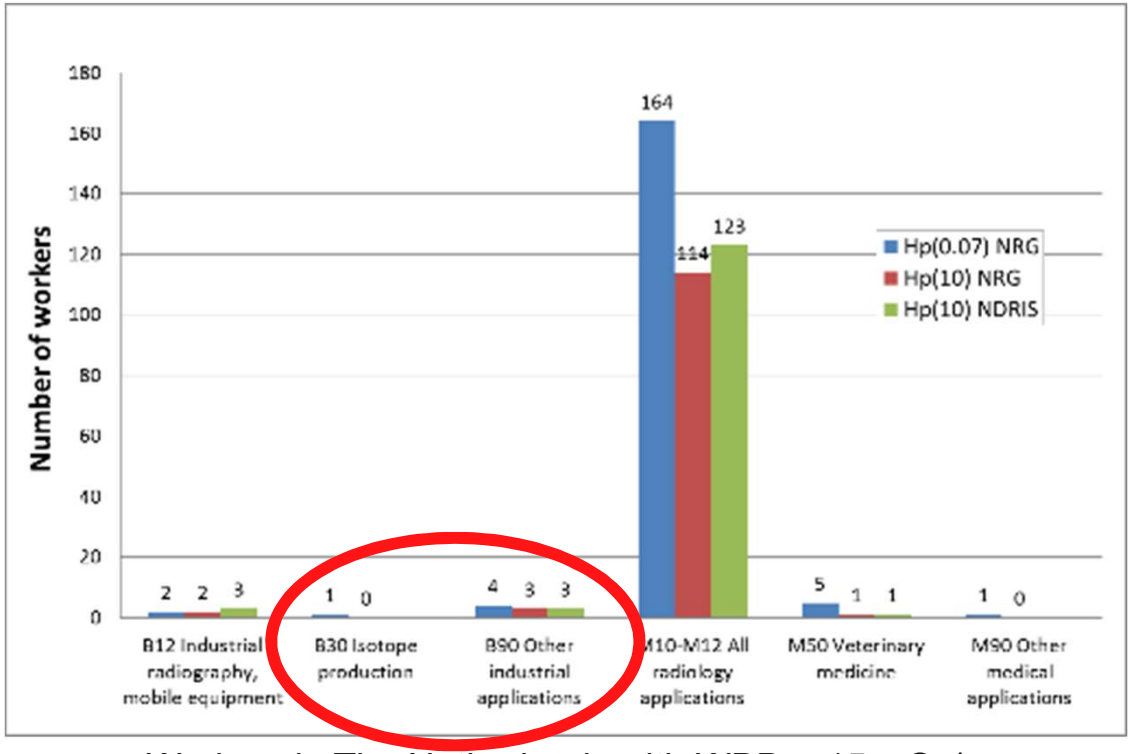


Workers in The Netherlands with WBD > 15 mSv/year

4. TYPICAL WORKER GROUPS – HIGHEST RISK GROUP

1. Interventional procedures in radiology and cardiology
2. Nuclear medicine
3. Industrial radiography
4. Veterinary medicine
5. Nuclear industry
6. Isotope production

Interventional cardiologist using cardiovascular imaging system

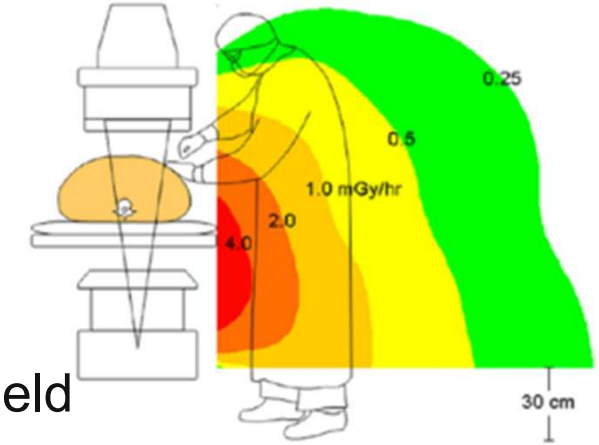
4. ADEQUATE MONITORING IN INTERVENTIONAL PROCEDURES

Adequate dose quantity:

