

# **PATIENT AND STAFF DOSES IN INTERVENTIONAL NEURORADIOLOGY**

**Dođan Bor<sup>1</sup> Ph.D, Saruhan ekirge<sup>2</sup>, M.D, Trkay Toklu<sup>1</sup> M.Sc.,  
Turan Olđar<sup>1</sup> M.Sc., Miyase Glay<sup>1</sup> M.Sc., Elif nal<sup>1</sup> M.Sc.,  
Barbaros il<sup>2</sup> M.D**

1:Ankara University Faculty of Engineering Department of Engineering Physics

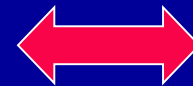
2: Hacettepe University Faculty of Medicine Department of Radiology

Ankara, Turkey

# INTRODUCTION

- Dose - Area Product (DAP) and entrance doses were measured simultaneously in a sample of 57 patients for diagnostic and therapeutical neurovascular examinations
- Staff doses were also assessed together with patient dose measurements

Measured dose quantity from patient



Staff dose

# THREE RADIOLOGISTS AND ONE RADIOGRAPHER INVOLVED WITH 57 PATIENT EXAMINATIONS

		RD1	RD2	RD3	RAD
<b>CEREBRAL</b>	Diagnostic	-	14	3	24
	Therapeutical	13	21	8	20
<b>CAROTID</b>	Diagnostic	-	2	1	4
	Therapeutical	2	4	-	2
<b>Total</b>		<b>15</b>	<b>41</b>	<b>12</b>	<b>50</b>

# SIEMENS NEUROSTAR TOP BIPLANE ANGIOGRAPHY SYSTEM

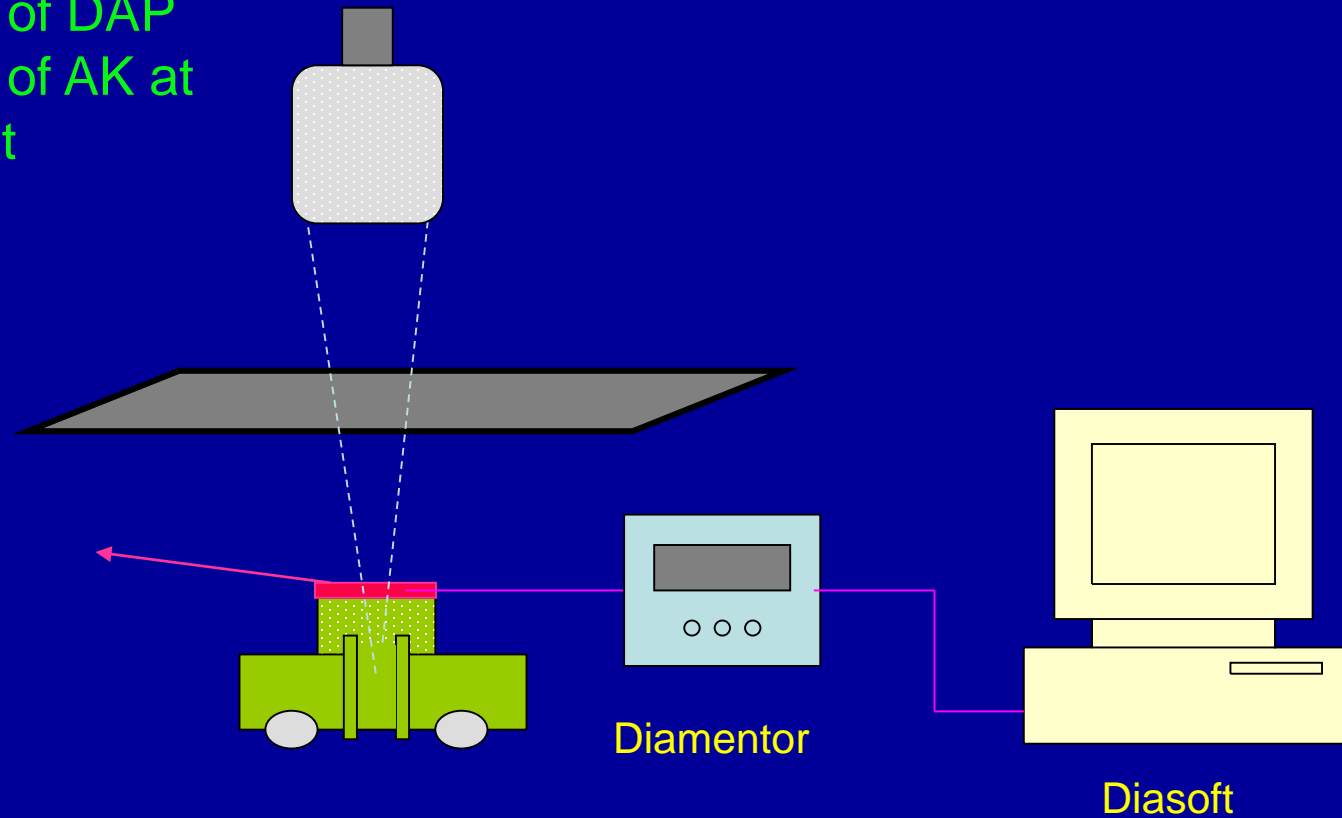
	Input Patient Exposure Rate		Image Intensifier Input Exposure Rate		HVL (mm-Al)
	Fluoroscopy (mGy/min)	Radiography (mGy/frame)	Fluoroscopy ( $\mu$ Gy/min)	Radiography ( $\mu$ Gy/frame)	
Tube A	4.27 (70 kVp – 0.15 mAs)	0.77 (73 kVp – 8.4 mAs)	22.6 (70 kVp – 0.14 mA)	2.56 (73 kVp – 7.3 mAs)	6.43
Tube B	4.11 (70 kVp – 0.14 mAs)	0.67 (73 kVp – 7.0 mAs)	21.3 (70 kVp – 0.14 mAs)	2.78 (73 kVp – 9.9 mAs)	5.52

- According to IPEM Protocols
- RADCAL instruments were used in these measurements

# DOSIMETRIC SYSTEM FOR PATIENT DOSE MEASUREMENTS

## DIAMENTOR M4KDK

- Measurement of DAP
- Measurement of AK at a specific point



## TLD - 100

- Measurement of skin doses (3.7 x 3.7 x 0.9 mm Chips)

