Cardiovascular Revascularization Medicine 17 (2016) 328–332

Contents lists available at ScienceDirect

Cardiovascular Revascularization Medicine

Effectiveness of the implementation of a simple radiation reduction protocol in the catheterization laboratory☆

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A R T I C L E I N F O

Article history:
Received 8 February 2016
Received in revised form 3 March 2016
Accepted 11 March 2016

Keywords:
Radiation
Interventional cardiology
Last fluoroscopy hold

A B S T R A C T

Background and purpose: A reduction in radiation doses at the catheterization laboratory, maintaining the quality of procedures is essential. Our objective was to analyze the results of a simple radiation reduction protocol at a high-volume interventional cardiology unit.
Methods: We analyzed 1160 consecutive procedures: 580 performed before the implementation of the protocol and 580 after it. The protocol consisted in: the reduction of the number of ventriculographies and aortographies, the optimization of the collimation and the geometry of the X ray tube-patient-receptor, the use of low dose-rate fluoroscopy and the reduction of the number of cine sequences using the software "last fluoroscopy hold".
Results: There were no significant differences in clinical baseline features or in the procedural characteristics with the exception of a higher percentage of radial approach (30.7% vs 69.6%; $p < 0.001$) and of percutaneous coronary interventions of chronic total occlusions after the implementation of the protocol (2.1% vs 6.7%; $p = 0{,}001$). Angiographic success was similar during both periods (98.3% vs 99.2%; $p = 0.2$). There were no significant differences between both periods regarding the overall duration of the procedures (26.9 vs 29.6 min; $p = 0.14$), or the fluoroscopy time (13.3 vs 13.2 min; $p = 0.8$). We observed a reduction in the percentage of procedures with ventriculography (80.9% vs 7.1%; $p < 0.0001$) or aortography (15.4% vs 4.4%; $p < 0.0001$), the cine runs (21.8 vs 6.9; $p < 0.0001$) and the dose–area product (165 vs 71 Gyxcm^2; $p < 0.0001$).
Conclusions: With the implementation of a simple radiation reduction protocol, a 57% reduction of dose–area product was observed without a reduction in the quality or the complexity of procedures.

1. Introduction

The frequency of interventional cardiology procedures has experienced exponential growth in recent years [1]. Furthermore, in the field of coronary disease, continuous technical improvements have led to the performance of more complex procedures [1,2].

However, although the benefits of coronary intervention have been extensively demonstrated, many of these procedures are also an important source of ionizing radiation and can produce deleterious effects for both patient and involved staff [2–4].

According to international recommendations for radiation protection, the implementation of measures to reduce radiation dose while maintaining the quality of the procedures is essential [4]. Notwithstanding that these measures are included in the training programs for interventional cardiologists, it is possible that in real current practice they may not be applied in the best possible way and that radiation protection has been often relegated to a second plane in the interest of interventional cardiologists. Moreover, the routine introduction of the "last fluoroscopic hold" (LFH) tool, available in most modern fluoroscopy equipments, which allows the collection and storage of images without the need for cine sequences, has not been studied until now in interventional cardiology.

Our objective was to analyze the results of a simple radiation reduction protocol (RRP) applied for diagnostic coronary angiography (CA) and percutaneous coronary interventions (PCI) in a high volume center.

2. Methods

2.1. Procedures and dose reduction protocol

From September 2014 to April 2015 we included 1160 consecutive procedures performed in the catheterization laboratory of our center: 580 before the implementation of the RRP and 580 after it.

Abbreviations: CA, coronary angiography; CTO, chronic total occlusions; DAP, dose–area product; FT, fluoroscopy time; LFH, last fluoroscopy hold; PCI, percutaneous coronary intervention; RRP, radiation reduction protocol.

☆ The authors have no conflicts of interest to declare.

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http://dx.doi.org/10.1016/j.carrev.2016.03.012
1553-8389/

Both CA and PCI were analyzed including those of complex lesions such as chronic total occlusions (CTO). Structural heart disease procedures, not strictly coronary, were excluded from the analysis.

All procedures were performed by three experienced interventional cardiologists with a Flat-panel Philips Allura Xper FD10 C equipment. Both fluoroscopy sequences and cine runs were made at 15 frames/s in the two study periods, not being available at that time the 7.5 frames/s mode. Access site and technical decisions regarding the PCI (number and type of stents and adjunctive medical treatment) were left to the operator decision in each case. An informed consent before the procedure was obtained from every patient.

The protocol consisted in the limitation of the number of ventriculographies and aortographies for cases where the assessment of the left ventricle and the aorta was not available with other imaging techniques; the use of suitable maximum collimation for each sequence; the optimization of the distances between the X-ray tube, the patient and receptor; the use of low dose rate (0.19 mGy/s) fluoroscopy whenever allowed to obtain adequate images; the limitation, as far as possible, of the number of highly angled projections and the reduction of the number of cine runs whenever appropriate images were achieved by the "last fluoroscopy hold" tool (a software that allows the storage of the last sequences fluoroscopy) [5].

We prospectively analyzed in each procedure the dose area product (DAP), fluoroscopy time (FT), the total duration of procedures and the number of cine runs. All these variables were calculated automatically by our Flat-panel Philips Allura Xper FD10 C equipment. We also analyzed the percentage of procedures with ventriculography or aortography.

2.2. Statistic analysis

The normality of the quantitative variables was demonstrated by the Kolmogorov–Smirnov test. The quantitative variables that follow a normal distribution were expressed as mean ± standard deviation and those which did not as median (range). The qualitative variables were expressed as percentages. For comparisons between two quantitative variables, T test was used if they followed a normal distribution. If they did not, the Wilcoxon test was used. The qualitative variables were compared using the Chi^2 or McNemar tests. The linear correlation between variables was calculated using the Pearson correlation coefficient. Statistically significant differences were considered with p values <0.05. All statistical analyzes were performed using SPSS (version 20.0, SPSS Inc).

