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Percutaneous Coronary Intervention

The Effectiveness and Safety between Monoplane and Biplane Imaging During Coronary Angiographies

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Background: Avoiding unnecessary radiation exposure is the main issue during coronary angiography. Herein, we aimed to investigate whether performing coronary angioplasties with monoplane or biplane imaging most effectively reduces radiation load and shortens the procedure time.

Methods: We retrospectively enrolled 294 patients who required either coronary angiography or coronary angioplasty. They were divided into groups of only diagnostic angiography, one-, two- or three-vessel diseases. The fluoroscopy dose-area product (DAP), skin dose, fluoroscopy and procedure time were recorded.

Results: Among the studied patients, 148 received the procedures with monoplane imaging. Compared with the radiation exposure in the monoplane group, there were significant increases in DAP and skin dose in those who received biplane imaging independently of the number of lesions. This phenomenon was also observed in the patients receiving either diagnostic angiography only or coronary interventions. In addition, there were no significant differences in contrast volume and procedure time between the monoplane and biplane groups. Notably, the average fluoroscopy time in those who received biplane imaging was significantly longer than in those who received monoplane imaging in the one- and two-vessel groups, while there were no significant differences in the diagnostic angiography only and three-vessel diseases groups.

Conclusions: Our findings indicated that using monoplane imaging resulted in lesser radiation exposure and similar procedure times in coronary diagnostic and interventional settings compared to using biplane imaging. This observation should be verified in prospective randomized studies.

Key Words: Contrast medium load • Fluoroscopy time • Mono- and biplane imaging • Radiation exposure

INTRODUCTION

The impact of radiation exposure is an important issue during coronary, peripheral and even electrophysiology interventions.[1-4] During fluoroscopy-guided percutaneous coronary interventions (PCIs), intersecting biplane imaging is most commonly used and is regarded to be more efficient than monoplane imaging.[3,4] Different from biplane imaging, monoplane imaging requires two separate contrast injections and two X-rays to obtain the same information.[3,4] Biplane imaging allows operators to visualize the target lesion simultaneously in both planes, especially in complex procedures.[3,4] According to previous studies, performing diagnostic coronary angiography and PCIs using biplane imaging can significantly reduce the total contrast volume compared with monoplane imaging.[4-6] Nevertheless, whether biplane imaging can reduce the radiation dose remains largely unknown. Some studies have found that radiation doses differ significantly depending on the

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angle of the tube, especially in the combination of steep left anterior oblique (LAO) and cranial (CRA) or caudal (CAU) angles, and that this is independent of either mono- or biplane imaging.[7-10] Therefore, the purpose of this study was to investigate whether biplane imaging can shorten the examination time, required use of fluoroscopy, contrast load and average radiation dose of the patients compared to monoplane imaging. In addition, by dividing the patients according to types of lesions including non-significant atherosclerotic coronary disease, one (1-V-D), two (2-V-D) and three (3-V-D) vessel diseases, we further investigated the impact of biplane and monoplane imaging in procedures of varying complexity.

METHODS

Patients

This study was conducted from 1 December 2015 to 31 December 2016, and consecutively enrolled 294 patients. Patients who had undergone coronary bypass and an estimated glomerular filtration rate < 60 were excluded. Due to the morphology and complexity of the coronary lesions of individual patients, we further divided the patients into groups of those who received only diagnostic angiography and those who received interventional procedures. This study was approved by the Ethics Committee of Chi-Mei Medical Center (protocol no: 10501-003), and the requirement for informed patient consent was waived.