# INITIAL CALIBRATIONS

## M4KDK Calibrations

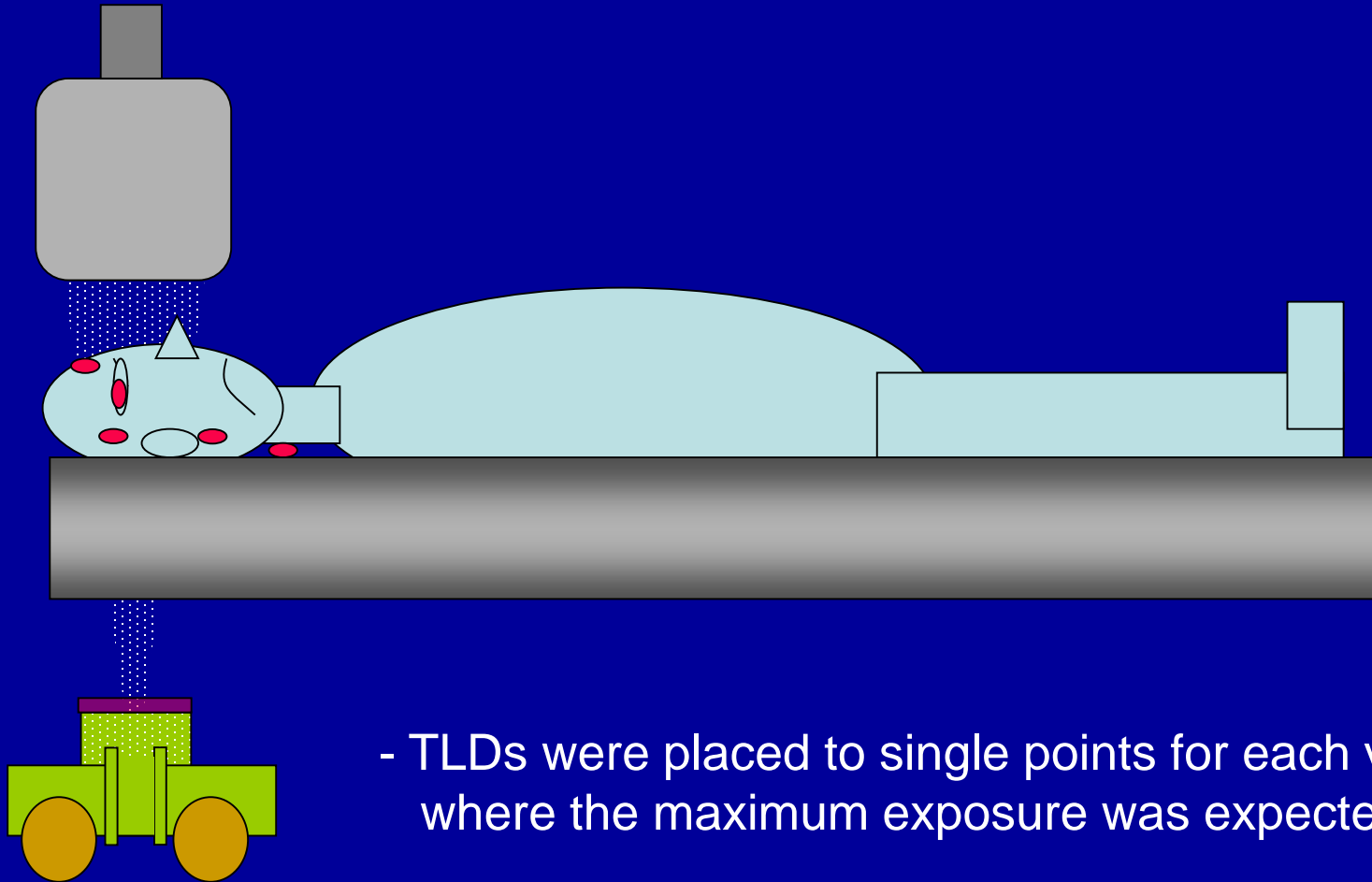
- Determine the calibration factor for DAP and AK using a reference ion chamber

## TLD Calibrations

- Batch to batch variability is within the  $\pm 5\%$

## Measurement of Table Attenuation Factor

# LOCATION OF TLDs



- TLDs were placed to single points for each view where the maximum exposure was expected
- Two chips were used for each point

# DATA ACQUISITION FOR PATIENTS

- DAP and AK measurements were recorded separately for each projection for retrospective evaluation.
- Position of the patient and irradiation geometry were continuously observed and recorded (PA, LLAT etc.)
- Fluoroscopic and Radiographic exposure parameters were recorded on-line

# RECORDED EXPOSURE PARAMETERS

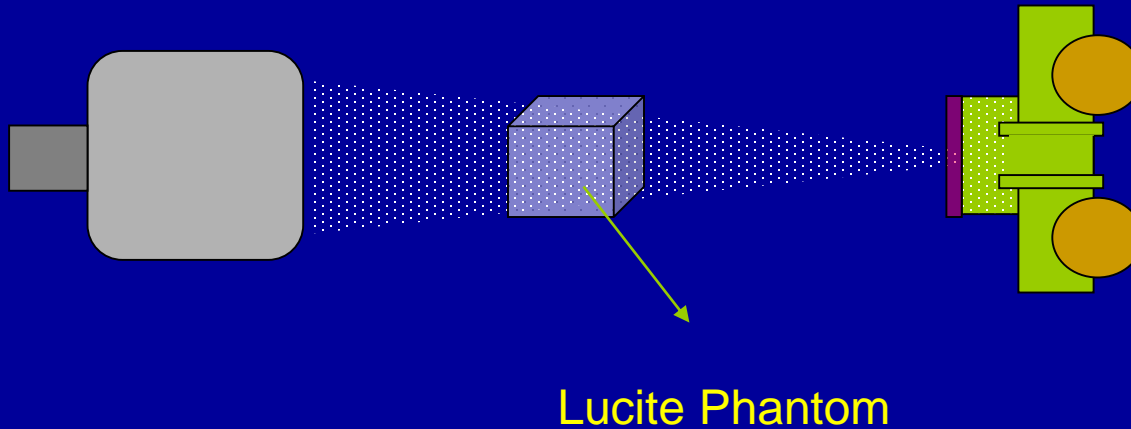
- Fluoroscopy

- Projection
- II FOV
- II angle
- Average mA
- Average kVp
- Fluoroscopy time
- Table-Focus distance
- DAP ( $\text{Gycm}^2$ )
- AK (mGy)

