Comparison of Fluoro and Cine Coronary Angiography: Balancing Acceptable Outcomes With a Reduction in Radiation Dose

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ABSTRACT: Use of last fluoro hold (LFH) mode in fluoroscopy, which enables the last live image to be saved and displayed, could reduce radiation during percutaneous coronary intervention when compared with cine mode. No previous study compared coronary angiography radiation doses and image quality between LFH and conventional cine mode techniques. **Methods.** We compared cumulative dose-area product (DAP), cumulative air kerma, fluoroscopy time, contrast use, interobserver variability of visual assessment between LFH angiography, and conventional cine angiography techniques. Forty-six patients were prospectively enrolled into the LFH group and 82 patients into the cine angiography group according to operator decision. **Results.** Mean cumulative DAP was higher in the cine group vs the LFH group (50058.98 ± 53542.71 mGy•cm^2 vs 11349.2 ± 8796.46 mGy•cm^2; *P*<.001). Mean fluoroscopy times were higher in the cine group vs the LFH group (3.87 ± 5.08 minutes vs 1.66 ± 1.51 minutes; *P*<.01). Mean contrast use was higher in the cine group vs the LFH group (112.07 ± 43.79 cc vs 88.15 ± 23.84 cc; *P*<.001). Mean value of Crombach's alpha was not statistically different between visual estimates of three operators between cine and LFH angiography groups (0.66680 ± 0.19309 vs 0.54193 ± 0.31046; *P*=.20). **Conclusion.** Radiation doses, contrast use, and fluoroscopy times are lower in fluoroscopic LFH angiography vs cine angiography. Interclass variability of visual stenosis estimation between three operators was not different between cine and LFH groups. Fluoroscopic LFH images conventionally have inferior diagnostic quality when compared with cine coronary angiography, but with new angiographic systems with improved LFH image quality, these images may be adequate for diagnostic coronary angiography.

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Cardiologists are responsible for about 40% of the entire cumulative radiation to the United States population from all medical sources excluding radiotherapy.[1] Radiation given during coronary angiography (CA) and percutaneous coronary intervention (PCI) may have some deleterious effects. The dose area product (DAP), related to the effective dose, is a measure of stochastic risk and a potential quality indicator. Angiographic systems used for interventional procedures have a digital acquisition or "cine" mode. A high radiation dose rate is used to obtain a series of high-resolution images with reduced image noise. The radiation dose per frame for digital acquisitions can be 15 times greater than for fluoroscopy. The number and length of digital acquisition or cine "runs" may be the greatest source of patient radiation dose in interventional cardiology procedures.

Last fluoroscopy hold (LFH) is a new advanced feature that dynamically stores only the last current sequence of fluoroscopy images for instant replay, editing, and storage in angiography systems without the need for operator presetting.[2-9] LFH could reduce the fluoroscopy time to half compared to when it is not used and enables the operator to examine the image as long as necessary without the use of radiation. There is no previous study about feasibility of LFH use in coronary angiography.

In our study, we compared cumulative DAP, cumulative air Kerma, fluoroscopy time, and interobserver variability in visual and quantitative coronary angiography (QCA) assessment of coronary stenoses during coronary angiography in LFH and cine angiography techniques.

Methods

In our prospective study, a total of 46 patients were enrolled into the LFH group and 82 patients were enrolled into the cine angiography group according to operator decision during a 6-month period. All angiographic images were taken at similar angles by all operators. Frame rate for both cine and fluoroscopy was 15 frames/second and constant for all operators and all studies. The study was approved by the ethics committee of the institutional review board and informed consent was obtained from all patients. All investigators were experienced and the least experienced cardiologist had experience with >100 PCIs. Imaging data were digitized and stored in DICOM format. Each angiogram was reviewed independently by three interventional cardiologists using the Philips Inturis Suite Lite version 2.1.1 DICOM viewer on a high resolution 19″ TFT flat screen and stenoses were visually assessed. The reviewers were blinded to clinical data and clinical outcome. Based on

Table 1. Patient demographic data.			
	LFH Angiography (n = 46)	Cine Angiography (n = 82)	*P*-Value
Age (years)	58.74 ± 10.48	60.76 ± 10.98	.31
Male Female	27 (58.69%) 19 (41.3%)	35 (42.68%) 47 (57.32%)	.56
Body mass index (kg/m²)	28.7 ± 4.3	30.26 ± 4.8	.07
Diabetes mellitus	14 (30.43%)	27 (32.9%)	.84
Creatinine (mg/dL)	0.93 ± 0.7	0.84 ± 0.2	.32
History of PCI	6 (13%)	17 (20.7%)	.34
History of CABG	1 (2.17%)	4 (4.88%)	.65
Clinical presentation of ACS	5 (10.87%)	5 (6.1%)	.31
Normal coronary arteries	16 (34.8%)	19 (23.17%)	.21

Data given as mean ± standard deviation or number (percentage).

