



Cardiac Center

KING CHULALONGKORN MEMORIAL HOSPITAL
THE THAI RED CROSS SOCIETY

Diagnostic reference levels in PCI

Suphot Srimahachota
Division of Cardio-vascular Medicine
Department of Medicine
King Chulalongkorn Memorial Hospital

2nd March 2024



Percutaneous coronary intervention (PCI)

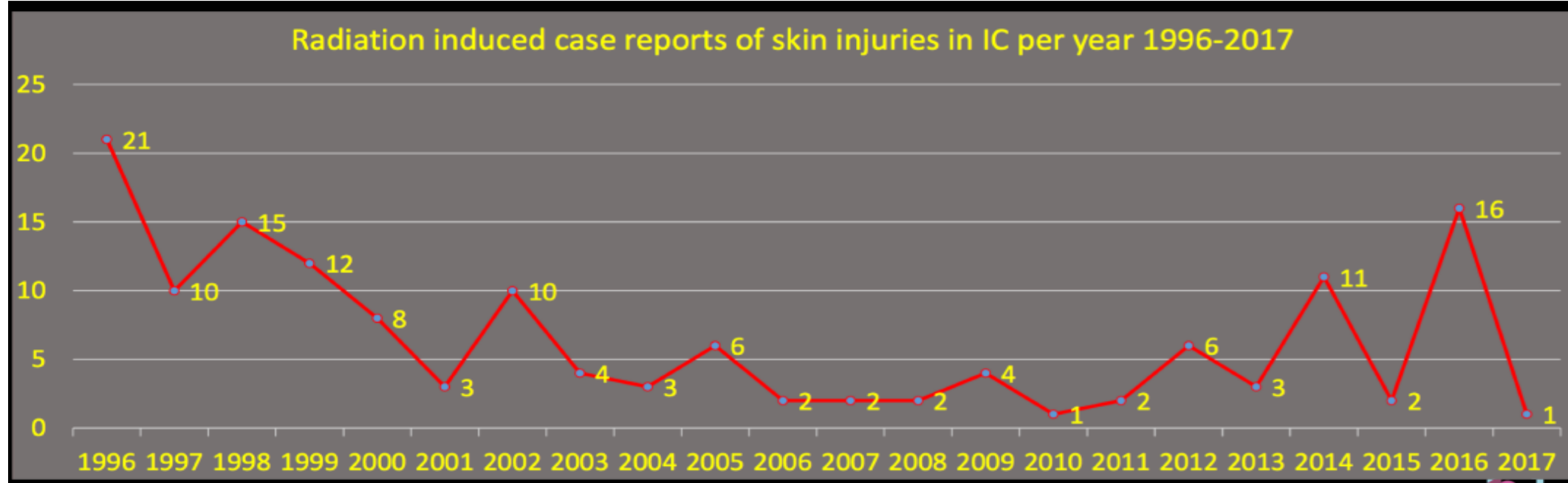
- PCI is now the standard treatment for coronary revascularization in patients who had symptomatic significant CAD.
- The complex PCI particularly chronic total occlusion (CTO) lesion may increase the radiation dose in both cath lab staffs and patients.
- High dose radiation exposure can cause radiation skin injury to the patients and chronic exposure may increase the incidence of premature lens opacity / cataracts as well as stochastic effect.



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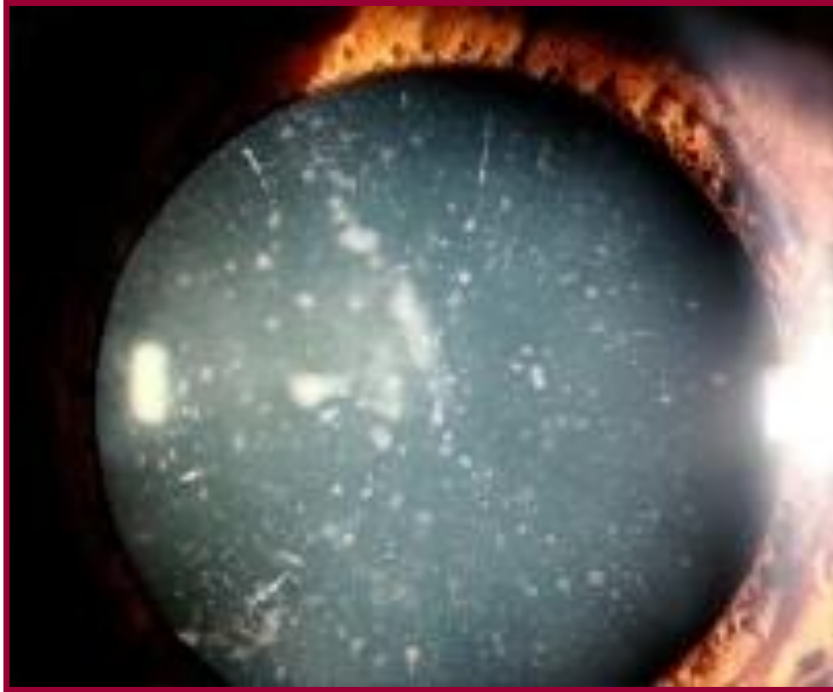
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Reports of skin reaction due to cardiac fluoroscopy guided





Radiation & Cataract



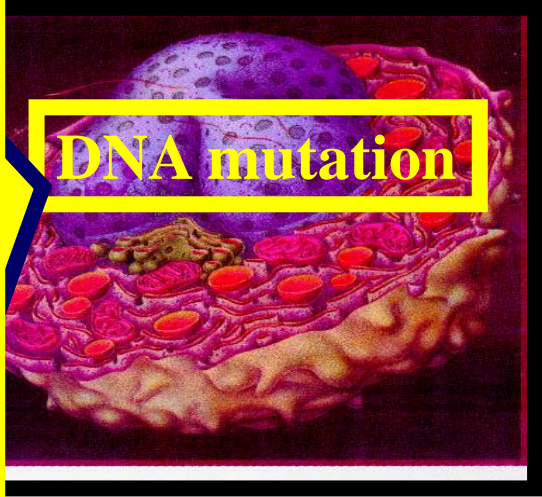
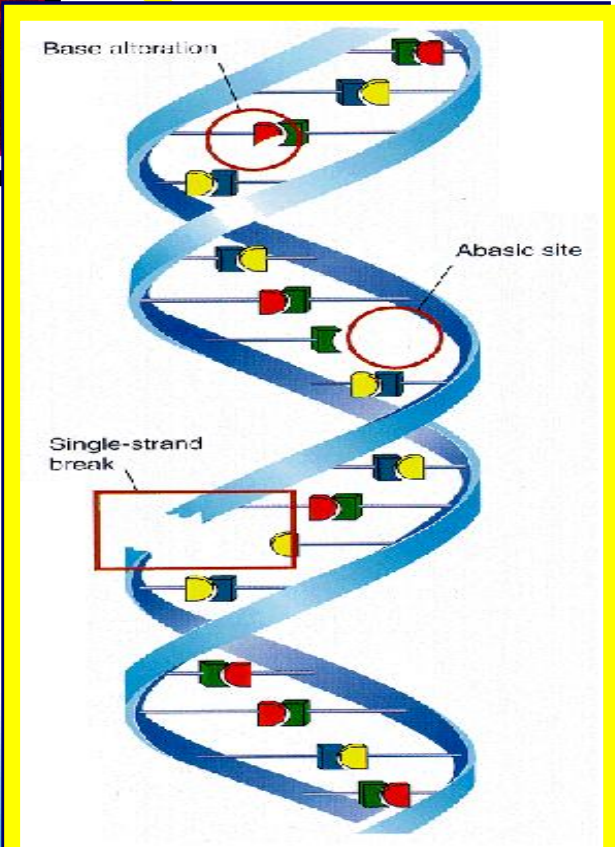
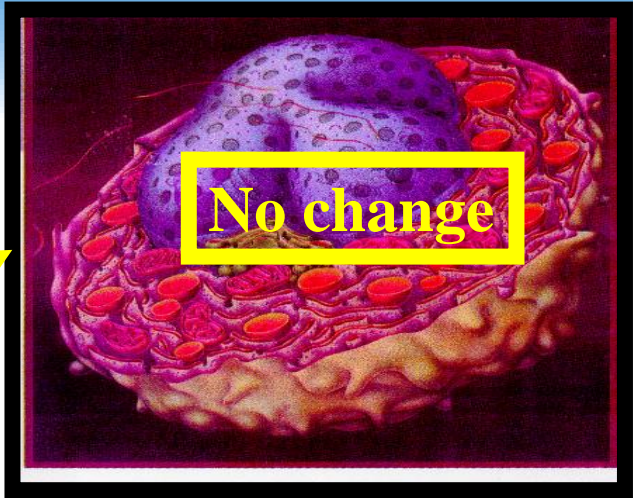
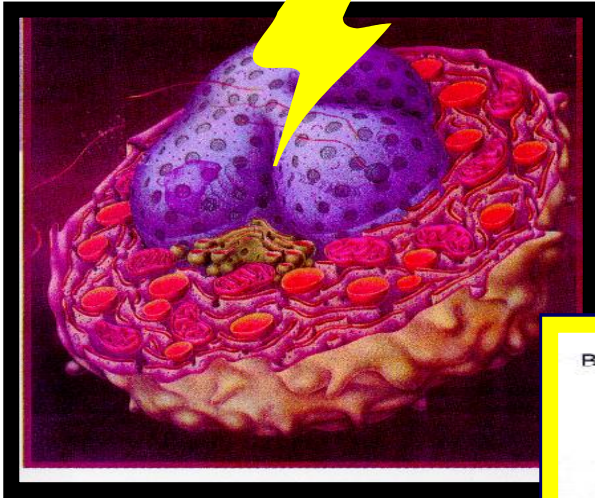
- Lens are now sensitive tissue
- Dot Opacities
- Latency depends on rate at which **damaged** epithelial cells undergo fibrogenesis and accumulate.
- **ICRP Publication 118 (2012)** decreased the dose limit of the eye lens from 150 to 20 mSv per year, average over 5 year period, due to the epidemiology of cataract and eye lens opacity.