- Radiography

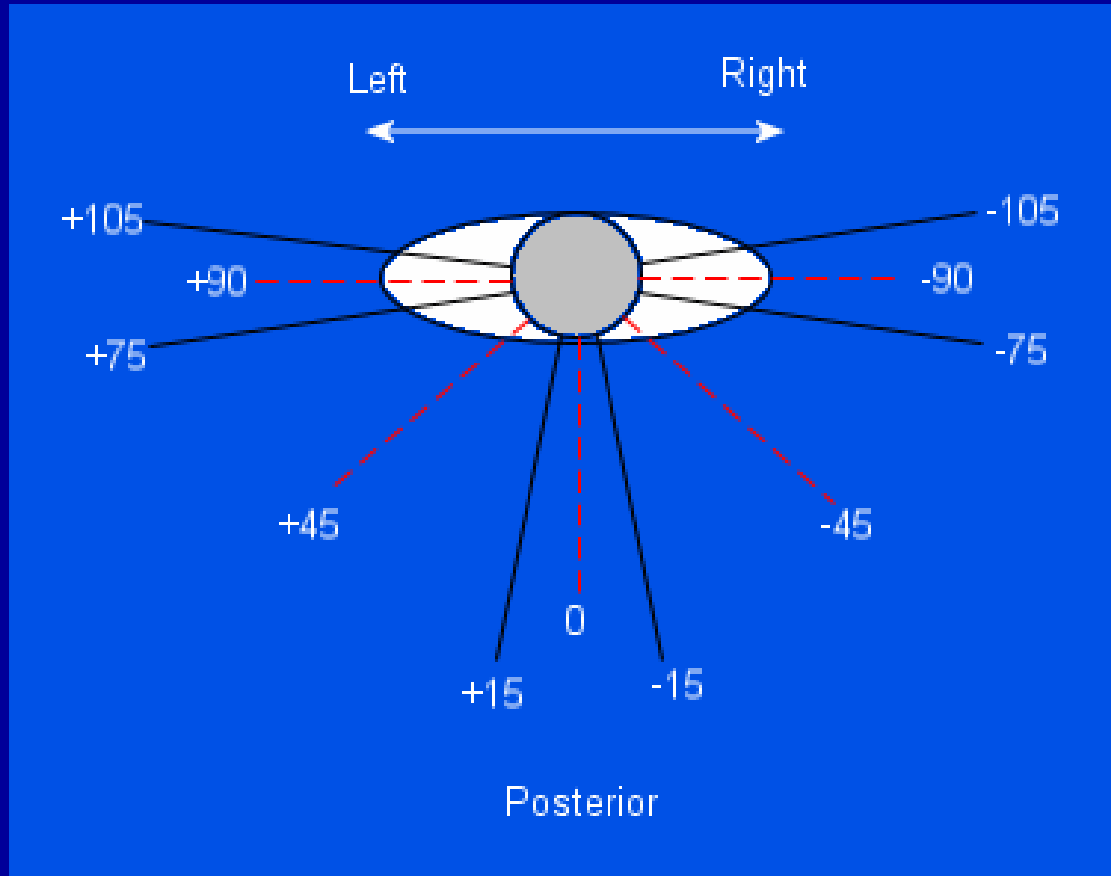
- Projection
- II FOV
- II angle
- mA
- kVp
- Puls width (ms)
- Frames / sec
- Total # of frames
- Table-Focus distance
- DAP ( $\text{Gycm}^2$ )
- AK (mGy)

# CONTRIBUTION OF SECOND X-RAY TUBE (PHANTOM EXPERIMENT)



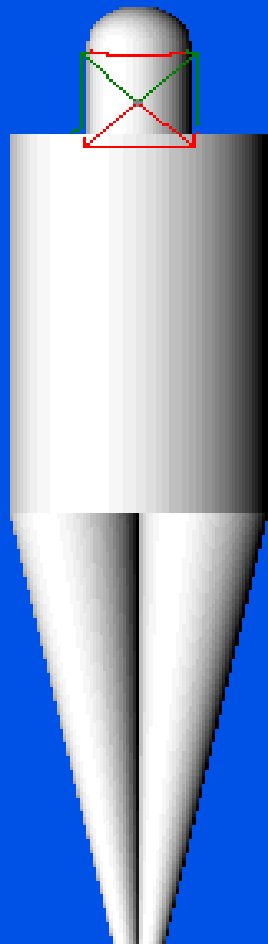
Measurement of DAP and AK  
for 1 Min of fluoroscopy  
and 1 frame of digital acquisition  
(for all exposure modes and FOVs)

