A comprehensive algorithm for radiation reduction for cardiac CTA with prospective gating and iterative image reconstruction

Ariel Gutstein, Gideon Shafir , nili zafrir,Ran Kornowsky

Rabin Medical Center, Beilinson Campus Cardiology and Radiology departments, Petach Tikva, Israel

To reduce radiation with CCTA....

- Tube current modulation : 20% dose reduction
- Prospective gating : 80% dose reduction
- Low tube voltage : 100 kVp or 80 kVp / 120 kVp : 40% dose reduction
- Iterative image reconstruction :15-20% dose reduction
- Flash mode :prospective spiral, high pitch (Siemens)

Background

Guidelines

SCCT guidelines on radiation dose and dose-optimization strategies in cardiovascular CT

Sandra S. Halliburton, PhD[a,*], Suhny Abbara, MD[b], Marcus Y. Chen, MD[c], Ralph Gentry, RT(R) (MR) (CT)[d], Mahadevappa Mahesh, MS, PhD[e], Gilbert L. Raff, MD[d], Leslee J. Shaw, PhD[f], Jörg Hausleiter, MD[g]

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Scan modes

Retrospective ECG-gated helical techniques may be used in patients who do not qualify for prospective ECG-triggered scanning because of
irregular heart rhythm or high heart rates or both (specific value depends on specific scanner characteristics and cardiovascular indication). Prospective ECG-triggered axial techniques should be used in patients who have stable sinus rhythm and low heart rates (typically
,60–65 beats/min, but specific values depend on specific scanner characteristics and cardiovascular indication). For prospective ECG-triggered axial techniques, the width of the data acquisition window should be kept at a minimum.

Tube potential

A tube potential of 100 kV could be considered for patients weighing> 90 kg or with a BMI > 30 kg/m2; a tube potential of 120 kV is usually indicated for patients weighing < 90 kg and with a BMI <30 kg/m2. Higher tube potential may be indicated for severely obese patients.

Problem ?

- When increasing tube voltage from 100 kVp to 120 kVp , radiation increases by 31-39%, at once ...

Table 2 Radiation doses of retrospective imaging with 64 MDCT based on body mass index (BMI)

BMI		Calcium scan		Retrospective		KvP		DLP	Estimated mSv including CAC scan
		kVp	mA	Max mA	Min mA				
				Int J Cardiovasc Imaging (2009) 25:279–287					
19 and less	250	120	300	280	140	100	C2/Small filte	244	4.148
20–22	275	120	350	325	170	100	C2/Small filte	289	4.913
23–25	300	120	375	350	190	100	C2/Small filte	311	5.287
26–28	325	120	450	425	215	100	C2/Small filte	359	6.103
29–31	350	120	500	475	240	120	C2/Small filte	640	10.88
32–35	375	120	600	575	290	120	C2/Small filte	772	13.124
36–37	400	120	700	650	290	120	C3/Med filter	954	16.218
≥38	425	120	800	750	375	120	C3/Med filter	1,170	19.89
>40	450	120	800	775	388	120	C3/Med filter	1,270	21.59

DLP dose length product; *kVp* killivolts; *mA* milliamperes; *CAC* coronary artery calcium scan

Buddof MJ Intern. J cardiovasc imaging 2009

How we did CTA 2009-2011 at RMC?