Posterior Subcapsular Lens Opacities

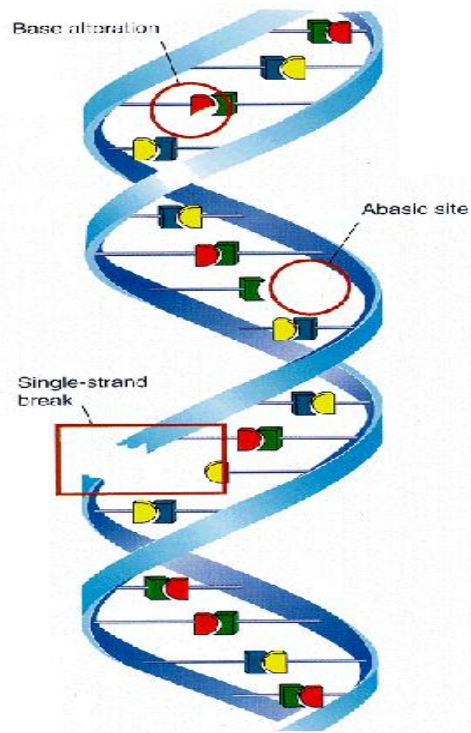
Subject (N)	Posterior lens opacities in one or both eyes (%) *	Relative risk	P valve
Interventional Cardiologist (7)	2 (28.6%)	14.4	0.013
Nurses and Technicians (41)	8 (19.5%)	8.73	0.020
All Interventional cardiology staffs (48)	10 (20.8 %)	9.47	0.014
Control (37)	1 (2.7%)	1	

*Posterior lens opacities if modified Merriam-Focht score is more than 1.0

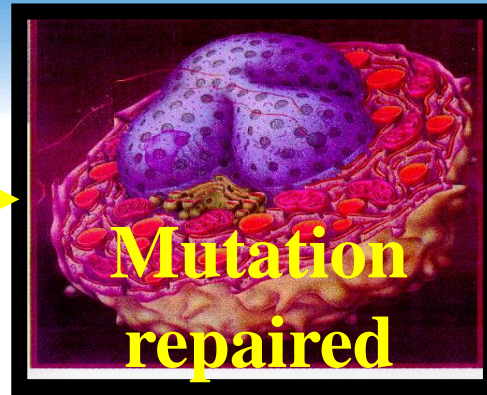


radiation
hits
nucleus!

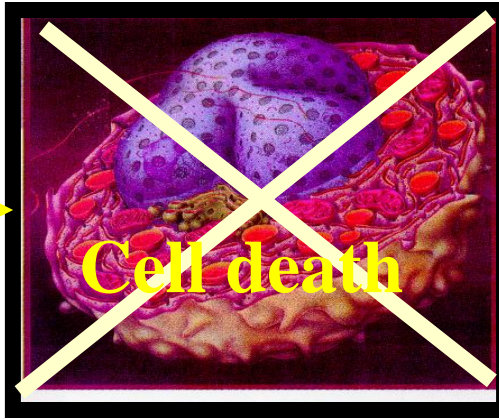
sible?



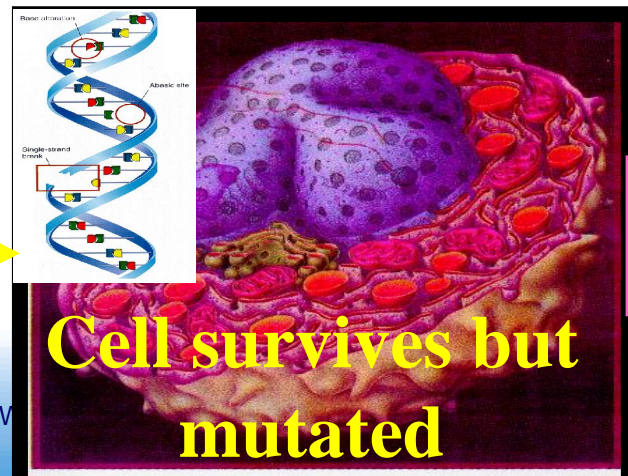
DNA Mutation
 $p \cong a D$



Viable Cell



Unviable Cell



Stoch. eff.

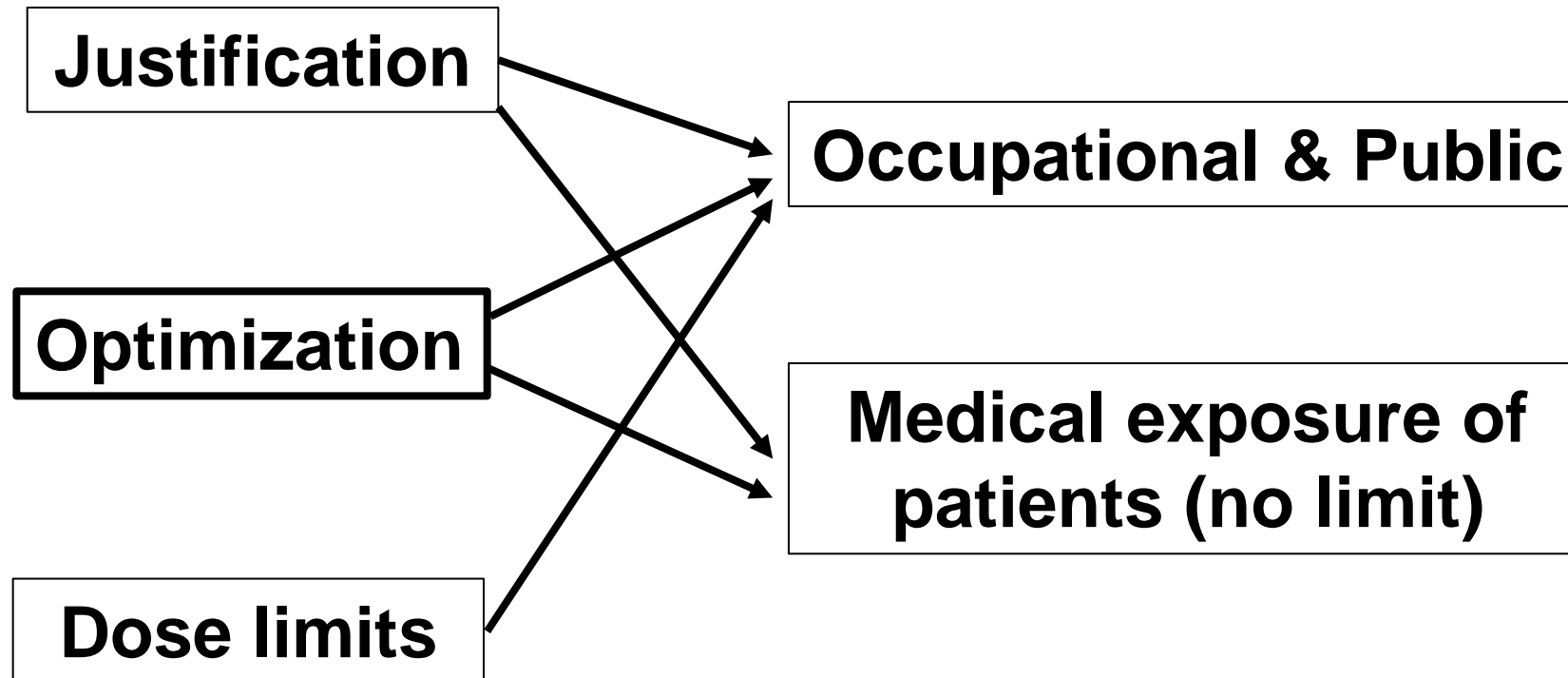


To minimize the radiation exposure, ICRP established the radiation protection system for humans.

- **Occupational exposures**
- **Public exposures**
- **Medical exposures of patients (the exposure is intentional and for the direct benefit of the patient)**
 - : **Diagnostic**
 - : **Interventional**
 - : **Therapeutic procedures**



The radiation protection system of ICRP for humans





What is optimization in Medical exposure?

- The process requiring a **diagnostic outcome** for a patient from an imaging procedure while **minimizing patient dose**.
- **The Diagnostic reference levels (DRLs)** have been proven to be an **effective tool** that aid in **optimization** of protection in the medical exposure of patients for diagnostic and interventional procedures.
- DRL is calculated by P75 of median value of KAP (or AK) all cath lab sites.