# PARTITION OF ROTATIONAL ANGIOGRAPHY TO THE PROJECTIONS

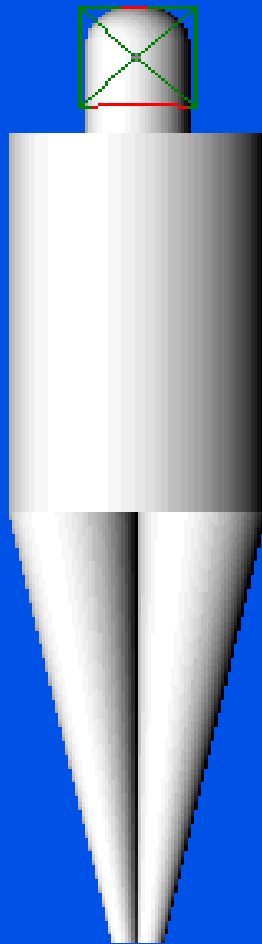


Contribution to the total DAP is 10-15 %

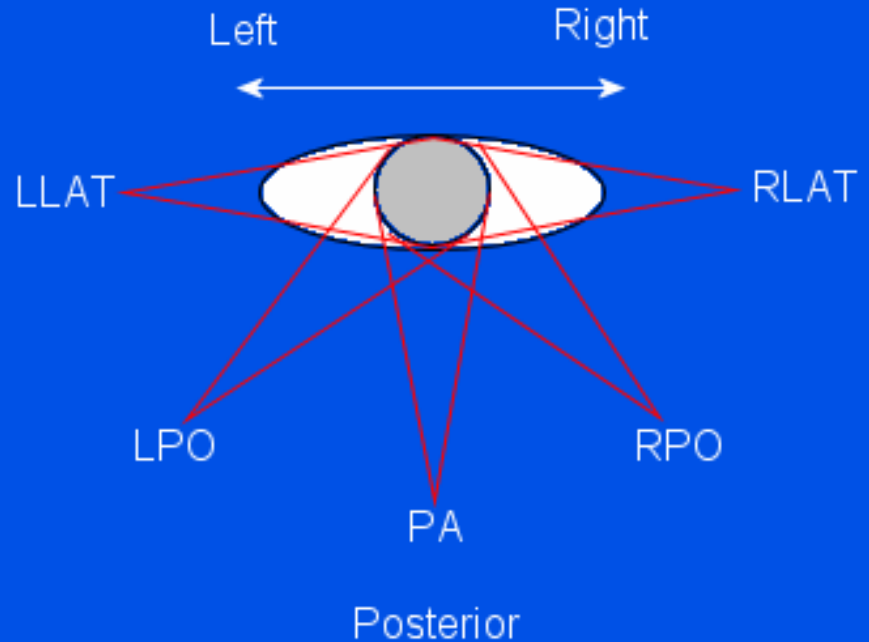
# SIMULATED PROJECTIONS



Carotid

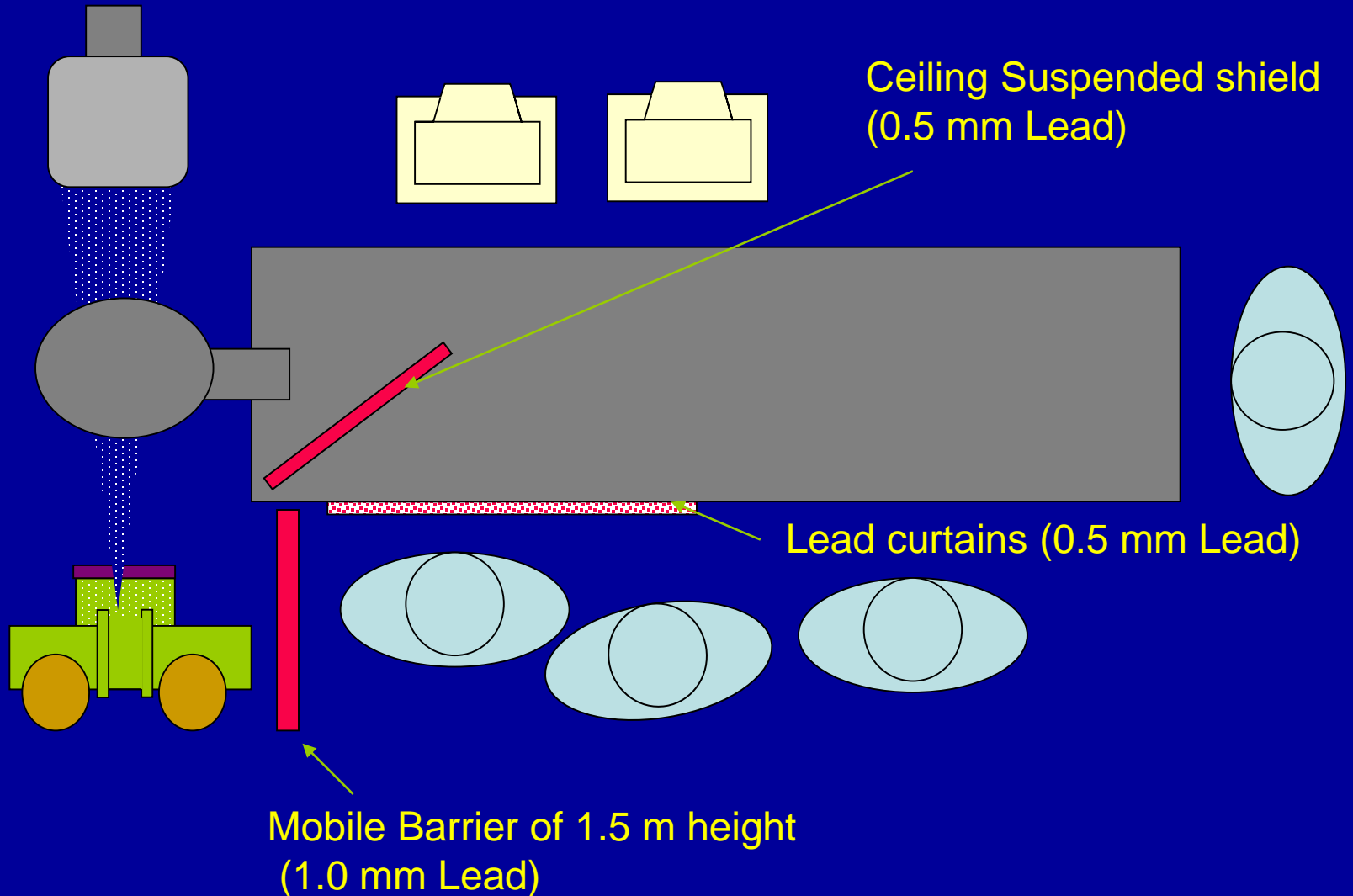


Cerebral



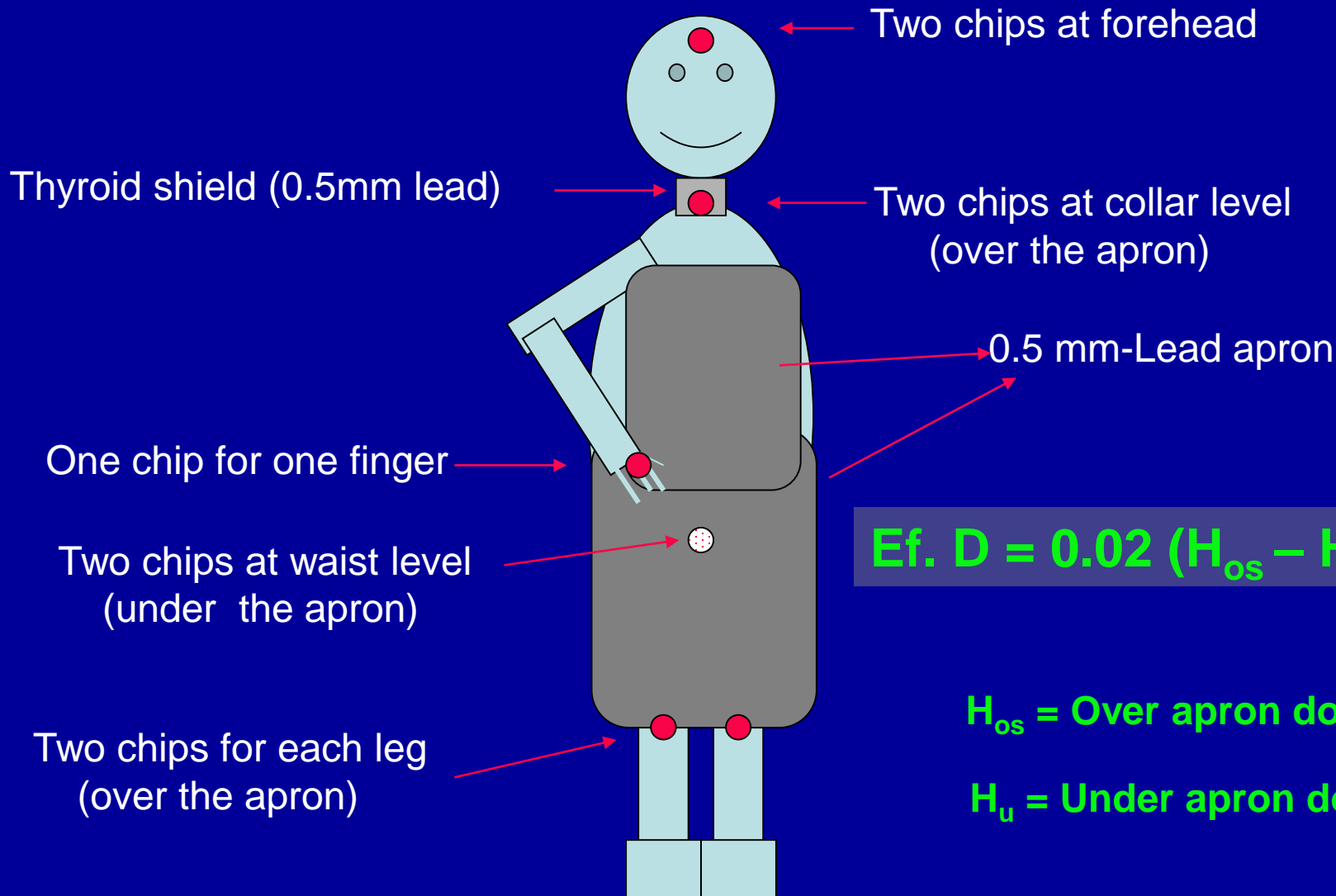
Effective doses were calculated from DAP results of each projection  
Using PCXMC software package

