

Impact of Complex Lesions on Radiological Exposure during Percutaneous Coronary Intervention

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ABSTRACT

Background: Percutaneous coronary interventions (PCIs) in complex lesions are increasingly common in daily practice. The objective of this study was to determine the impact of complex lesions on radiological exposure during PCI. **Methods:** Prospective cohort study including patients undergoing PCI between August 2010 and December 2011. Clinical, angiographic and radiation exposure characteristics were recorded in a dedicated database. Patterns of radiation exposure (total dose received, fluoroscopy time and dose-area product) were determined in patients undergoing PCI for noncomplex (A/B1) and complex (B2/C) lesions. Data were analyzed by the SPSS 18.0 program. Independent radiation exposure predictors were determined by multiple logistic regression. **Results:** We analyzed 413 PCIs, 83 lesions in group A/B1 and 330 in group B2/C. There were no clinically significant differences between groups. The median radiation dose received by patients was significantly higher in group B2/C (1,103.9 mGy vs 866.6 mGy; $P < 0.01$). The dose-area product (43,484 mGy.cm² vs 58,327 mGy.cm²; $P < 0.001$) and fluoroscopy time (9 ± 6 minutes vs 12.1 ± 9.5 minutes; $P = 0.001$) were also significantly higher in group B2/C. Predictors of increased radiation exposure were weight [odds ratio (OR) 1.02 for each increase of 1 kg, confidence interval (CI) 1.01-1.036; $P = 0.004$], type B2/C lesion (OR 1.9, CI 1.002-4.96; $P = 0.002$). **Conclusions:** Patients undergoing PCI in complex lesions are significantly more exposed to radiation. Weight and lesion type (B2/C) are predictors of increased radiation exposure.

DESCRIPTORS: Angioplasty. Radiation, ionizing. Radiation exposure.

RESUMO

Impacto das Lesões Complexas na Exposição Radiológica Durante Intervenção Coronária Percutânea

Introdução: Intervenções coronárias percutâneas (ICPs) em lesões complexas são cada vez mais comuns na prática diária. O objetivo deste estudo foi determinar o impacto das lesões complexas na exposição radiológica durante ICP. **Métodos:** Estudo de coorte prospectiva incluindo pacientes submetidos a ICP entre agosto de 2010 e dezembro de 2011. Características clínicas, angiográficas e de exposição à radiação foram registradas em banco de dados específico. Os padrões de exposição à radiação (dose total recebida, tempo de fluoroscopia e produto dose-área) foram determinados em pacientes submetidos a ICP de lesões não-complexas (A/B1) e complexas (B2/C). Os dados foram analisados em programa SPSS 18.0. Preditores independentes de exposição à radiação foram determinados por regressão logística múltipla. **Resultados:** Foram analisadas 413 ICPs, sendo 83 lesões no grupo A/B1 e 330 no grupo B2/C. Não ocorreram diferenças clínicas significativas entre os grupos. A mediana de radiação recebida pelos pacientes foi significativamente maior no grupo B2/C (1.103,9 mGy vs. 866,6 mGy; $P < 0,01$). O produto doseárea (43.484 mGy.cm² vs. 58.327 mGy.cm²; $P < 0,001$) e o tempo de fluoroscopia (9 ± 6 minutos vs. $12,1 \pm 9,5$ minutos; $P = 0,001$) também foram significativamente maiores no grupo B2/C. Os preditores de exposição radiológica aumentada foram peso [razão de chance (RC) 1,02 para cada aumento de 1 kg, intervalo de confiança (IC) 1,01-1,036; $P = 0,004$] e lesão tipo B2/C (RC 1,9, IC 1,002-4,96; $P = 0,002$). **Conclusões:** Pacientes submetidos a ICP em lesões complexas são significativamente mais expostos à radiação. Peso e tipo de lesão (B2/C) são preditores de exposição radiológica aumentada.

DESCRIPTORES: Angioplastia. Radiação ionizante. Exposição a radiação.