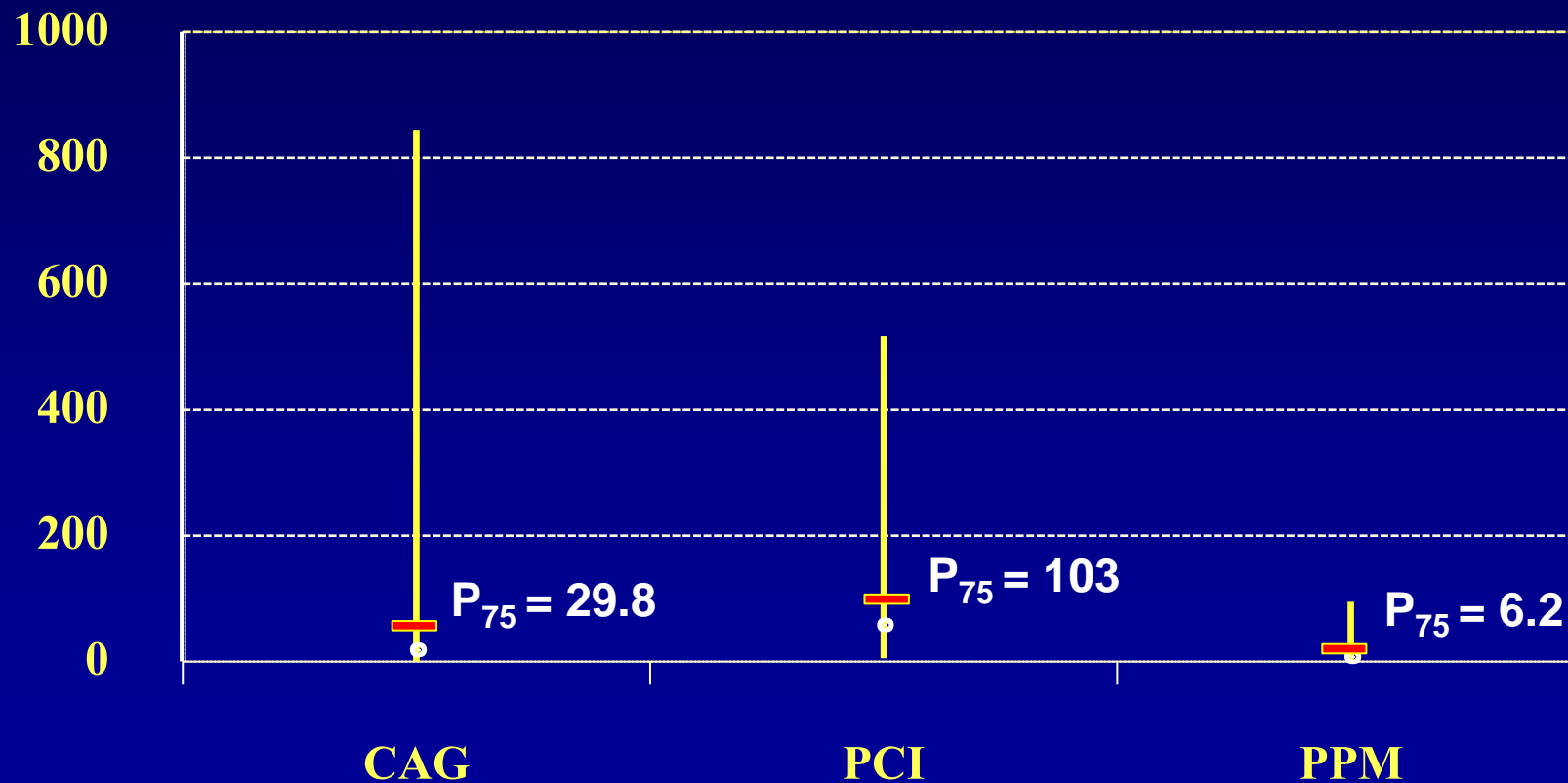


DRLs for cardiac procedure in Europe:KAP (Gycm²)

Procedure	BE	HR	CZ	FI	FR	GR	IR	LB	PL	RS	ES	SE	CH	3rd quartile
CA	35.6		35.5	21.2	22.0	-	35.3	12.8	14.1	42.2	34.2	17.5	65.7	35.5
PCI	87.3	35.9	89.8	45.7	57.6	44.5	73.0	37.7	28.5	98.1	63.4	31.7	135	87.3
CTO	-	-	-	-	120	-	(271)	-	-	-	-	143	-	137
TAVI	(305.4)	(55.4)	130	89.4	134	193	87.1	99.2	-	-	25.9	87.2	96.8	130
PI SCH	-	-	2.18	1.86	-	5.60	2.63	2.40	-	2.97	-	1.43	-	2.80
PI DCH	-	-	2.28	3.20	-	(25)	2.53	3.84	-	5.16	-	0.86	-	3.65
PI CRT	-	-	18.4	31.4	14	6.63	15.8	4.96	-	19.2	5.82	4.13	-	18.4
EF AVNRT	-	-	0.97	3.67	-	-	(2.26)	-	-	-	-	2.73	-	3.2
EF FL	-	-	0.96	14.5	-	-	-	-	-	-	-	6.58	-	10.5
EF AF	-	-	2.51	29.2	-	-	4.84	-	-	-	-	8.41	-	13.6
EF ALL	-	-	1.09	14.5	3.5	5.28	3.5	109.1 [*]	-	-	13.7	6.53	-	14.1 (11.9)

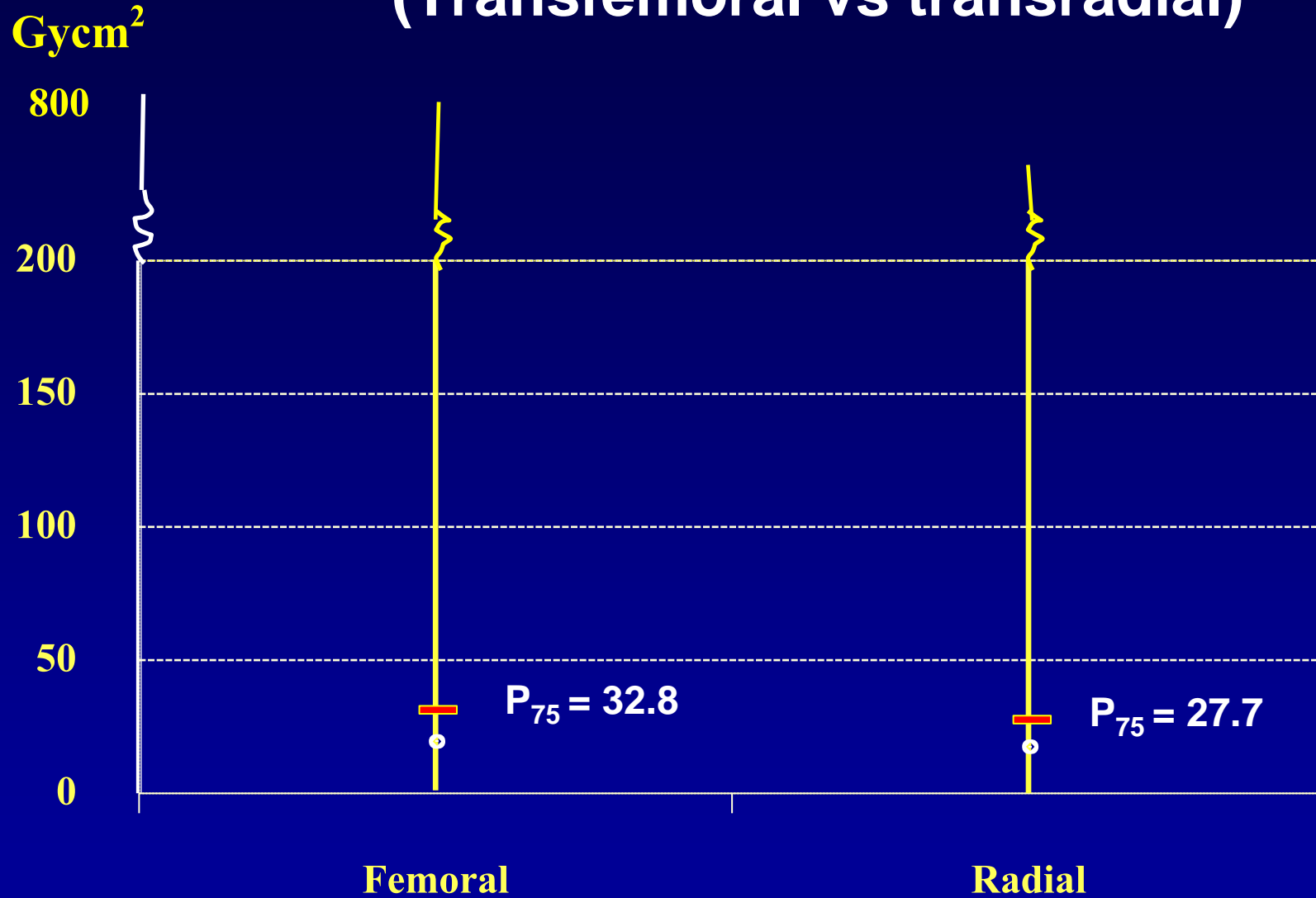


DRLs in common cardiac procedures: KAP (Gycm²)