# POSITION OF THE STAFF AND USE OF PROTECTION DEVICES



# STAFF DOSE MEASUREMENTS

These dosimeters were used only during the patient dose measurements

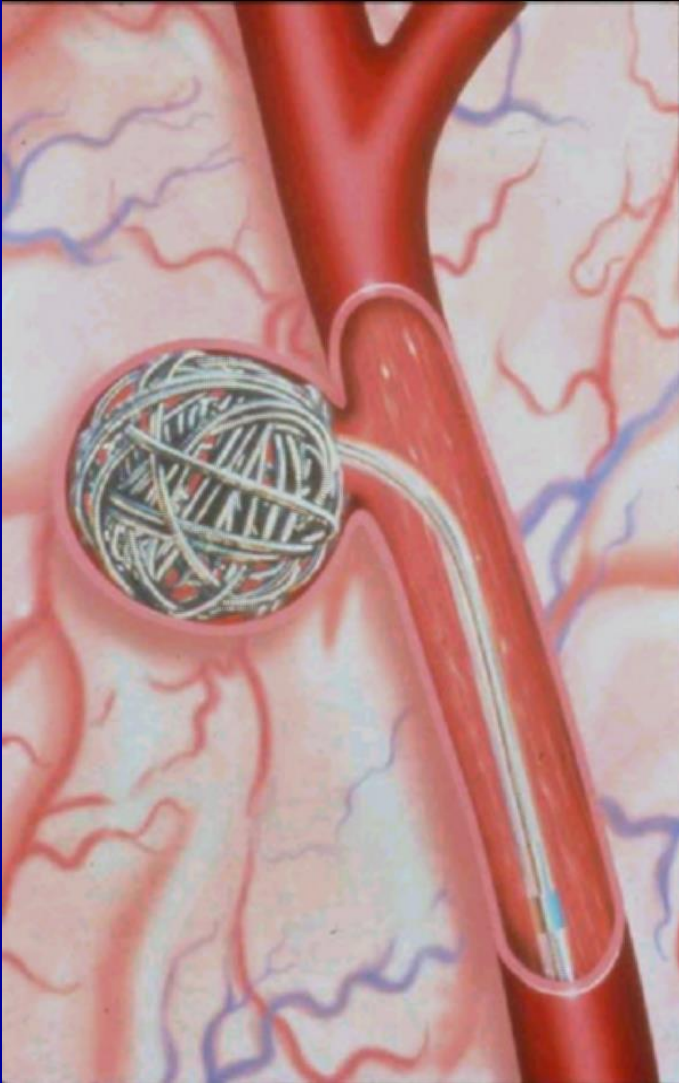


$$Ef. D = 0.02 (H_{os} - H_u) + H_u$$

$H_{os}$  = Over apron dose

$H_u$  = Under apron dose

# CLINICAL PROCEDURE

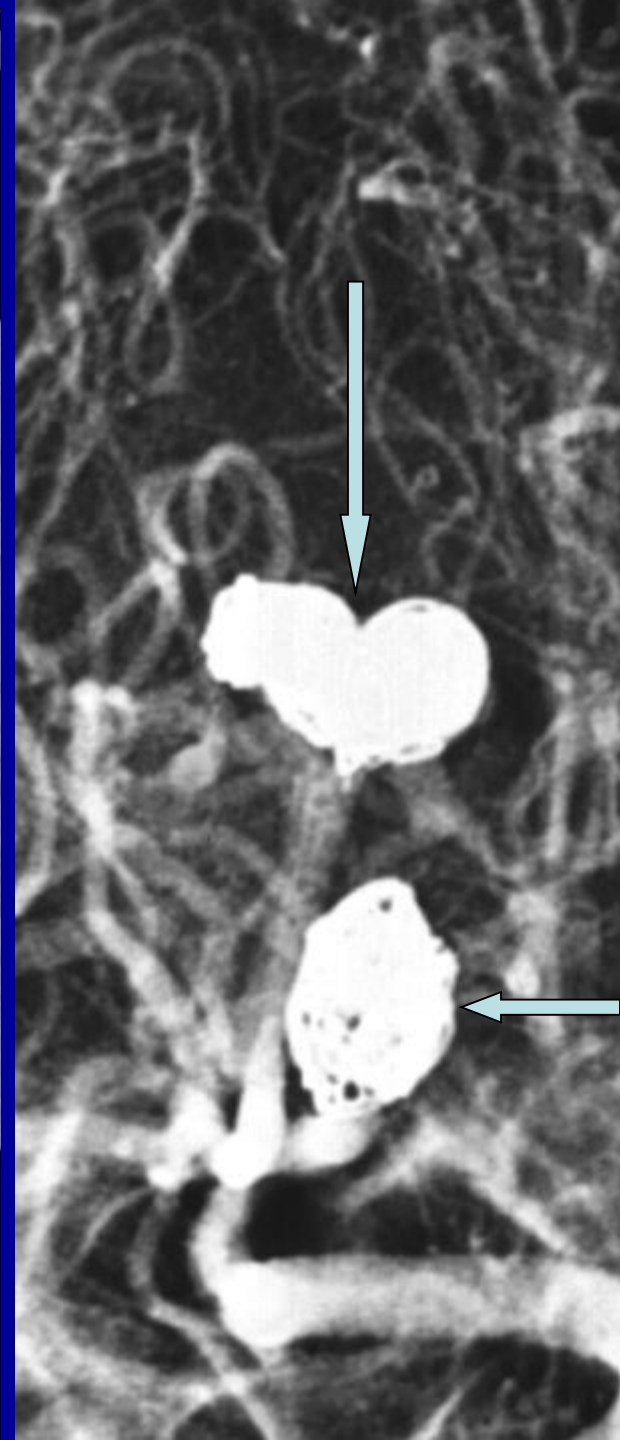
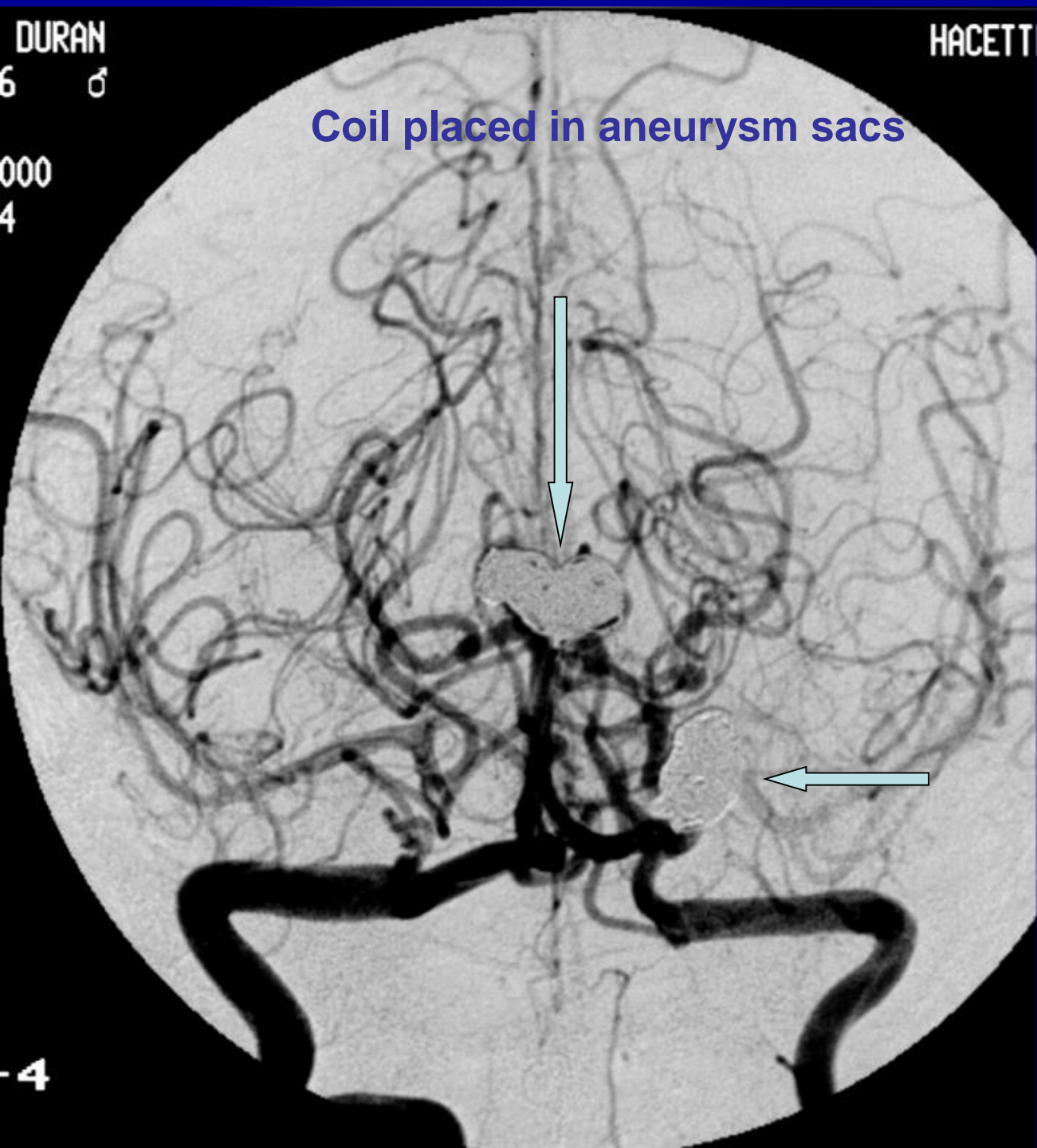