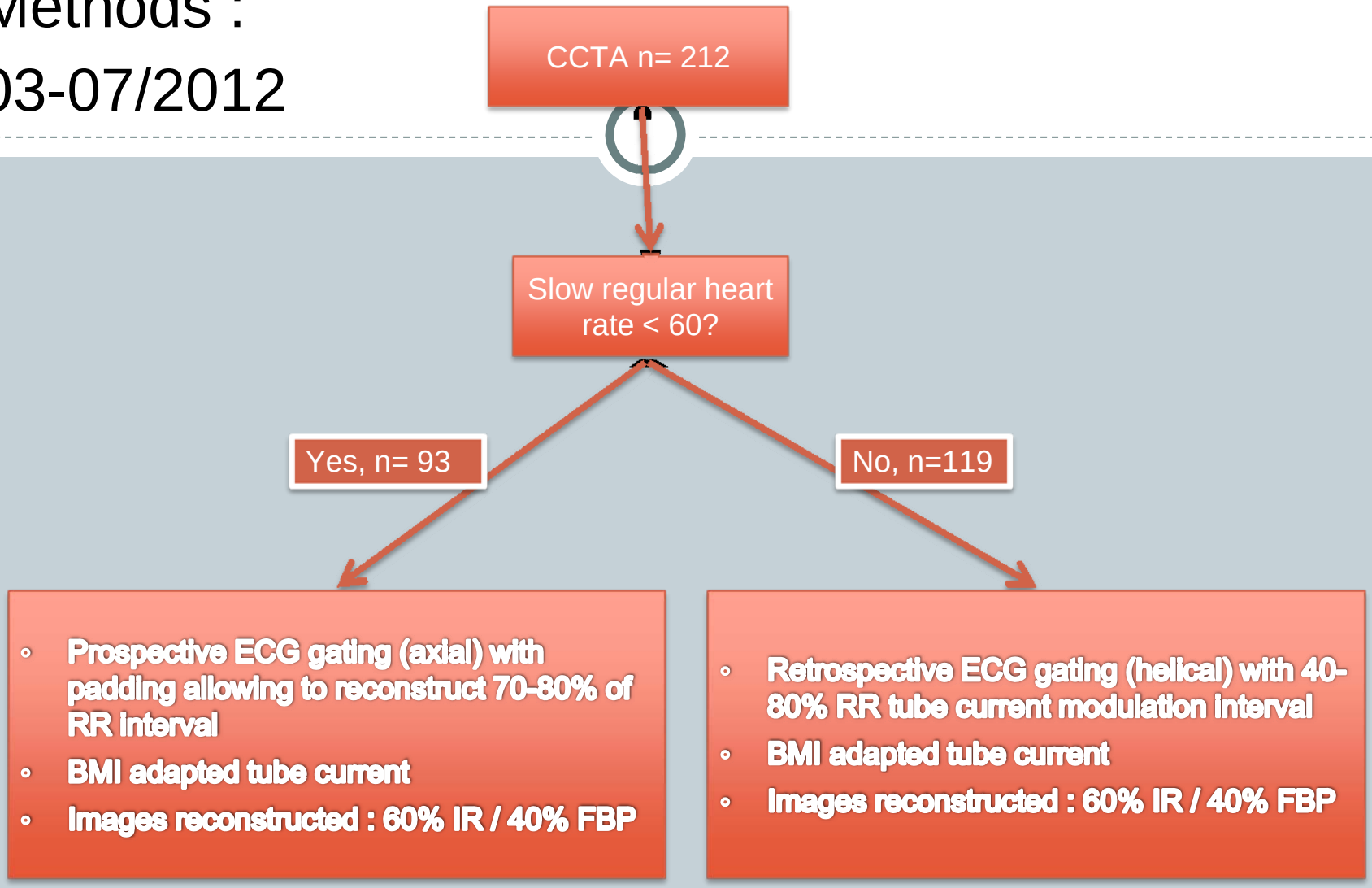
	BMI<25	25≤BMI<30	30≤BMI<35	BMI≥35
Estimated radiation (mSv)	4.6±0.9*	6.5±1.5	7.8±1.3	12.8±4.6#
Scan Length (mm)	122±20	120±10	116±8#	114±9
100 kVp : n(%)	29(100)	46(100)	24(96)	1(7.1)
Window: 70-80%	19(65.5)	26(56.5)	16(64)	10(71)
Tube current(mA)	344.8±15.2*	526.8±94.5	643±79	660±97
Noise (HU)	**30.1±5.9**	**31.5±5**	**31.5±5.6**	**30.6±6.5**
Contrast (HU)	709±120*	640+77	618±119	501.7±95.9#
CNR	24.2±4.9@	20.9±4.1	19.9±4.1	17.1±4.6**