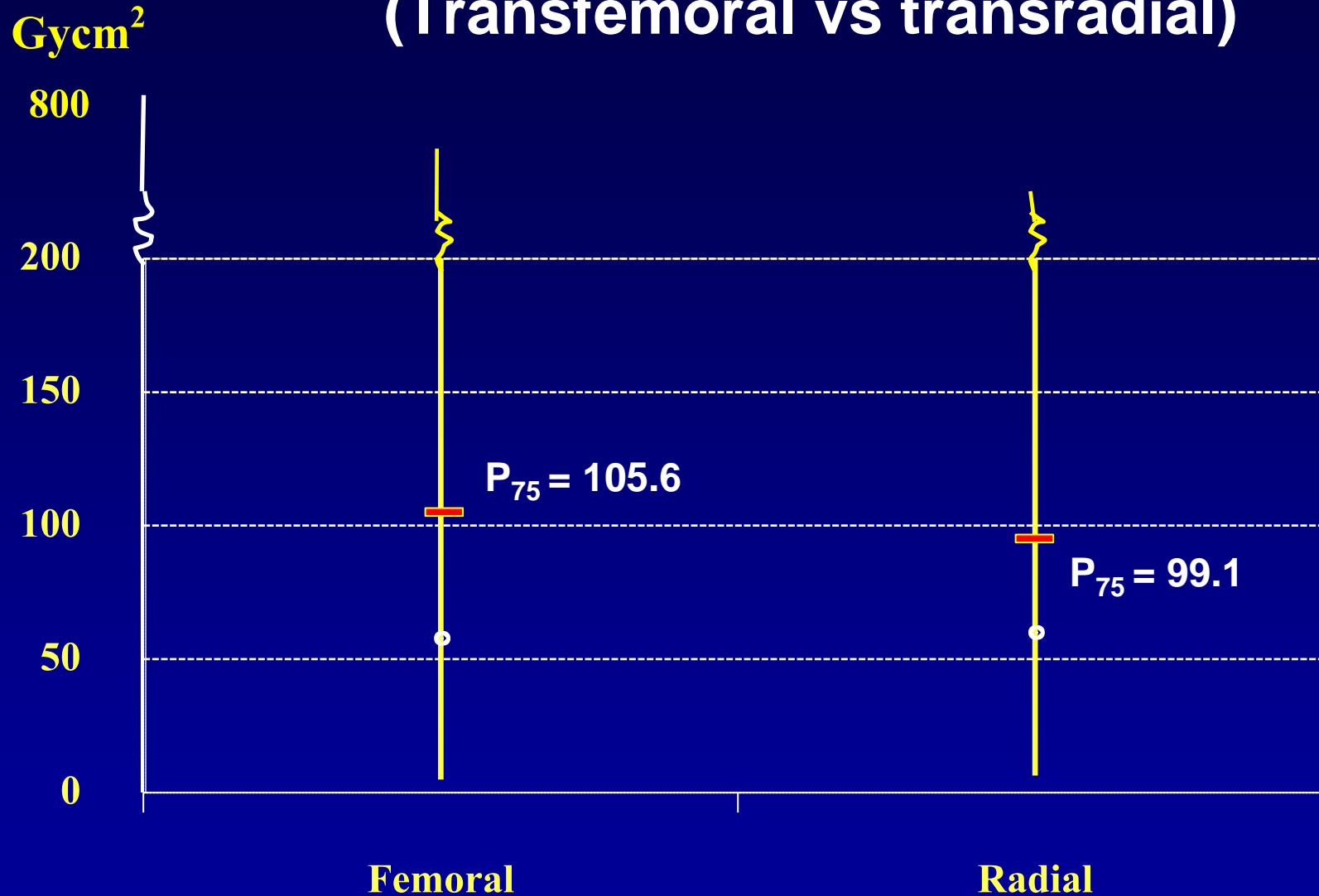


DRLs in CAG: KAP ($Gycm^2$) (Transfemoral vs transradial)



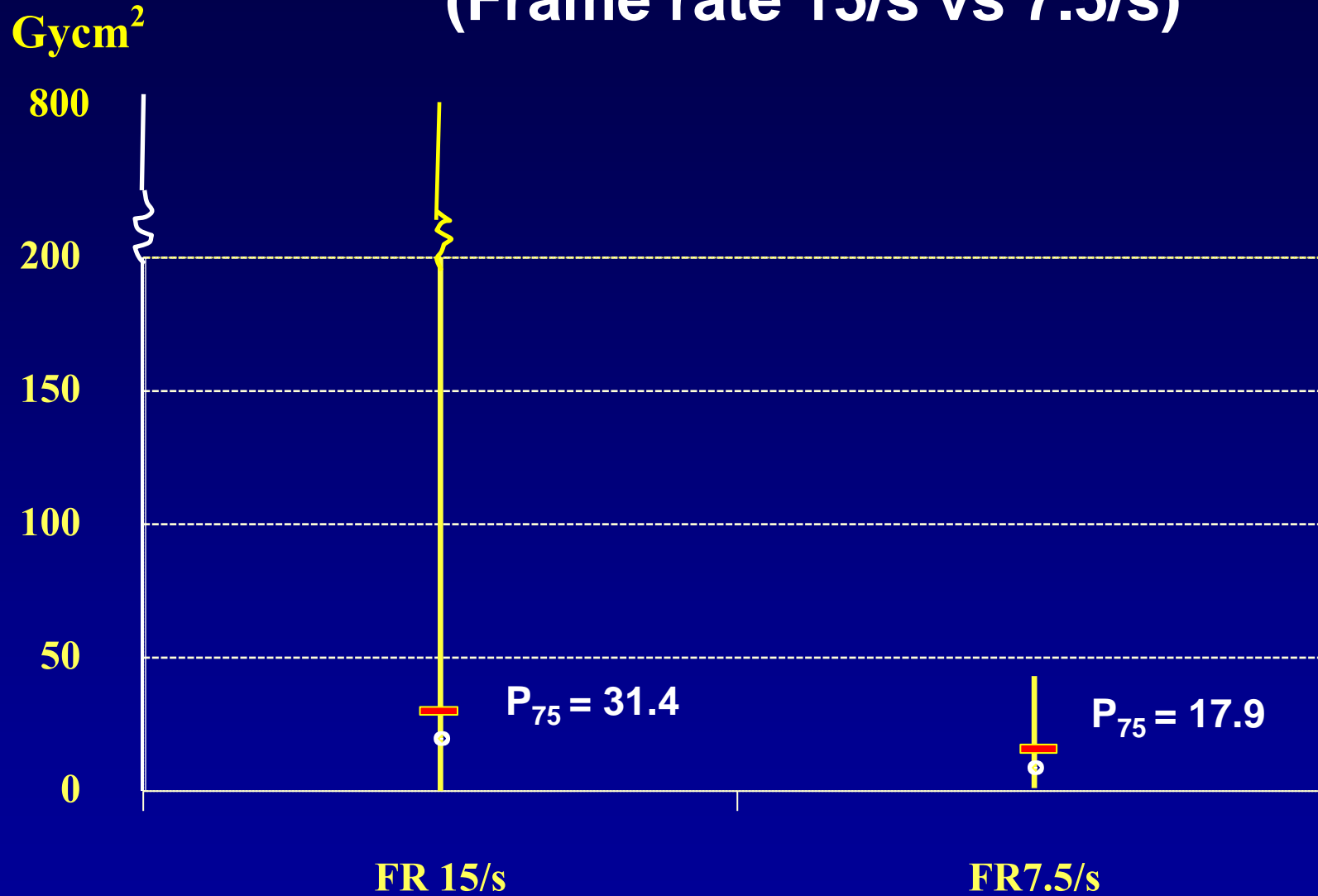


DRLs in PCI: KAP (Gycm²) (Transfemoral vs transradial)