- Mean energy may be < 40 keV
- Hp(0.07) or Hp(3) most adequate

Adequate wearing position:

- Small distance to patient ⇨ inhomogeneous field ⇨ monitoring near eye most adequate
- When eye protection in use ⇨ apply appropriate correction factor (ICRP139: DRF 2 is safe approach, don't use more than 4)



4. TYPICAL WORKER GROUPS – MODERATE RISK GROUPS

1. Interventional procedures in radiology and cardiology
2. Nuclear medicine
3. Industrial radiography
4. Veterinary medicine
5. Nuclear industry
6. Isotope production

Preparation of Radiopharmaceuticals

4. ADEQUATE MONITORING IN NUCLEAR MEDICINE

In general: expected eye lens dose < 10 mSv

Adequate dose quantity:

- SPECT applications: all quantities OK (E > 100 keV)
- PET & therapy (beta < 700 keV): Hp(3) or Hp(10) adequate
- PET & therapy (beta ≥ 700 keV): Hp(3) most adequate

Adequate wearing position:

- Small distance to source ⇨ inhomogeneous field
  ⇨ monitoring near eye most adequate
  (partial shielding may be present as well)

Preparation of Radiopharmaceuticals

4. TYPICAL WORKER GROUPS – MODERATE RISK GROUPS

1. Interventional procedures in radiology and cardiology
2. Nuclear medicine
3. Industrial radiography
4. Veterinary medicine
5. Nuclear industry
6. Isotope production

Inspection of welds thick-walled tube

4. ADEQUATE MONITORING IN INDUSTRIAL RADIOGRAPHY

In general: expected eye lens dose < 10 mSv

Adequate dose quantity:

- High energy of sources (X-ray/^{192}Ir/^{60}Co) ⇨ all quantities OK

Adequate wearing position:

- In general: photon irradiation at larger distances ⇨ monitoring at the chest is adequate
- During sealed source transport: chest dose provides safe estimate
- During incidents?

4. TYPICAL WORKER GROUPS – MODERATE RISK GROUPS

1. Interventional procedures in radiology and cardiology
2. Nuclear medicine
3. Industrial radiography
4. Veterinary medicine
5. Nuclear industry
6. Isotope production

Imaging of a horse hoof © MXR Podoblock B.V., 2016

4. ADEQUATE MONITORING IN VETERINARY MEDICINE

In general: expected eye lens dose < 10 mSv

- Highest exposure found when imaging horses

Adequate dose quantity:

- Mean energy may be < 40 keV
- Hp(0.07) or Hp(3) most adequate

Adequate wearing position:

- Small distance to animal ⇨ inhomogeneous field
  ⇨ monitoring near eye most adequate

Imaging of a horse hoof

4. TYPICAL WORKER GROUPS – MODERATE RISK GROUPS

1. Interventional procedures in radiology and cardiology
2. Nuclear medicine
3. Industrial radiography
4. Veterinary medicine
5. Nuclear industry
6. Isotope production

Inspection of a steam generator © EPZ, 2018

4. ADEQUATE MONITORING IN NUCLEAR INDUSTRY

Adequate dose quantity:

- Mask is shielding low energy betas
- Remaining radiation has high energy ⇨ Hp(3) or Hp(10) adequate

Adequate wearing position:

- Inhomogeneous field with head closer to source than chest ⇨ Monitoring near eyes most adequate
- Headband system may compromise hermiticity of mask ⇨ outside of mask + apply appropriate correction factor

Note: nuclear industry contains many different exposure situations!