**Intracranial aneurysm**

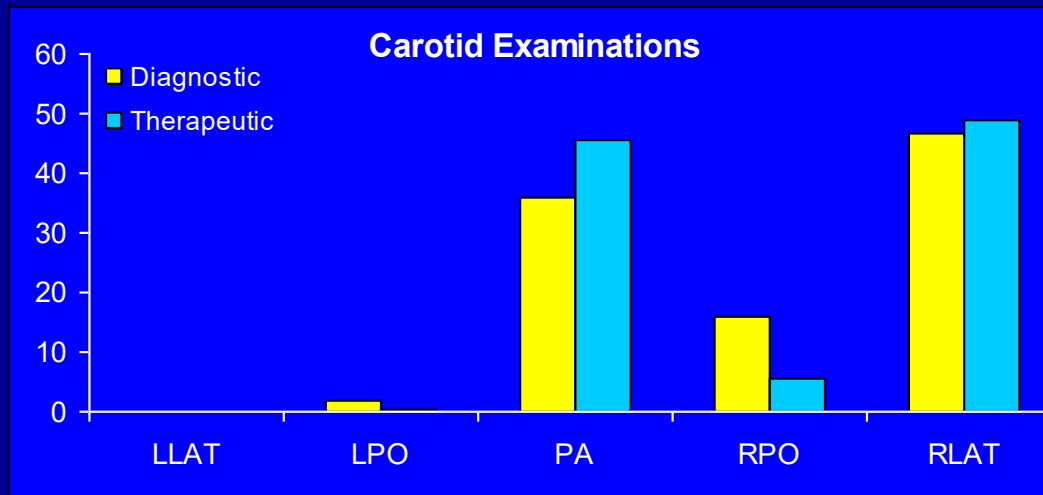
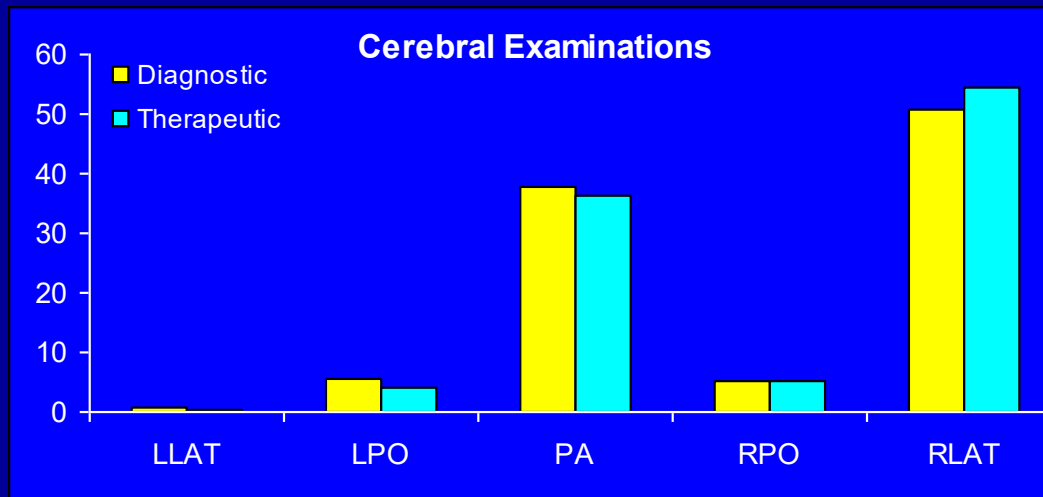


Microcatheters placed in aneurysm for coiling





# PERCENTAGE OF TOTAL DAP FOR EACH PROJECTION



# PERCENTAGE USE OF MAGNIFICATION FACTORS

		PA Projection				RLAT Projection			
FOV:		<b>33</b>	<b>22</b>	<b>17</b>	<b>13</b>	<b>33</b>	<b>22</b>	<b>17</b>	<b>13</b>
IPER (mGy/min):		4.2	7.6	11.5	18.7	4.11	7.05	11.0	17.8
Cerebral	Diagnostic	19 %	78 %	3 %	---	88 %	12 %	---	---
	Therapeutic	8 %	63 %	10 %	19 %	58 %	15 %	10 %	17 %
Carotid	Diagnostic	12 %	69 %	19 %	---	92 %	8 %	---	---
	Therapeutic	16 %	83 %	1 %	---	52 %	29 %	19 %	---

IPER: Input Patient Exposure Rate

# DAP AND EFFECTIVE DOSES FOR CEREBRAL STUDIES

			Fluoroscopy DAP (Gycm <sup>2</sup> )	DSA DAP (Gycm <sup>2</sup> )	Total DAP (Gycm <sup>2</sup> )	Effective Dose (mSv)
Cerebral	Diagnostic	Total	16.7(1.6-77.6)	74.8(20.6-175.5)	<b>91.5(29.2-217.1)</b>	---
		LLAT	0.001(0.0-0.03)	0.57(0.0-11.4)	0.57(0.0-11.4)	0.04(0.0-0.75)
		LPO	0.75(0.0-3.5)	4.4(0.0-14.2)	5.2(0.0-14.9)	0.3(0.0-1.0)
		PA	11.3(0.5-74.8)	23.4(6.0-55.4)	34.6(10.7-81.7)	1.7(0.5-4.3)
		RPO	2.3(0.0-15.0)	2.5(0.0-14.1)	4.8(0.0-22.8)	0.3(0.0-1.4)
		RLAT	2.4(0.2-11.8)	43.8(8.0-108.7)	46.2(8.4-120.5)	2.8(0.5-7.2)