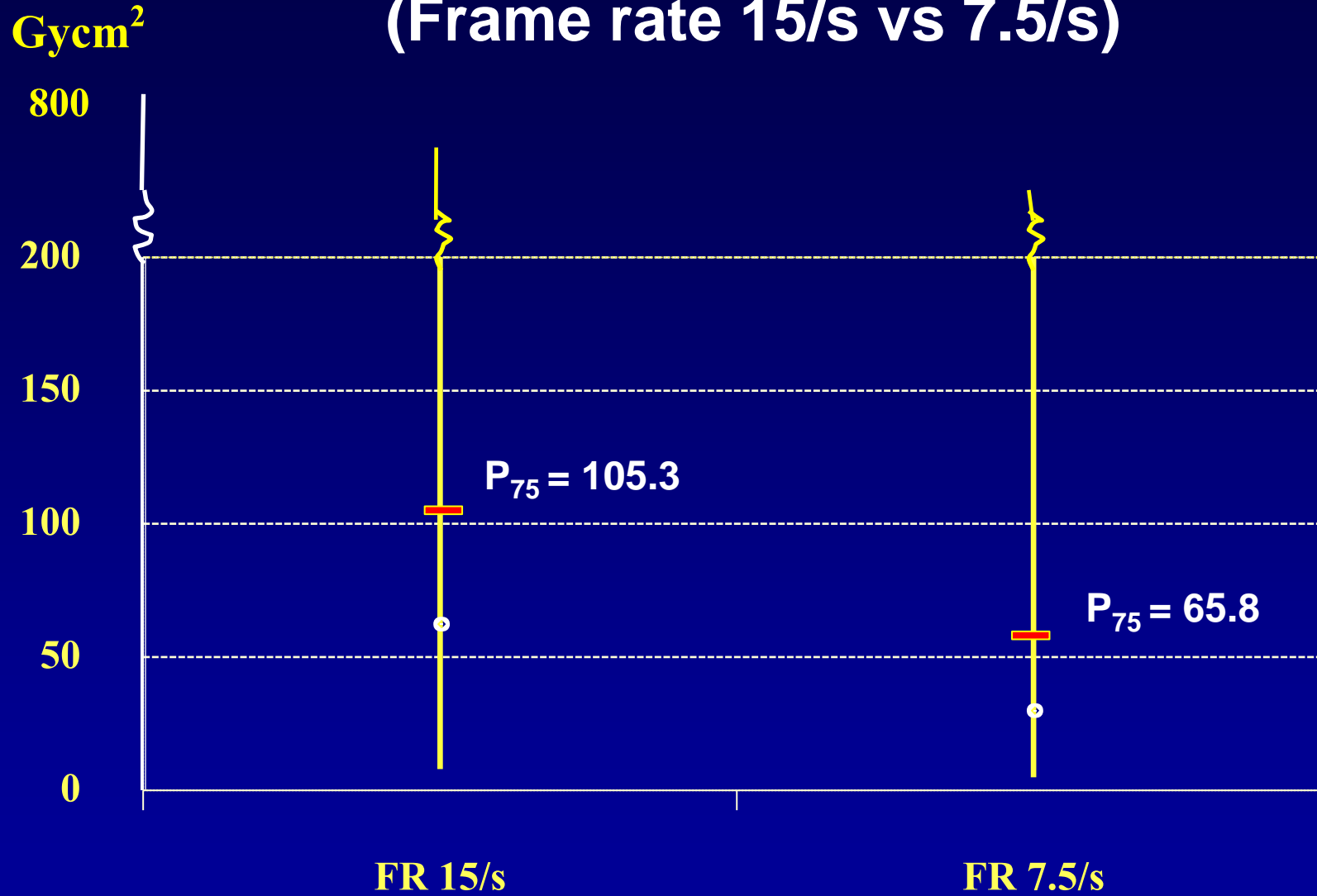


DRLs in CAG: KAP (Gycm²) (Frame rate 15/s vs 7.5/s)





DRLs in PCI: KAP (Gycm²) (Frame rate 15/s vs 7.5/s)

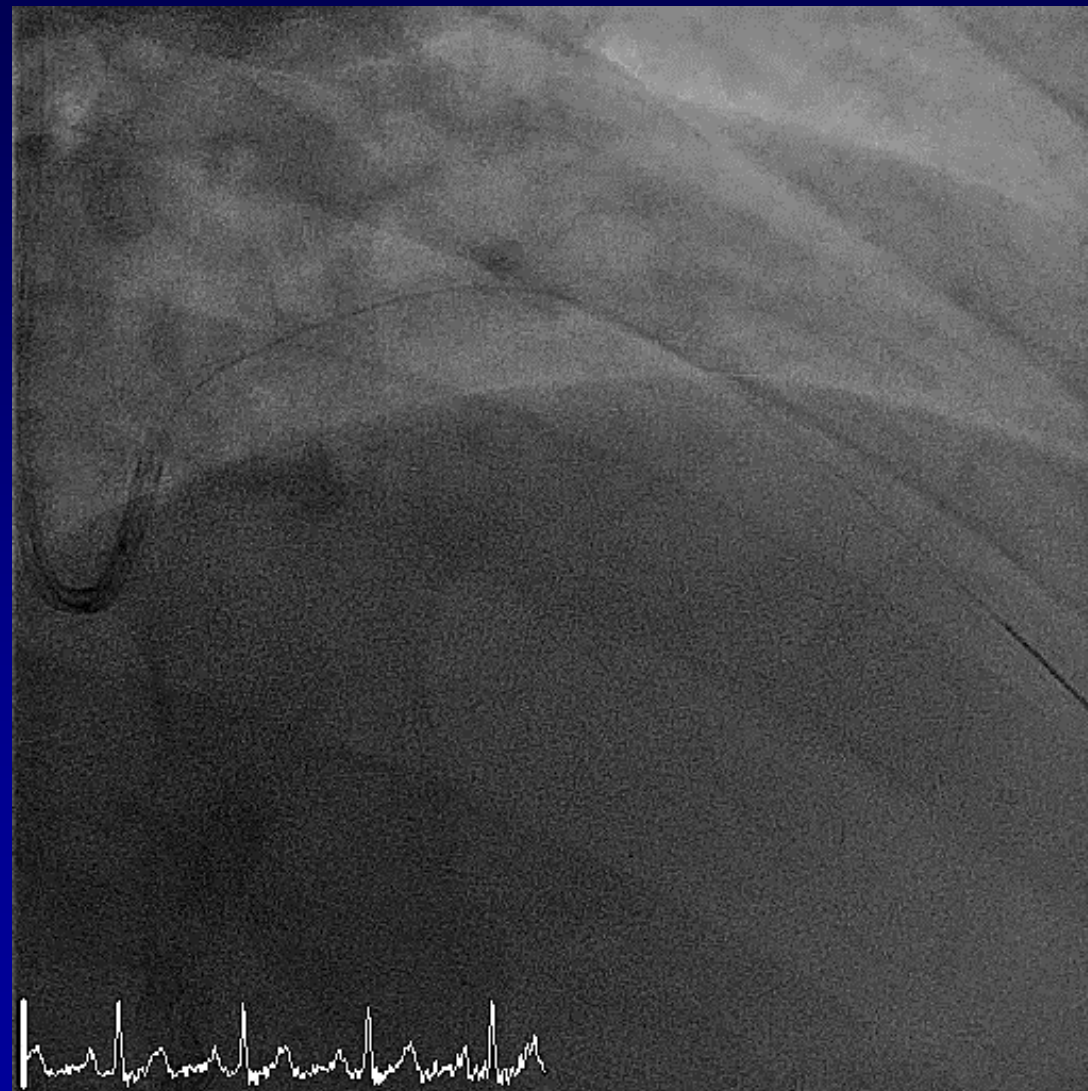




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Frame rate: 15 vs 7.5 f/s



DRL in Thai PCI registry

- **Cardiovascular Intervention Association of Thailand initiated the project of the Thai PCI registry.**
- **39 hospitals all over Thailand, including academic and non-academic training in cardiology.**
- **Consecutive cases of PCI were included in the study.**
- **Data were collected during May 2018 – August 2019.**
- **Inclusion criteria:**
 - **The KAP (Kerma area product) from 10 to 3,000 Gy cm^2**
 - **AK (Air Kerma) from 80 to 30,000 mGy**
 - **Fluoroscopy time from 1 minute to 300 minutes**

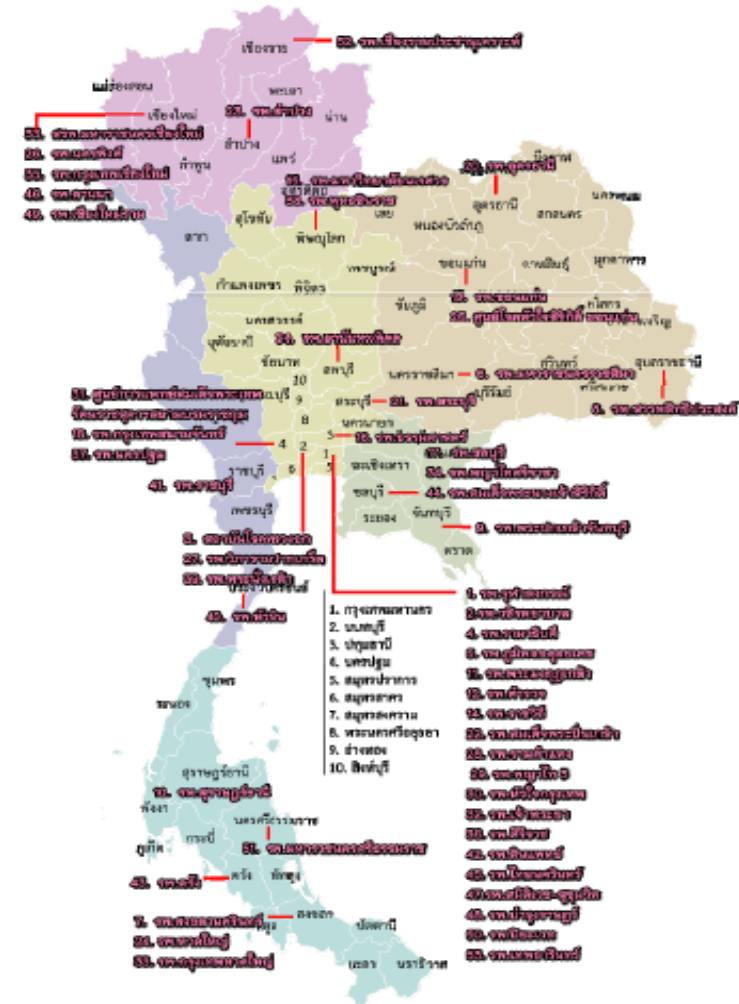


Thai PCI registry: $n = 22,741$

- **Data management using Department of Clinical Epidemiology and Biostatistics, Ramathibodi Hospital.**
- **The study was approved by Central Research Ethics Committee (CREC) of Thailand.**
- **The first case enrollment was May 2018 and last case was August 2019**
- **Auditing 100% of participating sites.**
- **This study was granted by Health Systems Research Institute (HSRI).**



Mapping of 39 hospitals participating in Thai PCI Registry



CRF data: part of radiation doses

PROCEDURE INFORMATION

F04: Procedure Date/Time: -- / :
(DD-MM-YYYY (พ.ศ.)) (24 hr.)