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Fluoroscopy-guided interventional procedures are performed in large numbers around the world, with increasing frequency over the past 20 years.¹ In addition to the progressive increase in the number of interventions, procedure complexity has also increased.^{2,3}

Interventions in complex lesions⁴ involve greater technical difficulty, which results in higher costs, contrast volume, procedure time, and radiation exposure.⁵⁻⁷ Recent studies have demonstrated that many percutaneous coronary interventions (PCIs) exceed the dose of 2 Gy, the threshold for development of skin lesions. However, the literature has no specific studies focusing on lesion complexity.

Therefore, the objective of this study was to determine the impact of complex lesions on radiological exposure during PCI.

METHODS

Design

This was a prospective cohort study including patients undergoing PCI between August 2010 and December 2011.

Sample

After signing the informed consent form approved by the local ethics and research committee, patients requiring PCI had their procedures monitored in order to record the patterns of radiological exposure. Technical details of the PCIs were prospectively recorded and entered into a specific database.

Analysed characteristics

Data on age, gender, risk factors for cardiovascular disease, clinical presentation and procedure indications, ventricular function, number of affected vessels, treated vessels, characteristics of lesions, and success rate were collected and analyzed. Specific data on radiological exposure (dose received, dose-area product, and fluoroscopy time) were also collected.

Radiological exposure parameters

The radiological exposure of patients was measured by the amount of incoming radiation on the skin (cumulative air KERMA [Kinetic Energy Released per unit MA.s]). The fluoroscopy time and dose-area product were also measured to determine the time of radiological exposure and the irradiated area, respectively.

The procedures were performed in equipment with Philips Allura Xper FD10 monoplanar detectors (Philips = Einthoven, Netherlands) with three magnification fields (15 cm, 20 cm, and 25 cm), double filter (copper and

aluminium), and standard programming with image acquisition rate of 15 frames/second.

Statistical Analysis

The patients were divided into two groups for comparison, according to the classification of the type of lesion proposed by the American College of Cardiology/American Heart Association (ACC/AHA):⁸ patients undergoing PCI of noncomplex (type A/B1) and complex lesions (type B2/C). Data were prospectively collected and stored in a database using ACCESS software. For analysis, SPSS for Windows version 18.0 was used. The chi-squared test, Student's *t*-test, and the Mann-Whitney test were used for comparison. Independent predictors of increased radiation exposure (dose > 2 Gy) were determined by multiple logistic regression. Two-tailed *p*-value < 0.05 was considered statistically significant.

RESULTS

During the study period, 413 PCIs were analyzed: 83 in the group of A/B1 lesions and 330 in the group of B2/C lesions.

Patients in both groups had similar clinical profiles, except for the higher prevalence of dyslipidaemia in the group A/B1. Regarding medications, the clinical treatment was similar between groups (Table 1).

It can be observed that the patients in group B2/C had higher angiographic complexity (Table 2). The percentage of stenosis pre- ($76.9 \pm 12.9\%$ vs. $78.5 \pm 13.7\%$; $P = 0.34$) and post-procedure ($3.8 \pm 5.6\%$ vs. $1.6 \pm 12.8\%$; $P = 0.14$) was similar between groups. Pre-procedure Thrombolysis in Myocardial Infarction (TIMI) 2/3 coronary flow was more frequent in the A/B1 group (95% vs. 86.5%; $P = 0.002$), but it became similar in both groups after the PCI (100% vs. 99.1%; $P = 0.30$).

The median radiation dose received by patients was significantly higher in group B2/C (Table 3). The fluoroscopy times (9 ± 6 minutes vs. 12.1 ± 9.5 minutes; $P = 0.001$), the number of radiographies (17.8 ± 7.1 vs. 21.2 ± 9.3 ; $P = 0.002$), and the total number of frames (986 ± 423 vs. $1,166 \pm 540$; $P = 0.005$) were also higher in the B2/C group.

In four (4.8%) PCIs in A/B1 the group and in 48 (14.5%) in the B2/C group ($P < 0.01$) the 2 Gy dose was exceeded.

The following predictors of increased radiation exposure were determined by multiple logistic regression: weight (odds ratio [OR], 1.02 per 1 kg increase; confidence interval [CI] of 1.01 to 1.036; $P = 0.004$), and lesion type B2/C (OR 1.9; CI 1.002 to 4.96; $P = 0.002$).