Therapeutic	Total	58.1(15.7-144.5)	157.6(80.8-257)	<b>215.7(100.2-394)</b>	---
	LLAT	0.0(0.0-0.0)	0.5(0.0-3.0)	0.5(0.0-3.0)	0.03(0.0-0.2)
	LPO	2.3(0.0-21.4)	6.5(0.0-40.2)	8.8(0.0-56.8)	0.6(0.0-3.9)
	PA	27.5(7.7-61.4)	50.5(24.6-96.1)	78.0(32.8-157.5)	4.1(1.8-7.9)
	RPO	5.6(0.0-34.4)	5.5(0.0-39.7)	11.1(0.0-74.1)	0.8(0.0-5.6)
	RLAT	22.8(1.6-83.1)	94.5(22.0-153.6)	117.3(27.7-237)	7.9(1.7-15.3)

# COMPARISON OF DAP AND FLUOROSCOPY TIME (CEREBRAL STUDIES)

	Reference	DAP (Fluoro. Time ) Gy-cm <sup>2</sup> (Min)	%DAP <sub>Fluor.</sub>	%DAP <sub>DSA.</sub>
Therapeutical	Marshall NW	122 ( 8 )		
	McParland BJ	105 ( 34 )		
	Bergeron P	168		
	Gfirtner H	140 ( 40 )		
	Zoetelief J	53		
	Ruiz-Cruces R	83 ( 17.7 )		
	<b>This Work</b>	<b>215.7 ( 48.4 )</b>	<b>27%</b>	<b>73%</b>
Diagnostic	Vano E	68.2		
	Kaufman GW	30 ( 11 )		
	Marshall NW	48 ( 4.7 )		
	McParland BJ	74.1 ( 12.1 )		
	Gfirtner H	92 ( 11.5 )		
	Zoetelief J	43		
	<b>This Work</b>	<b>91.5 ( 10.6 )</b>	<b>18%</b>	<b>82%</b>

# DAP AND EFFECTIVE DOSES FOR CAROTID STUDIES

			Fluoroscopy DAP (Gycm <sup>2</sup> )	DSA DAP (Gycm <sup>2</sup> )	Total DAP (Gycm <sup>2</sup> )	Effective Dose (mSv)
Carotid	Diagnostic	Total	33.2(11.7-65.7)	98.6(66.0-136.9)	131.8(88.8-161)	---
		LLAT	0.0(0.0-0.0)	0.0(0.0-0.0)	0.0(0.0-0.0)	0.0(0.0-0.0)
		LPO	0.6(0.0-2.5)	1.5(0.0-7.6)	2.2(0.0-8.3)	0.2(0.0-0.7)
		PA	11.3(6.7-18.5)	36.0(23.8-57.8)	47.3(7.6-64.5)	2.5(2.0-3.3)
		RPO	16.5(0.0-52.7)	4.3(0.0-8.1)	20.8(0.0-60.8)	1.4(0.0-4.0)
		RLAT	4.8(1.5-13.4)	56.8(40.4-79.1)	61.6(41.8-84.0)	7.0(4.7-9.4)

	Therapeutic	Total	85.6(44.7-182.8)	103.0(66.4-144)	188.6(111.1-327)	---
		LLAT	0.0(0.0-0.0)	0.0(0.0-0.0)	0.0(0.0-0.0)	0.0(0.0-0.0)
		LPO	0.0(0.0-0.0)	0.4(0.0-1.6)	0.4(0.0-1.6)	0.04(0.0-0.15)
		PA	49.8(22.1-113.6)	36.0(19.7-60.2)	85.8(44.4-173.8)	5.0(2.4-10.4)
		RPO	9.6(1.1-28.8)	0.7(0.0-2.9)	10.3(1.1-28.8)	0.7(0.1-1.9)
		RLAT	26.2(17.8-40.5)	65.9(38.5-82.4)	92.1(56.3-122.9)	10.7(6.4-15.0)

# COMPARISON OF DAP AND FLUOROSCOPY TIME (CAROTID STUDIES)

Reference		DAP (Fluoro. Time ) Gy-cm <sup>2</sup> (Min)	%DAP <sub>Fluor.</sub>	%DAP <sub>DSA.</sub>	
McParland BJ		49.3 ( 10.3 )			
Steele HR		27.4 ( 3.9 )			
Williams J		61			
Mini RL		98 ( 3.8 )			
Broadhead DA		61.4			
<b>This Work</b>	}	<b>Diag.</b>	<b>131.8 ( 16.5 )</b>	25%	75%
		<b>Ther.</b>	<b>188.6 ( 50.1 )</b>	45%	55%

# CALCULATION OF EFFECTIVE DOSES

Calculation for each projection :

<u>DAP Gy-cm<sup>2</sup></u>	<u>Effective Dose (mSV)</u>
PA : 85 ----->	4.22
RPO : 10 ----->	0.66
RLAT : 92 ----->	<b>10.42</b>
<hr/> Total : 188	<hr/> 15.3

Averaging of projections and use of single conversion factor and total DAP:

$$\sum \text{DAP} = 188 \text{ Gy-cm}^2 \quad \text{Eff. D.} = \mathbf{9.34} \text{ (using the conversion factor of PA view)}$$

# COMPARISON OF PATIENT EFFECTIVE DOSES

	Range	Mean
McParland	2.1 – 20	7
Feygelman	1.6 – 14	6.2
Bergeron	0.44 – 3.4	1.8
Berthelson		3.5
Cederblad		25
	? - 152	33
Gkanatsios*	? – 156	74
Cereb. Diag.	(1.7-11.8)	5.2
Cereb. Ther.	(5.6-23.2)	13.4
T.W.		
Car. Diag.	(7.3-13)	11.2
Car. Ther.	(9.5-27.5)	16.4

# SKIN DOSES

## TOTAL FLUOROSCOPY TIMES

### TOTAL NUMBER OF RADIOGRAPHIC FRAMES (Cerebral Studies)

			TLD (mGy)	ED (mGy)	Total Fluoroscopy Time (min)	Total # of Radiographic Frames
Cerebral	Diagnostic	LLAT	13.2(3.1-25.5)	0.6(0.0-6.0)	10.6(1.7-33.0)	481(149-1088)
		LPO	---	22.2(0.0-76.8)		
		PA	95.4(18.3-337.9)	148.0(42.2-429.7)		
		RPO	---	24.7(0.0-95.9)		
		RLAT	76.6(.3-226.0)	169.9(28.0-403.4)		

Therapeutic	LLAT	89.7(13.3-994.8)	2.1(0.0-13.4)	48.4(5.3-140.0)	1250(526-1912)
	LPO	---	87.6(0.0-871.5)		
	PA	231.2(31.3-1426)	503.8(182.9-918.3)		
	RPO	---	138.5(0.0-1026.0)		
	RLAT	222.1(30.7-743.4)	626.3(117.3-1189)		

# SKIN DOSES

## TOTAL FLUOROSCOPY TIMES

### TOTAL NUMBER OF RADIOGRAPHIC FRAMES

#### (Carotid Studies)

			TLD (mGy)	ED (mGy)	Total Fluoroscopy Time (min)	Total # of Radiographic Frames
Carotid	Diagnostic	LLAT	27.7(12.0-57.6)	0.0(0.0-0.0)	16.5(7.9-26.7)	613(442-831)
		LPO	---	10.7(0.0-36.0)		
		PA	153.3(65.4-296.0)	201.1(152.1-244.4)		
		RPO	---	72.4(0.0-232.9)		
		RLAT	143.9(50.4-314.8)	221.1(140.1-281.4)		
Therapeutic		LLAT	32.6(12.0-50.1)	0.0(0.0-0.0)	50.1(38.4-76.8)	727(485-864)
		LPO	---	3.2(0.0-12.8)		
		PA	609.5(278.8-1354)	458.1(223.0-960.7)		
		RPO	---	45.2(5.6-117.9)		
		RLAT	438.8(227.1-927.6)	453.0(317.4-554.)		