F05: Fluoroscopy Time: . min

F06: Dose (Air Kerma): . mGy

F07: DAP (Dose Area Product): Gy.cm²

Results:

	KAP (Gycm ²)				AK (mGy)				Fluoroscopy time (min)			
	cases	Median (IQR)	Min	Max	cases	Median (IQR)	Min	Max	cases	Median (IQR)	Min	Max
All site	18,368	64.4 (31,129)	10	2890	21,682	955 (491,1832)	80	22318	22,023	12.6 (7.5,22.0)	1.0	220
DRL	91.3 Gycm ²				1360 mGy				16.4 minutes			



Comparative analysis of our DRLs for PCI with European, Asian countries and USA.

	Belgium 2009	Greece 2013	Swiss 2012	USA 2012	European 2018	Korea 2019	Japan 2020	Thai PCI 2022
PCI : KAP (Gy.cm ²) : AK (mGy)	106	129	125	193	85 1200	171 2960		91 1360
PCI – non-CTO : KAP (Gy.cm ²) : AK (mGy)							130 1800	83 1302
PCI – CTO : KAP (Gy.cm ²) : AK (mGy)					137 2020		280 3900	156 2736

Interesting factors effect on KAP/AK

- **Center: university, public or private**
- **Disease complexity (using ACC/AHA classification – A, B1, B2, C)**
- **Chronic total occlusion (CTO) – the most challenging and highest radiation doses procedure.**
- **Access site (transfemoral / transradial approach)**
- **Cine frame rate (7.5 or 15 f/s)**

Multivariate comparison of **hospital type** according to KAP/AK at reference point

Factors	Number of cases	Median (IQR)	Multivariate		NDRLs
	n (%)		Coefficient (95% CI)	P-value	
Kerma Area Product (KAP, Gy-cm²)					
Hospital type					
University	7,599 (41.4)	100.2 (52.2, 184.3)	68.1 (62.8, 73.5)	<0.001	182.1
Private	1,765 (9.6)	52.4 (28.7, 92.1)	-37.9 (-48.3, 27.6)	<0.001	73.1
Public	9,004 (49.0)	45.9 (24.0, 90.7)	0		62.0
Air Kerma (AK, mGy)					
Hospital type					
University	8,206 (37.9)	1433.0 (762.0, 2522.0)	859.9 (800.6, 919.2)	<0.001	1972.0
Private	1,931 (8.9)	786.0 (408.4, 1456.0)	-337.4 (-451.1, -223.7)	<0.001	1406.7
Public	11,545 (53.2)	764.0 (406.1, 1360.0)	0		1075.2

Multivariate comparison of **hospital type** according to fluoroscopy time

Factors	Number of cases	Median (IQR)	Multivariate		NDRLs
	n (%)		Coefficient (95% CI)	P-value	
Fluoroscopy time (min)					
Hospital type					
University	8,370 (38.0)	17.0 (10.4, 28.1)	6.6 (5.9, 7.2)	<0.001	19.6
Private	1,943 (8.8)	10.3 (6.2, 16.6)	-1.2 (-2.5, 0.1)	0.063	16.5
Public	11,721 (53.2)	10.6 (6.5, 18.1)	0		13.9

Multivariate comparison of **lesion type** according to KAP/AK at reference point

Factors	Number of cases	Median (IQR)	Multivariate		NDRIs
	n (%)		Coefficient (95% CI)	P-value	
Kerma Area Product (KAP, Gy-cm²)					
Lesion type					
C	11,879 (65.0)	74.1 (36.0, 144.3)	51.5 (38.8, 64.3)	<0.001	106.8
B2	3,173 (17.4)	58.2 (29.0, 116.8)	31.6 (17.9, 45.4)	<0.001	82.6
B1	2,453 (13.4)	46.8 (24.9, 88.5)	11.7 (-2.4, 25.8)	0.105	67.9
A	766 (4.2)	35.2 (21.3, 61.8)	0		45.3
Air Kerma (AK, mGy)					
Lesion type					
C	13,890 (62.4)	1126.0 (584.4, 2121.0)	823.7 (687.3, 960.0)	<0.001	1704.9
B2	4,118 (18.5)	830.0 (440.0, 1526.0)	441.8 (295.7, 587.9)	<0.001	1246.9
B1	3,294 (14.8)	699.5 (371.0, 1243.9)	266.0 (116.6, 415.5)	<0.001	962.1
A	948 (4.3)	542.5 (320.0, 935.7)	0		789.5

Multivariate comparison of **lesion type** according to fluoroscopy time

Factors	Number of cases	Median (IQR)	Multivariate		NDRLs
	n (%)		Coefficient (95% CI)	P-value	
Fluoroscopy time (min)					
Lesion type					
C	14,111 (62.4)	14.9 (8.9, 25.4)	9.6 (8.1, 11.1)	<0.001	21.4
B2	4,185 (18.5)	11.3 (7.2, 18.2)	5.0 (3.5, 6.6)	<0.001	16.0
B1	3,349 (14.8)	9.2 (6.1, 14.4)	1.6 (0.0, 3.2)	0.049	13.1
A	968 (4.3)	8.4 (5.8, 13.0)	0		12.1

Multivariate comparison of **CTO lesion** according to KAP/AK at reference point and fluoroscopy time

Factors	Number of cases	Median (IQR)	Multivariate		NDRLs
	n (%)		Coefficient (95% CI)	P-value	
Kerma Area Product (KAP, Gy-cm²)					
Chronic total occlusion					
Yes	2,014 (11.0)	114.8 (48.8, 222.5)	84.7 (76.1, 93.2)	<0.001	155.8
No	16,354 (89.0)	61.0 (30.2, 119.1)	0		83.1
Air Kerma (AK, mGy)					
Chronic total occlusion					
Yes	2,290 (10.2)	1963.5 (888.8, 3503.0)	1629.0 (1534.3, 1723.7)	<0.001	2735.9
No	20,083 (89.8)	895.9 (469.0, 1662.3)	0		1302.0
Fluoroscopy time (min)					
Chronic total occlusion					
Yes	2,305 (10.1)	26.0 (15.2, 44.1)	21.3 (20.2, 22.3)	<0.001	34.9
No	20,433 (89.9)	12.0 (7.3, 19.6)	0		15.9

Multivariate comparison of **access site** according to KAP/AK at reference point and fluoroscopy time

Factors	Number of cases	Median (IQR)	Multivariate		NDRLs
	n (%)		Coefficient (95% CI)	P-value	
Kerma Area Product (KAP, Gy-cm²)					
Access site					
Radial	7,705 (42.0)	58.1 (28.4, 116.3)	-19.4 (-24.7, -14.1)	<0.001	93.5
Femoral	10,663 (58.0)	68.7 (33.9, 141.0)	0		98.9
Air Kerma (AK, mGy)					
Access site					
Radial	9,854 (44.0)	866.0 (452.4, 1583.7)	-393.2 (-450.3, -336.0)	<0.001	1328
Femoral	12,519 (56.0)	1038.4 (527.3, 2041.0)	0		1460
Fluoroscopy time (min)					
Access site					
Radial	10,060 (44.3)	11.5 (7.2, 19.3)	-2.1 (-2.7, -1.4)	<0.001	17.8
Femoral	12,678 (55.7)	13.5 (8.1, 23.7)	0		18.4

Multivariate comparison of **cine frame rate** according to KAP/AK at reference point and fluoroscopy time

Factors	Number of cases	Median (IQR)	Multivariate		NDRLs
	n (%)		Coefficient (95% CI)	P-value	
Kerma Area Product (KAP, Gy-cm²)					
Cine frame rate					
7.5 f/s	3,215 (19.5)	41.8 (23.2, 72.9)	-59.5 (-66.0, -52.9)	<0.001	60.3
15 f/s	13,287 (80.5)	69.6 (33.5, 144.0)	0		102.3
Air Kerma (AK, mGy)					
Cine frame rate					
7.5 f/s	5,187 (26.2)	694.9 (379.7, 1272.6)	-495.8 (-559.6, -432.0)	<0.001	1065.7
15 f/s	14,639 (73.8)	998.0 (502.0, 1922.0)	0		1472.6
Fluoroscopy time (min)					
Cine frame rate					
7.5 f/s	5,278 (26.2)	12.5 (7.8, 20.6)	-0.8 (-1.4, -0.1)	0.031	14.1
15 f/s	14,902 (73.8)	12.4 (7.3, 21.5)	0		17.8



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Establishment of national diagnostic reference levels for percutaneous coronary interventions (PCIs) in Thailand

Suphot Srimahachota^{a,*}, Anchali Krisanachinda^b, Worawut Roongsangmanoon^c,
Nakarin Sansanayudh^d, Thosaphol Limpijankit^e, Mann Chandavimol^e, Siriporn Athisakul^a,
Sukanya Siriyotha^f, Madan M. Rehani^g, on behalf of Thai PCI registry