Presented at the SCCT meeting Denver 2011

100 kVp	120 kVp

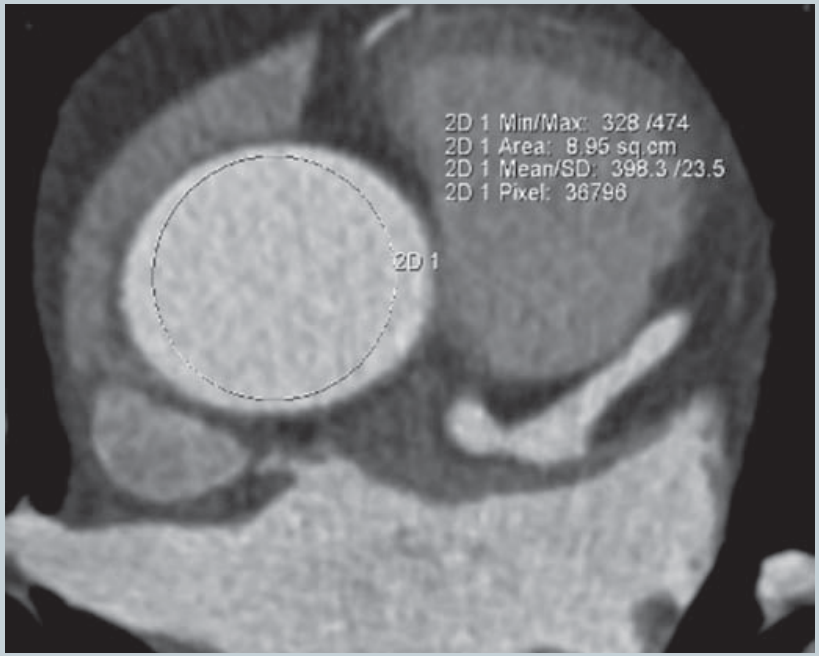
But in 3/2011 “clalit” finally upgraded the old 64-slices GE VCT with Prospective gating and iterative reconstruction in RMC….

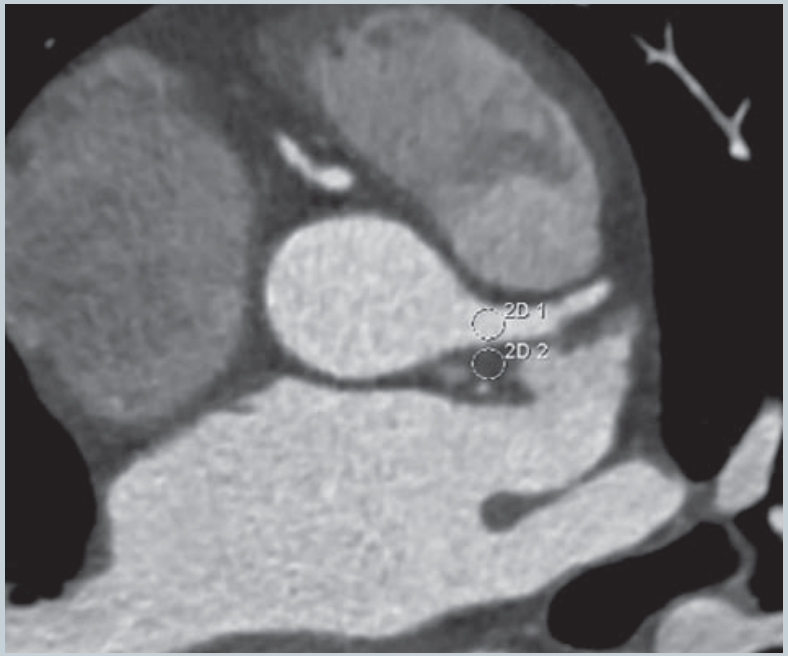
- Methods :
- 03-07/2012



Methods (2)

- Subjective image quality was graded 0 (non diagnostic) -3 (perfect) for each coronary artery. Image noise, contrast to noise (CNR) and signal to noise (SNR) ratios were measured





Methods (3) BMI adapted tube current (mA)

BMI (kg/m2)	mA	kVp
<18	250/175	80/100
19-20	300/200	80/100
21-23	250	100
24-25	300	100
26-27	350	100
28-29	400	100
30-31	500	100
32-35	600	100
36-39	700	100
>40	650	120