Table 2. Radiation doses and contrast use.			
	LFH Angiography	Cine Angiography	*P*-Value
Cumulative dose-area product values (mGy•cm²)	11349.2 ± 8796.46	50058.98 ± 53542.71	<.001
Cumulative air kerma product (mGy)	141.2 ± 114.6	660.46 ± 638.6	<.001
Fluoroscopy times (min)	1.66 ± 1.51	3.87 ± 5.08	<.01
Amount of contrast use (mL)	88.15 ± 23.84	112.07 ± 43.79	<.001
Body mass index (kg/m²)	28.7 ± 4.3	30.26 ± 4.8	.07

Data given as mean ± standard deviation or number (percentage).

visual assessment alone, each investigator was asked to classify the percent stenosis of each lesion. All procedures were undertaken on a Philips Integris Allura FD10 angiographic system. Prior to the study, quality control tests were carried out to assess the system performance and to calibrate the DAP meter installed on the machine. Cumulative DAP value, cumulative air kerma product, fluoroscopy time, total amount of contrast used, and operator's name were collected for each patient. Additional measured parameters were sex, age, weight, height, body mass index (BMI), presence of diabetes mellitus, creatinine level, history of coronary artery disease, history of PCI, history of coronary artery bypass grafting (CABG), in-hospital mortality and morbidity, and image quality as assessed by two cardiologists.

Definitions. *Air kerma* was defined as the energy extracted from an x-ray beam per unit mass of air in a small irradiated air volume. Air kerma is measured in grays. For diagnostic radiographs, air kerma is the dose delivered to that volume of air. *Fluoroscopy time (FT)* was defined as the total time that fluoroscopy was used during an imaging or interventional procedure. *Kerma-area product (PKA)* was defined as the integral of air kerma across the entire x-ray beam emitted from the x-ray tube. PKA is a surrogate measurement for the entire amount of energy delivered to the patient by the beam, and is measured in Gy • cm². Air kerma is measured at a specific point 15 cm on the gantry side from isocenter. PKA is usually measured without scatter. This quantity was previously called dose-area product, and earlier publications used the abbreviations "KAP" and "DAP" for this quantity.

Statistical analysis. All statistical analyses were done with the SPSS for Windows program, version 11.0 (SPSS, Inc). Continuous variables were compared by student t-test. Categorical variables were compared by Chi-square test. Values are expressed as mean ± standard deviation and percentages. The agreement in lesion assessment between reviewers was assessed by intraclass correlation coefficient and Cronbach's alpha. Statistical measures were calculated at observer- and vessel-segment level. For every single observer, the diameter stenosis estimates were compared for all 13 vessel segments. All tests were two-tailed and differences were considered significant at *P*-value <.05.

Results

There was no difference between age, sex distribution, presence of diabetes mellitus, creatinine level, acute coronary syndrome presentation, or history of PCI or CABG between LFH and cine stenting groups. Patients with normal coronary arteries represented 34.8% of the LFH group and 23.17% of the cine group, and the difference was not statistically different (Table 1).

Mean cumulative air kerma was higher in the cine group vs the LFH group (660.46 ± 638.6 mGy vs 141.2 ± 114.6 mGy; *P*<.001). Mean cumulative DAP was higher in the cine group vs the LFH group (50058.98 ± 53542.71 mGy•cm² vs 11349.2 ± 8796.46 mGy•cm²; *P*<.001). Mean fluoroscopy times were higher in the cine group vs the LFH group (3.87 ± 5.08 minutes vs 1.66 ± 1.51 minutes; *P*<.01). Mean contrast use was higher in the cine group vs the LFH group (112.07 ± 43.79 cc vs 88.15 ± 23.84 cc; *P*<.001). Body mass indices were not different between cine and LFH groups (30.26 ± 4.8 kg/m² vs 28.7 ± 4.3 kg/m²; *P*=.07) (Table 2).

There was no morbidity, mortality, or contrast-induced nephropathy in any of the patients. Cardiologists assessed LFH images sufficient for decision making and additional cine images were taken for better images in only 1 LFH case.

Mean value of intraclass correlation was not statistically different between percent stenosis visual estimates of the three operators between cine and LFH angiography groups (0.69387 ± 0.18711 vs 0.62327 ± 0.30585; *P*=.45) (Table 3).

Table 3. Cine and last fluoroscopy hold intraclass correlation between visual assessment of percent stenosis.

	Cine Intraclass Correlation	*P*-Value	LFH Intraclass Correlation	*P*-Value
LMCA	1.000	<.001	1.000	<.001
Proximal LAD	0.804	<.001	0.749	<.001
Mid LAD	0.879	<.001	0.918	<.001
Distal LAD	0.755	<.001	0.849	<.001
D1	0.570	<.001	0.579	<.001
D2	0.642	<.001	0.593	<.001
Proximal CX	0.551	<.001	0.808	<.001
Distal CX	0.557	<.001	0.611	<.001
OM1	0.748	<.001	0.789	<.001
OM2	0.689	<.001	0.582	<.001
Proximal RCA	0.885	<.001	0.864	<.001
Mid RCA	0.854	<.001	0.590	<.001
Distal RCA	0.678	<.001	0.477	<.01
RPD	0.554	<.001	0.053	.41
RPL	0.242	.69	-0.113	.64

LMCA = left main coronary artery; LAD = left anterior descending coronary artery; D = diagonal artery; CX = circumflex artery; RCA = right coronary artery; RPD = right posterior descending artery; RPL = right posterolateral artery.