# SKIN DOSES

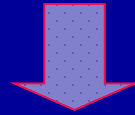
## Diagnostic Examinations:

$$(\text{Skin Dose})_{AK} > (\text{Skin Dose})_{TLD}$$

%55-%65 Higher (  $r^2 = 0.65$  )

## Therapeutical Examinations:

$$(\text{Skin Dose})_{AK} \gg (\text{Skin Dose})_{TLD}$$



Use of Magnification factors (small exposed areas )

Diagnostic Examinations: None

Therapeutical Examinations: %10 and %17 use of  
17" and 13" FOVs

# COMPARISON OF SKIN DOSES IN CEREBRAL STUDIES

Reference		Gy	Maximum reading
Norbash AM		1.52	
Bergeron P		0.615	
McParland BJ		0.340	
O'Dea TJ	Diag.	0.94	6.0
„	Ther.	2.1	8.8
Gkanatsios NA	Diag.	1.3 Frontal	5.1
„	„	0.6 Lateral	4.1
„	Ther.	2.8 Frontal	5.0
„	„	1.9 Lateral	5.2
<b>This Work</b>	<b>Diag.</b>	<b>0.15 (0.095)<sup>1</sup> PA</b>	<b>0.43 (0.33)</b>
„	„	<b>0.17 (0.076) RLAT</b>	<b>0.4 (0.22)</b>
„	<b>Ther.</b>	<b>0.5 (0.23) PA</b>	<b>0.9 (1.42)</b>
„	„	<b>0.62 (0.22) RLAT</b>	<b>1.2 (0.74)</b>

# PATIENT LENS DOSES

		Left Eye Lens Doses (mGy)	Right Eye Lens Doses (mGy)
Cerebral	Diagnostic	8.5 (2.5-37.2)	20.9 (4.9-66.7)
	Therapeutic	18.7 (7.8-38.5)	45.3 (14.7-86.4)
Carotid	Diagnostic	7.5 (5.3-10.7)	19.5 (13.3-28.2)
	Therapeutic	10.2 (4.5-19.5)	24.6 (9.1-43.1)

# COMPARISON OF SKIN DOSES IN CEREBRAL STUDIES

<u>Reference</u>		<u>Mean Value (Gy)</u>		<u>Maximum reading (Gy)</u>
Norbash AM		1.52		
Bergeron P		0.615		
McParland BJ		0.340		
O'Dea TJ	Diag.	0.94		6.0
„	Ther.	2.1		8.8
Gkanatsios NA	Diag.	1.3 Frontal		5.1
„	„	0.6 Lateral		4.1
„	Ther.	2.8 Frontal		5.0
„	„	1.9 Lateral		5.2
This Work	Diag.	0.15 (0.095) <sup>1</sup>	PA	0.43 (0.33)
„	„	0.17 (0.076)	RLAT	0.4 (0.22)
„	Ther.	0.5 (0.23)	PA	0.9 (1.42)
„	„	0.62 (0.22)	RLAT	1.2 (0.74)

# STAFF DOSES

	RD1		RD2		RD3		RAD	
	N=15, 2760 Gy <sub>cm</sub> <sup>2</sup>		N=41, 6786 Gy <sub>cm</sub> <sup>2</sup>		N=12, 1844 Gy <sub>cm</sub> <sup>2</sup>		N=50, 7464 Gy <sub>cm</sub> <sup>2</sup>	
	μGy/Proc.	μGy/DAP	μGy/Proc.	μGy/DAP	μGy/Proc.	μGy/DAP	μGy/Proc.	μGy/DAP
Thyroid	44.7	0.243	12.7	0.077	29.2	0.190	14.4	0.097
Waist <sup>1</sup>	32.1	0.174	11.0	0.067	10.8	0.071	7.2	0.048
Eye	114.1	0.620	40.8	0.246	87.0 <sup>3</sup>	0.804 <sup>3</sup>	22.4	0.150
Left Finger	103.4	0.562	52.7	0.319	90.8	0.591	27.3 <sup>4</sup>	0.186 <sup>4</sup>
Right Finger	53.4	0.290	45.6	0.276	120.0	0.781	33.4 <sup>4</sup>	0.228 <sup>4</sup>
Left Leg	43.4	0.236	22.0	0.133	---	---	23.2	0.156
Right Leg	80.1 <sup>2</sup>	0.477 <sup>2</sup>	22.2	0.134	27.5	0.179	20.6	0.138

<sup>1</sup> Under Apron

<sup>2</sup> N=9, DAP=1513 Gy<sub>cm</sub><sup>2</sup>

<sup>3</sup> N=5, DAP=541 Gy<sub>cm</sub><sup>2</sup>

<sup>4</sup> N=47, DAP= 6903 Gy<sub>cm</sub><sup>2</sup> (Wrist)

RD: Radiologist

RAD: Radiographer

N: Number of patient

# STAFF EFFECTIVE DOSES AND EFFECTIVE DOSE TO DAP RATIOS

	RD1 <sup>1</sup>	RD2 <sup>2</sup>	RD3 <sup>2</sup>	RAD <sup>2</sup>
Eff.D. / Procedure ( $\mu\text{Sv} / \text{Proc.}$ )	32.32	13.23	11.20	7.36
Eff.D. / DAP ( $\mu\text{Sv} / \text{Gycm}^2$ )	0.176	0.078	0.073	0.049

<sup>1</sup> Involved only with therapeutical examinations

<sup>2</sup> Involved both with therapeutical and diagnostic examinations

# COMPARISON OF STAFF DOSES

Reference(N)	Eye	Thyroid	Hands	Legs	Abdomen
Kicken PJ (27)	10	15	55	98	22
„ (26)	9	20	31	18	-
„ (17)	20	27	27	66	30
Riley RC (26)	51	61	65		
Santen BC (37)	48	-	11		
Chopp M (18)	31	28	20		
Burgess AE (69)			10		
Tryhus M (10)	26	41	71		
HughesDG (53)	54		11		
„ (47)	62		43		
Marshall (30)	14		19		
This work	67.3	28.8	77.6	39	18 *

# **HIGHER PATIENT AND STAFF DOSES WERE MEASURED**

**Complexity of the procedure**

**Use of biplane system and rotational angiography**

**System design (Staff near the X-ray tube)**

**Frequent use of magnification factors**

**Frequent use of RLAT projection**