^a Cardiac Center and Division of Cardiovascular Medicine, King Chulalongkorn Memorial Hospital and Chulalongkorn University, Bangkok, Thailand

^b Division of Nuclear Medicine, Department of Radiology, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand

^c Division of Cardiology, Department of Medicine, Faculty of Medicine, Srinakharinwirot University, Nakornnayok, Thailand

^d Division of Cardiology, Department of Medicine, Faculty of Medicine, Phramongkutklao Hospital, Bangkok, Thailand

^e Division of Cardiology, Department of Medicine, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

^f Department of Clinical Epidemiology and Biostatistics, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

^g Radiology Department, Massachusetts General Hospital, Boston, MA, USA



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	Belgium 2009	Greece 2013	Swiss 2012	USA 2012	European 2018	Korea 2019	Japan 2020	Thai PCI 2022	Thai 2023 (P75 all)
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PCI – non-CTO : KAP (Gycm ²) : AK (mGy)							130 1800	83 1302	69 1062
PCI – CTO : KAP (Gycm ²) : AK (mGy)					137 2020		280 3900	156 2736	105 1739





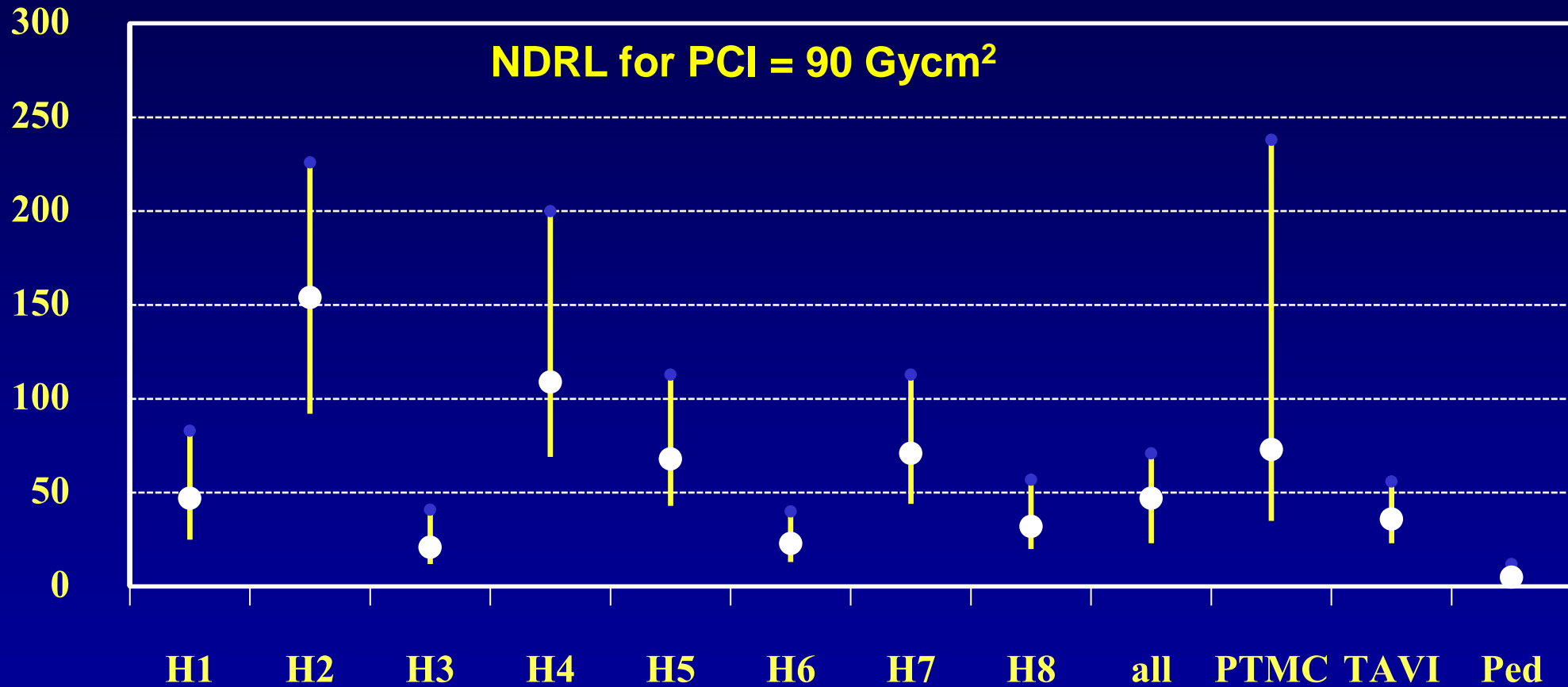
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DRLs for PCI: KAP (Gycm²)

(9 Hospitals in Thailand – during 2021-2022, n=5185)

Gycm²



CU=1 (flu 7.5/Cine 7.5, EP-3.75), CDI=2 (flu 6/Cine 15), CMU=3 (flu 7.5/Cine 15), มน-4(flu 7.5/Cine 15), มศว-5 (flu 15/Cine 15),
 ลำปาง-6(flu 7.5/Cine 7.5), ศูนย์สิริกิติ์ มท=7 (flu 15/Cine 15), สุราษฎร์=8 (flu 7.5/Cine 7.5), Ramathibodi=9 (flu 7.5/Cine 7.5),

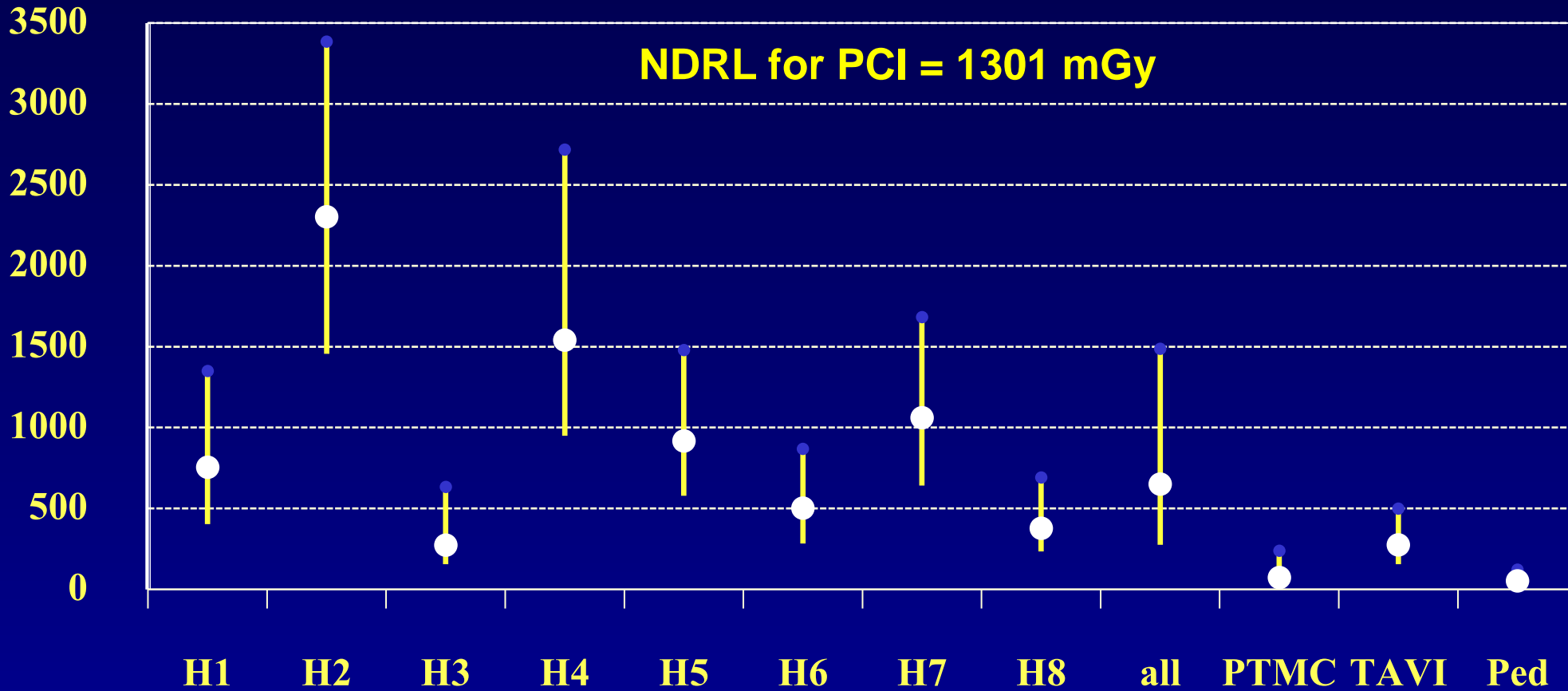


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DRLs for PCI: Air Kerma (mGy) (9 Hospitals in Thailand – during 2021-2022, n=5185)

mGy



CU=1 (flu 7.5/Cine 7.5, EP-3.75), CDI=2 (flu 6/Cine 15), CMU=3 (flu 7.5/Cine 15), มน-4(flu 7.5/Cine 15), มศว-5 (flu 15/Cine 15),
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% of patients who received radiation > trigger level (DAP > 500 Gy_{cm}², Air Kerma > 5 Gy, Fluoroscopy time > 60 m.)



