OVERVIEW OF DOUBLE DOSIMETRY PROCEDURES FOR THE DETERMINATION OF THE EFFECTIVE DOSE TO THE INTERVENTIONAL RADIOLOGY STAFF

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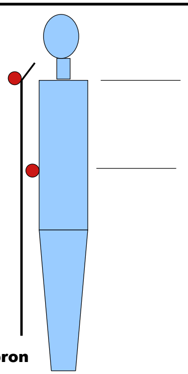
Introduction

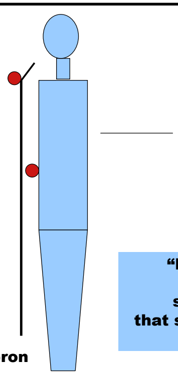
- **Interventional radiological procedures can lead to significant radiation doses to staff members**
- **In order to evaluate the personal doses with respect to the regulatory dose limits, doses measured by dosemeters have to be converted to effective doses (*E*)**



Apron

measurement with dosemeter above the apron can lead to overestimations.

measurement with dosemeter under the apron can lead to underestimations.



Apron

Measurement with two dosemeters (one above, one over the apron) is proposed to increase accuracy for determination of E (Double dosimetry)

"Interventional radiology departments should develop a policy that staff wear two dosemeters" (ICRP 85)

Objectives

- **To review double dosimetry practices and the algorithms to derive effective dose in high dose interventional procedures**

Final aim (CONRAD): to develop general guidelines for personal dosimetry in interventional radiology procedures.

Methods

- **Questionnaire** on double dosimetry to participating countries (13 countries)
  - regulations, position of dosemeter(s), measured dose quantity, dose calculation algorithms and the use of protection devices.
- **A literature review** on algorithms for the determination of effective dose
- **Testing of the accuracy** of selected algorithms by calculations based on published studies of dosemeter data with corresponding effective doses.

Results: Dosimetry regulations and practices

- 13 dosimetry services in 13 European countries

	Number of countries
Personal dose equivalent $H_p(10)$ as the measured quantity	13
Dosemeter under the apron	5
Dosemeter above the apron	8
Dosemeter above and under the apron	1
DD a legal requirement	2
No recommendations on DD	8
Algorithm for DD reported	3

Results: Dosimetry regulations and practices

- The position of the dosemeter mostly on the chest
- Significant differences in the application of protective devices
  - Mostly lead aprons of wrap-around type
  - Tilted plate thyroid collars
- Effective dose is not evaluated and reported routinely but only in specific cases
- Effective dose is mainly assessed from single dosemeter measurement as
  - $H_p(10)$ (when the dosemeter is used below the apron)
  - A fraction of $H_p(10)$ (dosemeter above the apron)

Results: Dosimetry regulations and practices

Algorithms for DD

2 countries (by regulation in Switzerland)	1 country Niklason et al. (1994)
$H_p(10) = H_u + \alpha H_o$ α = 0.1 without TS α = 0.05 with TS	(a) without TS $E = H_u + 0.06(H_{os} - H_u)$ (b) with TS $E = H_u + 0.02(H_{os} - H_u)$

TS: Thyroid shield

Results: DD algorithms

- Literature search: 140 publications, 14 different algorithms
- Early algorithms without consideration of the thyroid shield
  - *Gill et al.* (1980), *Webster* (1989) and *Balter et al.* (1993) based on effective dose equivalent (*EDE*; ICRP 26)
  - Further algorithms based on effective dose *E* (ICRP 60): *Wambersie and Delhove* (1993) - rigorously conservative, *Rosenstein and Webster* (1994), *Huyskens et al.* (1994)- only single dosimetry, *NCRP Report 122* (1995)

No single dosimeter can accurately monitor E

Results: DD algorithms

- Algorithms to cover also thyroid shields
  - *Niklason et al.* (1994): algorithm independent of lead apron thickness and accounting for thyroid shield
  - *Niklason et al.* (1994) supported by Mateya & Claycamp (1997), Kicken et al. (1999) and Padovani et al. (2001)
  - *Swiss ordinance* (1999), *McEwan* (2000), *Franken and Huyskens* (2002)
  - *Sherbini and DeCicco* (2002): based on MC calculations
  - *Von Boetticher et al.* (2003) and *Lachmund* (2005): based on TLD measurements in Alderson phantom