Table 1
Clinical characteristics and administered drug treatment

Clinical characteristics	Group A/B1 (n = 83)	Group B2/C (n = 330)	P-value
Age, years	62.8 ± 10.2	62.3 ± 11.3	0.73
Male gender, n (%)	47 (56.5)	199 (60.3)	0.62
White, n (%)	72 (86.7)	284 (86.1)	0.52
Height, cm	165.9 ± 9.2	166.6 ± 8.5	0.54
Weight, kg	76.3 ± 16.1	78.1 ± 14.1	0.31
Current smoking, n (%)	16 (19.3)	69 (20.9)	0.86
Arterial hypertension, n (%)	70 (84.3)	251 (76.1)	0.14
Diabetes, n (%)	23 (27.7)	109 (33)	0.42
Insulin use	9 (10.8)	47 (14.2)	0.52
Dyslipidaemia, n (%)	52 (62.7)	158 (47.9)	0.02
Family history of CAD, n (%)	51 (61.4)	187 (56.7)	0.50
Previous PCI, n (%)	26 (31.3)	126 (38.2)	0.30
Previous CABG, n (%)	8 (9.6)	37 (11.2)	0.83
Previous AMI, n (%)	33 (39.8)	127 (38.5)	0.93
Previous stroke, n (%)	3 (3.6)	9 (2.7)	0.94
Current medication use, n (%)			
ASA	59 (71.1)	229 (69.4)	0.86
Clopidogrel/ticlopidine	39 (47)	175 (53)	0.38
Beta-blocker	47 (56.6)	204 (61.8)	0.45
Nitrate	27 (32.5)	140 (42.4)	0.12
Statin	50 (60.2)	195 (59.1)	0.94
ACE inhibitor	42 (50.6)	151 (45.8)	0.50
Calcium antagonist	12 (14.5)	47 (14.2)	0.50
Diuretics	15 (18.1)	45 (13.6)	0.39
Aldosterone antagonist	8 (9.6)	24 (7.3)	0.62
Oral hypoglycemics	12 (14.5)	53 (16.1)	0.84

CAD, coronary artery disease; PCI, percutaneous coronary intervention; CABG, coronary artery bypass grafting; AMI, acute myocardial infarction; ASA, acetyl salicylic acid; ACE, Angiotensin-converting enzyme.

DISCUSSION

The present study determined that the radiological exposure is higher in patients submitted to PCI in complex lesions. The harmful effects of radiation, mainly dose-dependent (deterministic), have been widely reported in procedures involving ionising radiation.⁹⁻¹² However, physicians' knowledge about the harmful effects of radiation is not proportional to their exposure.¹³

Table 2
Angiographic and procedural characteristics

	Group A/B1 (n = 83)	Group B2/C (n = 330)	P-value
Access route, n (%)			0.82
Femoral	63 (75.9)	253 (76.7)	
Radial	20 (24.1)	77 (23.3)	
Treated vessel, n (%)			0.13
LAD	35 (42)	140 (42)	
LCx	14 (16.9)	71 (21.5)	
RCA	26 (31.3)	87 (26.4)	
LMCA	3 (3.6)	2 (0.6)	
Others	5 (6.2)	30 (9.5)	
Reference diameter, mm	3 ± 0.6	3 ± 0.37	> 0.99
Lesion length, mm	13 ± 4.2	19 ± 2	< 0.01
Bifurcations, n (%)	13 (15.7)	92 (28)	0.03
Calcifications, n (%)	23 (27.7)	226 (68.9)	< 0.001
Percentage of pre-procedural stenosis, %	76.9 ± 12.9	78.5 ± 13.7	0.34
Percentage of post-procedural stenosis, %	3.8 ± 5.6	1.6 ± 2.8	0.14
Pre-procedural TIMI flow 2/3, %	95	86.5	0.002
Post-procedural TIMI flow 2/3, %	100	99.1	0.30
Pre-dilation, n (%)	29 (35.4)	166 (50.6)	0.01
Post-dilation, n (%)	34 (41)	142 (43.4)	0.77
Final pressure, atm	13.2 ± 2.3	13.7 ± 2.5	0.80

LAD, left anterior descending artery; LCx, left circumflex artery; RCA, right coronary artery; LMCA, left main coronary artery; TIMI, Thrombolysis in Myocardial Infarction.