CU=1 (flu 7.5/Cine 7.5, EP-3.75), CDI=2 (flu 6/Cine 15), CMU=3 (flu 7.5/Cine 15), มน-4(flu 7.5/Cine 15), มศว-5 (flu 15/Cine 15),
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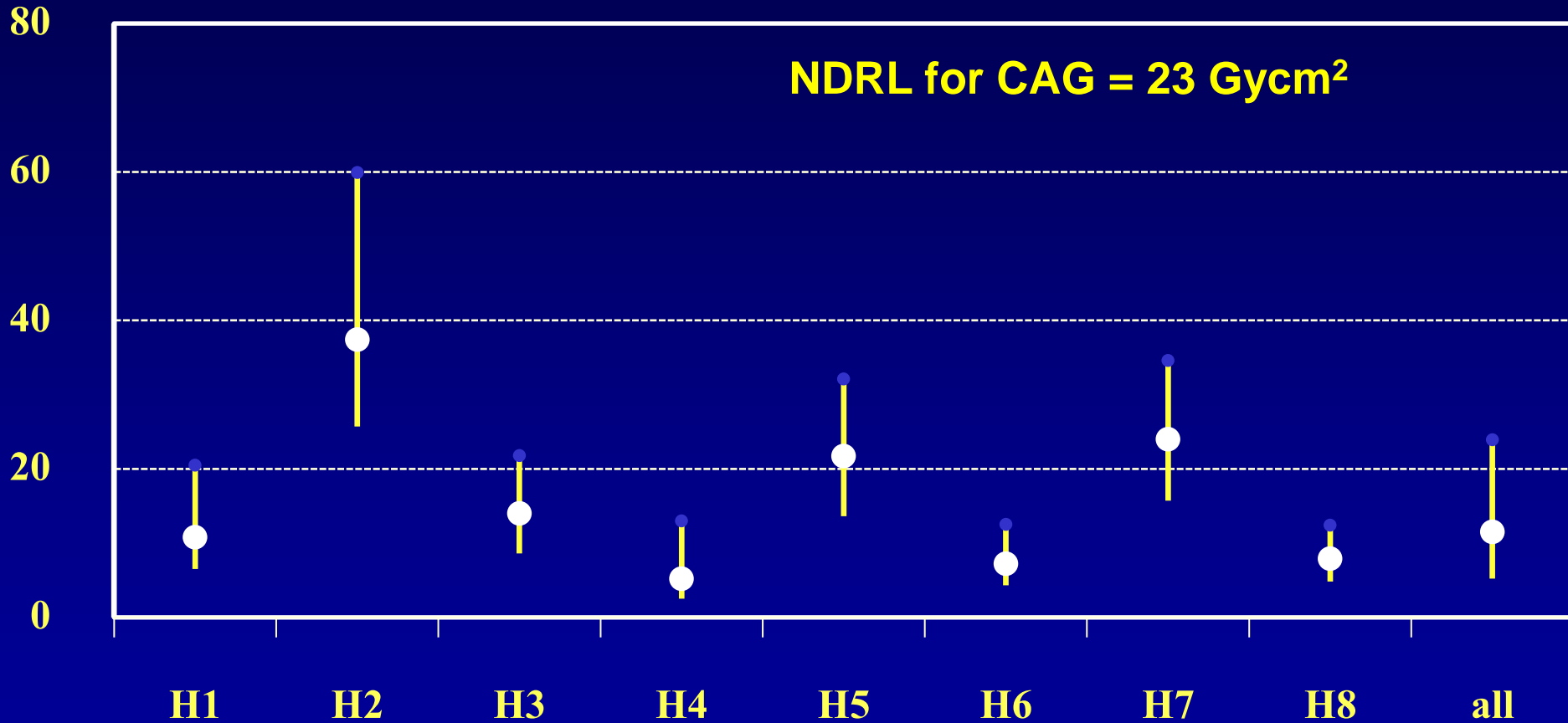
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DRLs for CAG: KAP (Gycm²)

(9 Hospitals in Thailand – during 2021-2022, n = 5250)

Gycm²



CU=1 (flu 7.5/Cine 7.5, EP-3.75), CDI=2 (flu 6/Cine 15), CMU=3 (flu 7.5/Cine 15), มน-4(flu 7.5/Cine 15), มศว-5 (flu 15/Cine 15),
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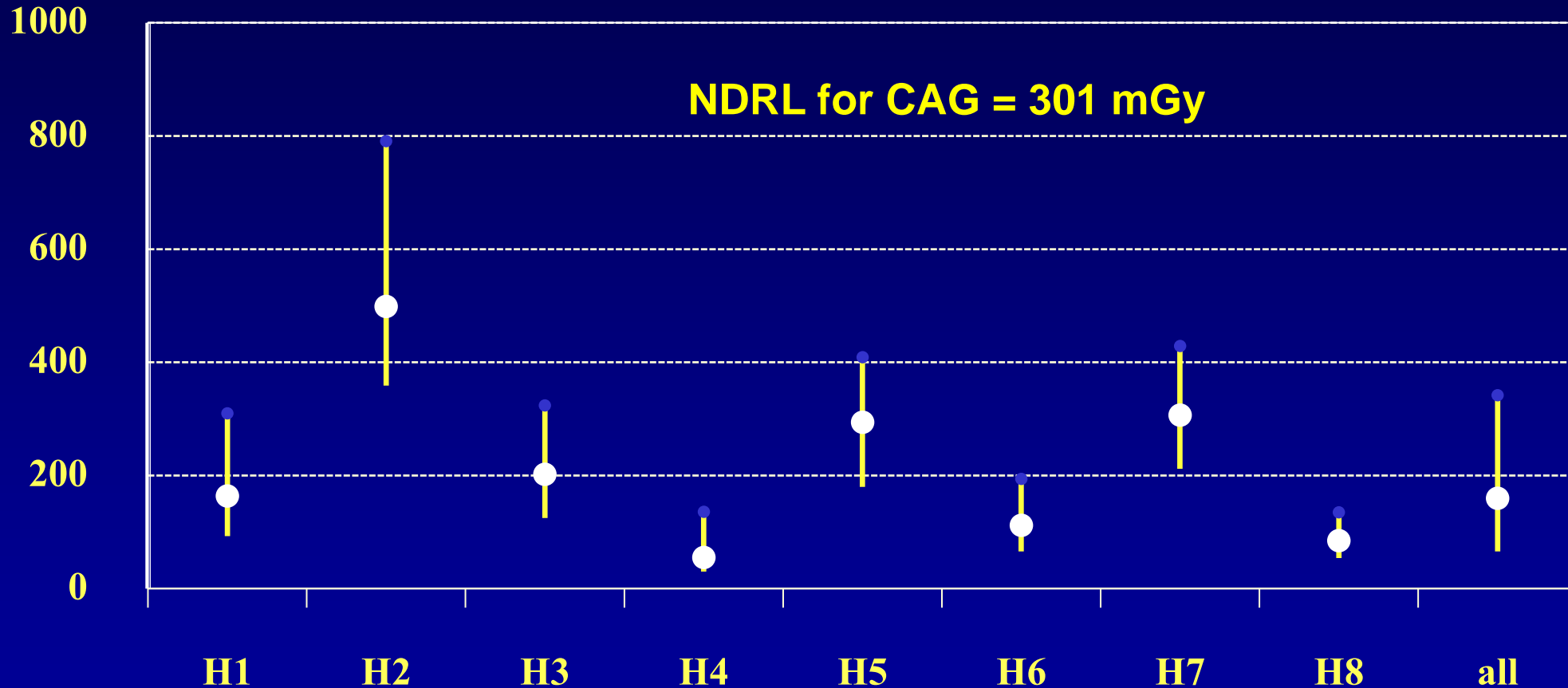
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DRLs for CAG: Air Kerma (mGy)

(9 Hospitals in Thailand – during 2021-2022, n = 5250)

mGy



CU=1 (flu 7.5/Cine 7.5, EP-3.75), CDI=2 (flu 6/Cine 15), CMU=3 (flu 7.5/Cine 15), มน-4(flu 7.5/Cine 15), มศว-5 (flu 15/Cine 15),
 ลำปาง-6(flu 7.5/Cine 7.5), ศูนย์สิริกิติ์ มท=7 (flu 15/Cine 15), สุราษฎร์=8 (flu 7.5/Cine 7.5), Ramathibodi=9 (flu 7.5/Cine 7.5),



Summary

- **This is the first data available in Thailand (and probable in SEA) for DRL in common cardiac procedures.**
- **When compared with other countries, our DRL are a bit higher than European countries but lower than Korea.**
- **We recommended to use lower frame rate (7.5 f/s) acquisition instead of 15 f/s for lower radiation exposure.**
- **Dose surveys to specialist areas offers important insights to practitioners on dose and image quality.**



Summary

- **It is useful to understand the relative patient doses associated with fluoroscopy.**
- **If the values of DRL quantities for patients are higher than expected, the investigation should start with**
 - : evaluation of equipments, then**
 - : evaluation of procedure protocols**
 - : evaluation of operator technique**
- **Equipment faults or incorrect set up are easiest to evaluated and correct.**
- **While operator performance is the most difficult process to analyze and influence.**



Thank you for your attention