Results (1) Prospective gating

	BMI≤25(n=37)	25>BMI≤30 (n=39)	BMI>30 (n=17)	P value
Weight (kg)	67±9	80±10	95±13	<0.001
Height (cm)	170±9	173±10	170±10	ns
BMI	23.0±1.4	26.6±1.2	32.6±1.9	<0.001
Tube current (mA)	276±64	320±61	604±90	<0.001
Noise	35.0±6.6	36.1±8.4	34.6±8.5	ns
Signal to noise ration	20.9±5.0	18.1±4.1	19.4±5.4	0.012*
Contrast to noise ratio	20.6±5.0	18.2±4.5	18.8±5.4	0.02#
Radiation(mSv)	0.8±0.2	1.0±0.2	1.9±0.3	<0.001
DLP (mGy)	60.6±13.6	72.8±17	139±21	<0.001

* and # : Between BMI≤25 and the other groups

Results(2) : Retrospective gating

	BMI≤25(n=35)	25>BMI≤30 (n=39)	BMI>30 (n=45)	P value
Weight (kg)	62.7 ± 8.2	76.6±10	95.5±16	<0.001
Height (cm)	166±8	166±10	164±10	ns
BMI	22.6±2.0	27.5±1.3	35.2±4.5	<0.001
Tube current (mA) 80/100 kVp	402±58 / 302.3±38	571±76 / 421.9±56	622±90	<0.001
Noise	47.2±12.7	45.6±10	39.3±7.1	<0.001
Contrast to noise ratio	17.4±4.4	15.5±3.5	14.6±4.3	0.009
Radiation	3.6±1.4	5.4±1.3	8.0±2.9	<0.001
DLP	259±98	387±91	602±168	<0.001

Results: Diagnostic yield (3)

- 39/1116 (3.5%) non diagnostic segments and 7/93 (7.5%) non diagnostic studies in prospective-gating group, 5 needed to be repeated
- 7/1428 (0.5%) non diagnostic segments ($p<0.001$ with prospective gating) and 2/119 (1.7%) non diagnostic studies in retrospective-gating group ($p=0.07$)

Recent examples

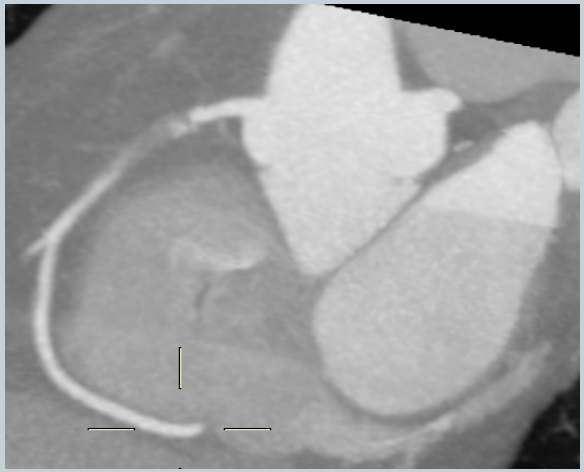
30 year old man with LDL 220, family history of IHD

admitted for chest pressure. Normal ECG, normal echoc ardiogram, negative troponin