Table 3
Radiological exposure parameters

Radiological exposure	A/B1 group (n = 83)	B2/C group (n = 330)	P-value
Patient cumulative air KERMA, mGy			< 0.01
Lower quartile (Q _{1/4})	556.7	606.5	
Median (Q _{2/4})	866.6	1,103.9	
Upper quartile (Q _{3/4})	1,171.6	1,674	
Dose-area product, mGy.cm ²			< 0.001
Lower quartile (Q _{1/4})	29,327	33,861	
Median (Q _{2/4})	43,484	58,327	
Upper quartile (Q _{3/4})	62,062	96,996	

KERMA, kinetic energy released per unit mass.

Along with the growing number of more complex procedures, hemodynamics equipment has also developed. The more modern flat panel technology is very attractive because it allows for higher quality and better image resolution.¹⁴ However, clinical studies have demonstrated that the incorporation of this technology causes higher radiation exposure.^{15,16} For this reason, scientific societies have published recommendations and guidelines aiming to reduce radiation levels during procedures.^{1,17}

Since the publication of the SYnergy between Percutaneous Coronary Intervention and Cardiac Surgery Study (SYNTAX),¹⁸ which demonstrated that patients with low angiographic and anatomical complexity (score < 22) have a favourable clinical outcome when submitted to PCI with drug-eluting stents, interventions in multiple vessels have become common in hemodynamics laboratories. However, little has been discussed about radiological exposure. Although this study does not refer to the type of intervention (single or multivessel), the simple fact that PCI was performed in complex lesions promoted a 27% increase in radiation exposure for the patient. This fact is relevant, as increasingly more cases of radiation-related lesions have been reported in patients and health professionals.¹² In practice, health professionals can minimize occupational radiation by using individual lead protection clothing associated with physical shields. However, patients do not have this protection.

According to the International Atomic Energy Agency (IAEA), the radiation exposure during cardiac diagnostic and therapeutic procedures should not exceed 2 Gy. However, that dose was exceeded in 14% of patients undergoing complex interventions in the present study. This fact is relevant, as most PCIs were performed in type B2/C lesions, as in the real world.⁴ Considering that many patients were obese,¹⁹ a known predictor of increased exposure, overexposure can be even greater. It is therefore essential that professionals take that into consideration and minimize radiation exposure during radiological assessment.

Study limitations

The main limitation of the present study is the small number of patients included. Moreover, the dose received by the interventional physician could not be measured.

CONCLUSIONS

Patients submitted to PCI in complex lesions are significantly more exposed to radiation. Weight and complex lesions (B2/C type) are predictors of increased radiation exposure.

CONFLICT OF INTEREST

The authors declare no conflicts of interests.