Results:
DD algorithms

- MC simulations
  - *Schultz and Zoetelief* (2006): Comparisons of algorithms for cardiac catherization procedures
  - *Siiskonen et al.* (2007): Study on the effect of apron in cardiac and cerebral IR procedures
- MC simulations and TLD measurements
  - *Clerinx et al.* (2007): MC calculations and TLD measurements in Rando-Alderson phantom for typical scatter field geometries in IR --> algorithm *Clerinx et al.* (2007)

$E = \alpha H_u + \beta H_o$

DD algorithm without TS	α	β	Remarks
Wambersie and Delhove (1993)	1	0,1	
Rosenstein and Webster (1994), NCRP Report 122 (1995)	0,5	0,025	
Niklason et al. (1994)	1	0,06	H_o-->H_o-H_u
Swiss ordinance (1999)	1	0,1	
McEvan (2000)	0,71	0,05	
Franken and Huyskens (2002)	1	0,1	
Sherbini and DeCicco (2002)	1	0,07	
Von Boetticher et al. (2003), Lachmund (2005)	0,65	0,074	
Clerinx et al. (2007)	1,64	0,075	

$E = \alpha H_u + \beta H_o$

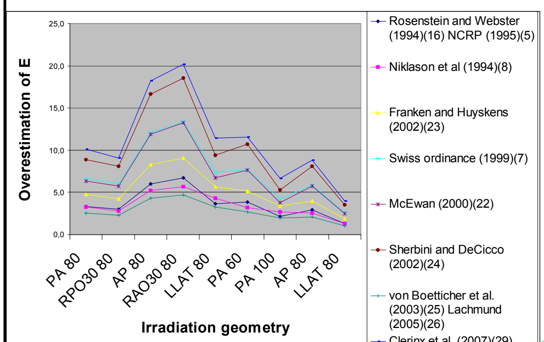
DD algorithm with TS	α	β	Remarks
Wambersie and Delhove (1993)	1	0,1	
Rosenstein and Webster (1994), NCRP Report 122 (1995)	0,5	0,025	
Niklason et al. (1994)	1	0,02	H_o-->H_o-H_u
Swiss ordinance (1999)	1	0,05	
Franken and Huyskens (2002)	1	0,033	
Sherbini and DeCicco (2002)	1	0,07	
Von Boetticher et al. (2003), Lachmund (2005)	0,65	0,017	
Clerinx et al. (2007)	1,64	0,075	

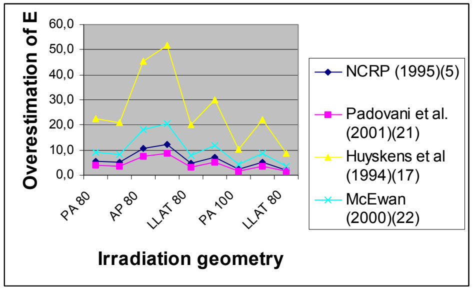
$E = H_o/\gamma$

Single dosimetry algorithm	γ	Remarks
NCRP Report 122 (1995)	21	
Huyskens et al. (1994)	5	Or: $E = 3*H_u$
Padovani et al. (2001)	14 (without TS) 33 (with TS)	*Assuming* $H_u \sim 0{,}01\ H_o$
McEvan (2000)	12,5	Or: $E = 2*H_u$
Franken and Huyskens (2002)	5	

$E = \alpha H_u + \beta H_o$

1. Measure by TLD in phantoms or calculate by MC
2. Calculate E_1 from the algorithm
3. Determine E_2 from experiments or MC simulation, compare with E_1





DD algorithm	Max overest.of E by a factor of			Max underest. of E by a factor of	
	Ref.	Schulz & Zoetelief	Siiskonen et al.	Ref.	Schulz & Zoetelief
Rosenstein & Webster (1994)	Up to 1,89	2,25	6,7	Up to 3,3	1,2
NCRP 122 (1995)	Up to 2,03		16,7		
Niklason et al. (1994)	< 2	2	5,6		1,3
Franken & Huyskens (2002)	Up to 1,5	3	9,1		
Swiss ordinance (1999)		4,5	13,4		

CONCLUSIONS

- **No harmonized regulations and practices for DD --> estimations of E not comparable**
- **No firm consensus of the best DD algorithm**
- **Most algorithms overestimate E, at max over a factor of 10**
- **DD generally recommended, mainly due to the risk of underestimations of E**
- **No single algorithm optimum for all IR procedures**
- **Further intercomparisons in critical configurations needed (-->CONRAD)**