Average Cronbach's alpha was 0.69 and 0.62, which is in the acceptable range for visual assessment:

Cronbach's alpha	Internal consistency
$\alpha \geq 0.9$	Excellent (high-stakes testing)
$0.7 \leq \alpha < 0.9$	Good (low-stakes testing)
$0.6 \leq \alpha < 0.7$	Acceptable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

Discussion

The increasing use and complexity of imaging and interventional techniques have not been matched by increasing awareness and knowledge by prescribers and practitioners. The majority of doctors — including cardiologists — grossly underestimate the radiation doses for most commonly requested tests.[10,11] Interventional cardiologists are competitive and perfectionist-type people, but a recent publication about brain and neck tumors in interventional cardiologists should warn and encourage them to reduce radiation doses and perfection during procedures.[12] The significant increase in the cumulative exposure of patients and population to ionizing radiation, which is an important and potentially avoidable public health threat, is likely to increase the incidence of cancer in the future.[13]

Quantitative coronary angiography improved our ability to more accurately estimate the percent stenosis of a lesion and its length. Although this technique is a well-validated tool for accurately and reproducibly defining coronary lesion severity, these validations were done mostly in the cine film era using high-dose radiography and high-speed filming rates (60 frames/second). Its use, as originally validated, remains mostly in specialized research using experimental models and in clinical trials. With the transition to so-called lossless compression digital angiography, the use of lower-dose radiography, and the lower cine capture rates (15 frames/second), the information captured has been compromised.[14,15]

In our study, radiation doses were about 4 times higher in the cine group vs the LFH group. Fluoroscopy times were 2 times higher in the cine group vs the LFH group. Contrast use was prominently higher in the cine group vs the LFH group. Operators independently assessed LFH images adequate for decision making. With recent improvements in imaging equipment and software, fluoroscopic LFH image quality has greatly improved. Even perfect angiographic images on their own do not provide enough functional information without intravascular ultrasound, fractional flow reserve, or thallium scintigraphy; therefore, the need for a "perfect" angiographic image for clinical decision-making is disputable.

Visual stenosis estimates of three operators were tested statistically for intraclass variability for different vessels in the cine and LFH groups. Mean intraclass variability was not different between groups in the analysis, which supports our hypothesis that the LFH angiography technique can be used as reliably as the cine angiography technique. Extra radiation doses did not produce a difference in variability.

Consistent collimation, adequately low-level acquisition modes, fewer irradiating angulations, reduced magnification and full inspiration during radiography whenever possible, long source-to-skin, and short patient-to-detector distances are other important and effective techniques.[16] We did not use these effective techniques during this study, which would reduce radiation doses much more in both the LFH and cine groups.

LFH technique for coronary angiography should be tested in a larger population with different angiographic device brands despite interventional cardiologists' reluctance to select an examination protocol that intentionally sacrifices image quality. Management decisions given by cine and LFH angiographic images should be tested by fractional flow reserve, intravascular ultrasound, or thallium scintigraphy; if concordant results are obtained, the low-dose LFH technique for coronary angiography should universally be accepted by the clinicians in interventional cardiology and new industry standards in imaging should be established by device manufacturers.

In clinical practice, stenosis severity is typically determined during or shortly after the procedure and most commonly relies on visual estimation by physicians. This approach, however, has well-known limitations.[17,18] Older studies, conducted a decade or more ago, described interobserver and intraobserver variation in visual estimations of stenosis severity and inaccuracies compared with computer-assisted techniques, expert panel review, autopsy results, or simulations.[19-28]

Study limitations. Some operators switched to cine mode when performing radial angiography because catheter engagement was weak and visualization was suboptimal. Some operators were dissatisfied with image quality and resisted using LFH angiography. One cardiac surgeon was not satisfied with images and requested cine images in his patient, but three other cardiac surgeons found images acceptable. In one case, additional cine images were obtained when there was a doubtful image. We propose that these techniques be used especially by experienced operators, and when in doubt additional cine images should be taken. There are also potential legal issues, wherein LFH images may cause problems in lawsuits. LFH, quantitative coronary angiography, fractional flow reserve, and thallium correlations should be performed to determine the safety of the LFH technique for diagnostic coronary angiography.

Conclusion

Radiation doses, contrast use, and fluoroscopy times are lower in fluoroscopic LFH angiography than cine angiography. Intraclass variability of visual stenosis estimation between three operators was not different between cine and LFH groups. Four times higher radiation dose does not give any extra accuracy in the interpretation of coronary stenoses. Fluoroscopic LFH images conventionally have inferior diagnostic quality when compared with cine coronary angiography, but with new angiographic systems with improved LFH image quality, these images may be adequate for diagnostic coronary angiography.

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