REFERENCES

1. Miller DL, Vano E, Bartal G, Balter S, Dixon R, Padovani R, et al. Occupational radiation protection in interventional radiology: a joint guideline of the Cardiovascular and Interventional Radiology Society of Europe and the Society of Interventional Radiology. *Cardiovasc Intervent Radiol*. 2010;33(2):230-9.
2. Mattos LA, Lemos Neto PA, Rassi A Jr, Marin-Neto JA, Sousa AGMR, Devito FS, et al. Diretrizes da Sociedade Brasileira de Cardiologia – intervenção coronária percutânea e métodos adjuntos diagnósticos em cardiologia intervencionista (II edição – 2008). *Arq Bras Cardiol*. 2008;91(4 Supl 1):1-58.
3. Picano E, Vano E. The radiation issue in cardiology: the time for action is now. *Cardiovasc Ultrasound*. 2011;9:35.
4. Osugue KR, Esteves V, Pipolo A, Ramos DS, Massih CA, Solorzono UA, et al. In-hospital outcomes of percutaneous coronary interventions in type C lesions: CENIC registry. *Rev Bras Cardiol Invasiva*. 2012;20(1):53-7.
5. Brasselet C, Blanpain T, Tassan-Mangina S, Deschildre A, Duval S, Vitry F, et al. Comparison of operator radiation exposure with optimized radiation protection devices during coronary angiograms and ad hoc percutaneous coronary interventions by radial and femoral routes. *Eur Heart J*. 2008;29(1):63-70.
6. Chambers CE, Fetterly KA, Holzer R, Lin PJ, Blankenship JC, Balter S, et al. Radiation safety program for the cardiac catheterization laboratory. *Catheter Cardiovasc Interv*. 2011;77(4):546-56.
7. Cardoso CO, Sebben JC, Fischer L, Vidal M, Broetto GG, Silva BS, et al. Radiological exposure patterns and overexposure predictors of patients undergoing invasive cardiologic procedures in flat detector fluoroscopy systems. *Rev Bras Cardiol Invasiva*. 2011;19(1):84-9.
8. Guidelines for percutaneous transluminal coronary angioplasty. A report of the American College of Cardiology/American Heart Association Task Force on Assessment of Diagnostic and Therapeutic Cardiovascular Procedures (Subcommittee on Percutaneous Transluminal Coronary Angioplasty). *J Am Coll Cardiol*. 1988;12(2):529-45.
9. Klein LW, Miller DL, Balter S, Laskey W, Haines D, Norbash A, et al. Occupational health hazards in the interventional laboratory: time for a safer environment. *J Vasc Interv Radiol*. 2009;20(7 Suppl):S278-83.
10. Lin PJ. Operation logic and functionality of automatic dose rate and image quality control of conventional fluoroscopy. *Med Phys*. 2009;36(5):1486-93.
11. Mavrikou I, Kottou S, Tsapaki V, Neofotistou V. High patient doses in interventional cardiology due to physicians negligence: how can they be prevented?. *Radiat Prot Dosimetry*. 2008;129(13):67-70.
12. Padovani R, Bernardi G, Quai E, Signor M, Toh HS, Morocutti G, et al. Retrospective evaluation of occurrence of skin injuries in interventional cardiac procedures. *Radiat Prot Dosimetry*. 2005;117(13):247-50.
13. Correia MJ, Hellies A, Andreassi MG, Ghelarducci B, Picano E. Lack of radiological awareness among physicians working in a tertiary-care cardiological centre. *Int J Cardiol*. 2005;103(3):307-11.
14. Gurley JC. Flat detectors and new aspects of radiation safety. *Cardiol Clin*. 2009;27(3):385-94.
15. Medeiros RF, Sarmiento-Leite R, Cardoso CO, Quadros AS, Risso E, Fischer L, et al. Exposure to ionizing radiation in the cardiac catheterization lab. *Rev Bras Cardiol Invasiva*. 2010;18(3):316-20.
16. Trianni A, Bernardi G, Padovani R. Are new technologies always reducing patient doses in cardiac procedures?. *Radiat Prot Dosimetry*. 2005;117(13):97-101.

17. Hirshfeld JW Jr, Balter S, Brinker JA, Kern MJ, Klein LW, Lindsay BD, et al. ACCF/AHA/HRS/SCAI clinical competence statement on physician knowledge to optimize patient safety and image quality in fluoroscopically guided invasive cardiovascular procedures. A report of the American College of Cardiology Foundation/American Heart Association/American College of Physicians Task Force on Clinical Competence and Training. *J Am Coll Cardiol.* 2004;44(11):2259-82.
18. [faltam autores]. The SYNergy between Percutaneous Coronary Intervention and Cardiac Surgery (SYNTAX) Study. In: *Annals of the European Society of Cardiology Congress*; 2008; Munich, Germany.
19. Vargas FG, Silva BSd, Cardoso CO, Leguisamo N, de Moraes CAR, de Moares CV, et al. Impact of body weight on radiation exposure during invasive cardiac procedure. *Rev Bras Cardiol Invasiva.* 2012;20(1):63-8.