4. TYPICAL WORKER GROUPS – MODERATE RISK GROUPS

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4. Veterinary medicine
5. Nuclear industry
6. Isotope production

Replacement of cyclotron target © GE Healthcare, 2017

4. ADEQUATE MONITORING IN ISOTOPE PRODUCTION

Adequate dose quantity:

- Emitted photons with higher energies
  ⇨ all quantities OK

Adequate wearing position:

- Small distance + partially shielde field
  ⇨ monitoring near eye most adequate

Replacement of cyclotron target

4. ADEQUATE MONITORING: NCS RECOMMENDATIONS

When expected eye lens dose > 15 mSv:

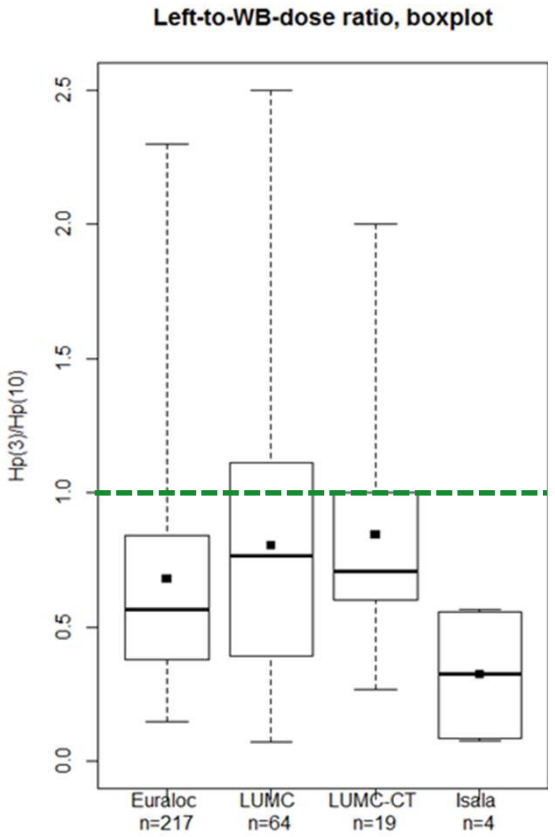
Adequate monitoring position	near eye lens	chest
1.Interventional applications	☑	
2.Nuclear medicine	☑	
3.Industrial radiography		☑
4.Veterinary medicine	☑	
5.Nuclear industry	☑	
6.Isotope production	☑	

5. DISCUSSION – THEORY VS PRACTICE

- How realistic is it to expect a structural use of eye lens dosimetry?
- Wearing discipline / compliance is difficult
- Consider estimations based with lower accuracy?
- Approaches for workers with an expected eye lens dose < 15 mSv

5. DISCUSSION – SURROGATES FOR ESTIMATION EYE LENS DOSE

- Estimate the eye lens dose with Hp(10) measurement?
- Specific circumstances where monitoring at the collar or chest may be adequate
  - ratio between Hp(3) and Hp(10) is constant
  - Hp(10) is consistently higher than Hp(3)
- Advise: verify assumptions with dosimetry!
- Pilot period: ≥ 3 sequential months (ISO15382)
- ICRP-139: *above a certain value (e.g. 10 mSv), it may be advisable to improve the accuracy of assessment by wearing an eye lens dosimeter adjacent to the most exposed eye*



6. CONCLUSIONS

- The legal framework for protection of the eye lens needs translation to the local workplaces
- An adequate system for eye lens dose monitoring should be set up for workers with an expected eye lens dose > 15 mSv
- Dependence on exposure conditions should be taken into account, including:
  - Particle type
  - Energy and angle
  - Geometry [homogeneity of field]
  - Presence of protective equipment
- Adequate eye lens dose monitoring in practical workplaces is a challenging job due to wearing discipline of workers

MULTIDISCIPLINARY WORK

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RPD paper on an adequate system for monitoring

RP Kollaard, E Carinou, M Ginjaume, L Struelens

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THANKS FOR YOUR ATTENTION

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