3. Results

Sixty eight percent of patients were male, with a mean age of 66.8 ± 12.5 years. The mean body mass index was 28.5 ± 6.5 kg/m^2. A significant burden of cardiovascular risk factors (diabetes mellitus 34.2%, hypertension 69%, hyperlipidemia 44.6%) was observed. The indication of the procedures was for stable coronary disease in 28.5% of patients, acute coronary syndrome in 45%, and 26.5% for other reasons (valvular heart disease, cardiomyopathies and ventricular arrhythmias).

There were no significant differences in baseline characteristics of the patients or in the percentage of PCI performed before and after the RRP (56.7% vs 54.9%; p = 0.5) (Tables 1 and 2). There were also no differences in the characteristics of the procedures or their complexity except for a higher use of radial approach (30.7% vs 69.6%; p < 0.0001) and a higher rate of PCI of CTO after the implementation of the RRP (2.1% vs 6.7%; p = 0.001). A smaller contrast volume was used in the second period (221 ± 117 vs 160 ± 95; p < 0.0001). The success rate of the procedure was similar in both periods (98.3% vs 99.2%; p = 0.6) (Table 2).

The DAP was significantly higher for procedures including PCI, compared with diagnostic CA (155.2 ± 61.4 vs 123.9 ± 48.8 Gy x cm^2; p < 0.0001), and higher in PCI with higher anatomical complexity: bifurcations (176.2 ± 126.3 vs 114.7 ± 109.4 Gycm^2; p < 0.0001), CTO (147.1 ± 143.8 vs 108.8 ± 103.1 Gycm^2; p = 0.007) or aorto-ostial lesions (145.4 ± 132.3 vs 111.5 ± 107.4 Gycm^2; p = 0.03). The performance of ventriculography was also significantly associated with increased DAP (138.8 ± 88.9 vs 119.2 ± 91.7 Gycm^2; p < 0.0001). Moreover, we observed a significant strong linear correlation of DAP with the FT, the number of cine runs, procedure duration and volume of contrast used, and a weak linear correlation with the Syntax score, body mass index and the number of stents implanted in the procedure (Table 3).

Comparing the procedures performed before and after the RRP, no significant differences were observed regarding the FT (13.3 ± 11 vs 13.2 ± 10 min; p = 0.8) or the duration of procedures (26.9 ± 21.3 vs 29.6 ± 23 min; p = 0.14). After the implementation of the RRP, we observed a significant reduction in the percentage of procedures in which ventriculography (80.9% vs 7.1%; p < 0.0001) or aortography (15.4% vs 4.4%; p < 0.0001) was performed, and a reduction in the number of cine runs (21.8 ± 8.1 vs 6.9 ± 3; p < 0.0001) and DAP (165.7 ± 68 vs 71.4 ± 32.8 Gy x cm^2; p < 0.0001) (Fig. 1). These results were similar when analyzing different types of procedures: coronary angiography; PCI; coronary angiography + ad hoc PCI (Table 4).

Table 1
Baseline characteristics.

	Before RRP (n = 580)	After RRP (n = 580)	p
Male	393 (67.8%)	414 (71.4%)	0.2
Age (years)	67.3 ± 12.7	66.4 ± 12.3	0.2
BMI (kg/m^2)	28.4 ± 7.4	28.6 ± 5.7	0.8
HT	413 (71.2%)	410 (70.7%)	0.9
DM	210 (36.2%)	199 (34.3%)	0.6
DL	260 (44.8%)	271 (46.7%)	0.5
Previous PCI	133 (22.9%)	151 (26%)	0.3
LVEF (%)	50.8 ± 14.2	51.4 ± 12.2	0.5
Indication			
SCD	159 (27.4%)	171 (29.5%)	0.7
NSTEMI	152 (26.3%)	147 (25.3%)	
STEMI	113 (19.5%)	111 (19.1%)	
Other	154 (26.5%)	151 (26%)	

RRP: radiation reduction protocol; BMI: body mass index; HT: hypertension; DM: diabetes mellitus; DL: Dyslipidemia; LVEF: left ventricle ejection fraction; SCD: stable coronary artery disease; NSTEMI: Non-ST elevation myocardial infarction; STEMI: ST elevation myocardial infarction. Other: valvular heart disease, cardiomyopathies, ventricular arrhythmias.

4. Discussion

This study demonstrates how the implementation of a protocol of simple measures to reduce radiation in the catheterization laboratory, some of them, such as LFH, scarcely described in the literature, can achieve a decrease of DAP over 50%.

It is remarkable that, these measures do not involve a reduction in the complexity of the procedures. In our work, we note that Syntax

Table 2
Characteristics of the procedures.

	Before RRP (n = 580)	After RRP (n = 580)	p
Radial approach (%)	178 (30.7%)	404 (69.6%)	<0.0001
PCI	292 (50.3%)	305 (52.6%)	0.4
PCI of LM and/or 3vessels disease	38 (6.5%)	25 (4.3%)	0.07
Syntax score	18.1 ± 15	18.8 ± 14.6	0.6
Bifurcations PCI	153 (26.4%)	173 (29.8%)	0.3
PCI of aorto-ostial lesions	22 (3.8%)	33 (5.7%)	0.1
PCI of OCT	12 (2.1%)	39 (6.7%)	0.001
Contrast volume (cc)	221 ± 117	160 ± 95	<0.0001
Angiographic success	98.3%	99.2%	0.2

RRP: radiation reduction protocol; PCI: Percutaneous coronary intervention; LM: left main; CTO: chronic total occlusion.