Weighs 125 kg, 184 cm, BMI 37

Scanned with prospective gating, tube current 700 mA, 100 kVp

Radiation 2.2 mSv




AR: 8.42 mm²
AV: -53.00
SD: 27.82
Range: -125 - 4
AR: 166.45 mm²
AV: 614.00
SD: 27.85
Range: 537 - 709
AR: 12.43 mm²
AV: 605.00
SD: 24.48
Range: 527 - 687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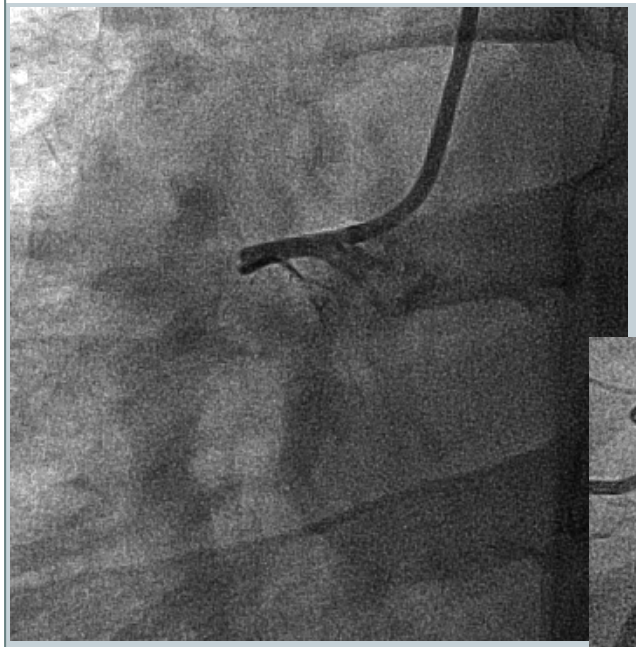
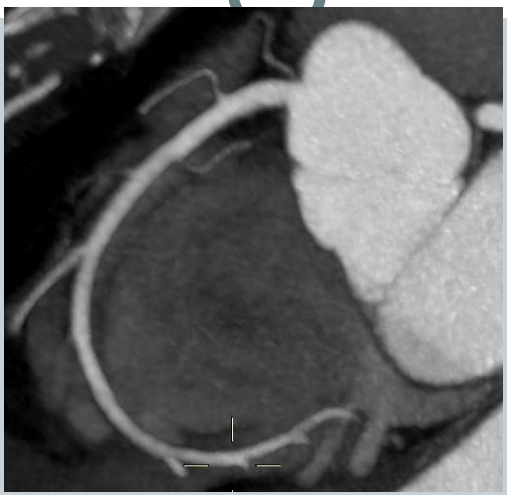
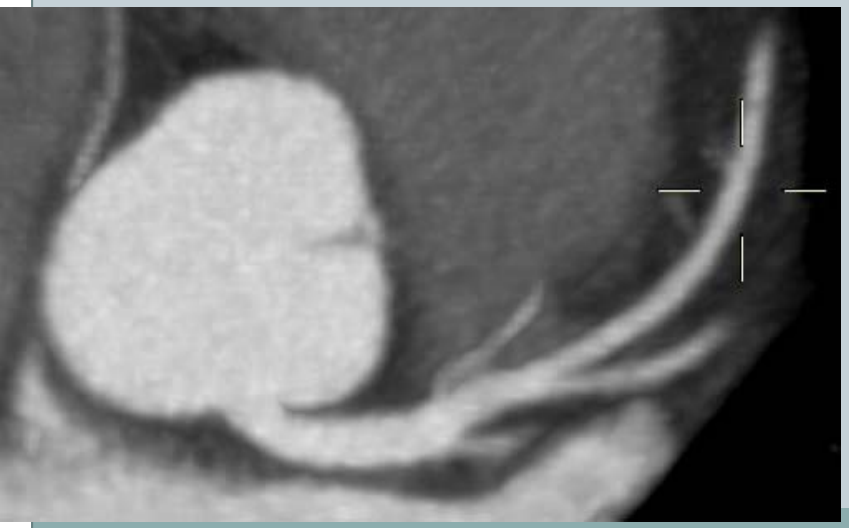
Invasive angiography



52 year old woman chest pain. 54 kilo 164 cm , BMI 20, scanned with 80 kVp , 275 mA





Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)
1	Scout	-	-	-
200	Axial	I61.250-I61.250	3.11	1.55
2	Cine	I65.000-I204.375	2.71	37.90
			Total Exam DLP:	39.45

0.56 mSv

Discussion

- The adaptation of tube current (mA) to patient's BMI allows to extend the use of 100 kVp up to a BMI < 40 and "saves" a lot of radiation. A simple table can be created for every scanner and used by technologists
- About half of the patients "eligible" for prospective gating with 64-slices CT.
- Better noise, SNR, CNR for the prospective gating group and very low radiation, however more non diagnostic segments and need to repeat study with 64-slice CT

Discussion (2)

- Use of 80 kVp for BMI > 22 creates high level of noise and is more complicated due to the need to compensate with higher mA. Not recommended.
- Globally although the noise level is higher for the “helical” group, SNR and CNR still in the normal range.

Conclusions

- BMI adapted tube current allows for a significant radiation reduction by extending the use of 100 kVp
- With 64- slice CT, about half the patients can be imaged with the combination of prospective gating ,iterative reconstruction and BMI adapted tube current and a short padding while obtaining very low radiation.
- Careful patient selection is warranted for performing prospective gating with 64-slice.

Thank you!