Imaging system

We used a stationary floor-mounted under-couch C-arm system equipped with a Philips Allura clarity FD10/10 flat panel (biplane) and Siemens AXIOM. The choice of biplane or monoplane imaging was at the discretion of the operators. The procedure was performed at 15 frames per second in both continuous angiography and fluoroscopy. The field of view, which could vary during the procedure, was widely open with no collimation shelter, and the exposure was controlled automatically during both fluoroscopy and cine-angiography. All coronary angioplasty procedures were performed using automatic exposure control. The biplane systems were equipped with ion-chamber PTW meters mounted within the diaphragm housing of the X-ray tube. Dose-area product (DAP) was measured with a flat ionization chamber (Diamentor K1S; PTW, Freiburg, Germany) built into the angiography system. Because the various vascular regions of the clinical coronary view have different angles such as right anteror oblique (RAO)/LAO, cranial/caudal projections, it is difficult to maintain a fixed distance between source to receptor to assure image quality. However, we followed the radiation operation safety practice principle that the exposure source should be as far away as possible from the patient, with the receptor being as close as possible to the patient. Reference point air kerma (a measure of energy transferred from radiation to matter and representing the kinetic energy released to matter) was displayed as skin dose in milligrays on the flat-panel system. Manufacturers calibrate DAP instruments annually and ensure compliance with relevant safety regulations and standards. The skin dose corresponded to the international reference point located 15 cm in front of the isocenter.

Data collection

Patient characteristics, including gender, height, weight and age, procedure time, fluoroscopy time and contrast volume, clinical information such as case type (single or multiple blood vessels), and details of each lesion for angioplasty were routinely recorded in the database system. The examination protocol was printed directly from the angiography system, including the number of acquired images, total angiography and fluoroscopy time, DAP, and corresponding skin doses. The fluoroscopy time was defined as the time (in seconds) at which the target subject was visualized by X-ray penetration and displayed on the screen. The procedure time was calculated from the time when the arterial access was established until the end of the procedure. The data were extracted from the angiography software after the procedure had been completed. All clinically relevant reports and clinically identifiable information corresponding to the patient were extracted and digitally encoded.

Data analysis

Comparisons of the continuous variables were performed using the Student's t-test, and a two-tailed p-value < 0.05 was considered to be significant for statistical analysis in this study. All analyses were performed using SAS software (SAS, version 9.2;SAS, Cary, NC).

RESULTS

Baseline characteristics

A total of 148 procedures were done with monoplane imaging and 146 procedures with biplane imaging. The baseline characteristics are summarized in Table 1. Notably, patients who are older, male and with a higher body weight were more likely to receive monoplane imaging. In contrast, more patients with cardiovascular risks including diabetes, hypertension and hyperlipidemia received biplane imaging. Also, more of the patients who had undergone PCIs previously received biplane imaging. There was no significant difference in the severity of coronary lesions between the patients who received biplane and monoplane imaging (Table 2).

Increased DAP and skin dose in biplane imaging was independent of the number of lesions

In the patients who received only diagnostic angiography, biplane imaging resulted in a 51% increase in the average DAP compared to monoplane imaging [biplane imaging (BP): 30800 $cGycm^2$ vs. monoplane imaging (MP): 15660 $cGycm^2$, $p < 0.0001$] (Table 3). In the interventional subgroup of 1-V-D lesions, the patients with biplane imaging had a significant increase in the mean DAP compared to those with monoplane imaging (BP: 119000 $cGycm^2$ vs. MP: 37460 $cGycm^2$, $p < 0.0001$) (Table 4). Also, the patients who received coronary interventions for 2-V-D and biplane imaging had a significantly greater DAP than those who received monoplane imaging (BP: 209900 $cGycm^2$ vs. MP: 78840 $cGycm^2$, $p < 0.0001$). Likewise, among the patients who received coronary interventions for 3-V-D, the DAP in the patients who received biplane imaging was significantly higher than in those who received monoplane imaging (BP: 321400 $Gycm^2$ vs. MP: 133100 $Gycm^2$, $p = 0.008$). Correspondingly, biplane imaging resulted in a significantly greater radiation exposure than monoplane imaging in the group who received only diagnostic angiography (BP: 322.6 mGy vs. MP: 173.3 mGy), the group with 1-V-D (BP: 1293 $Gycm^2$ vs. MP: 382 $Gycm^2$), the

Table 1. Baseline characteristics of patients under mono or biplane imaging

Total number (n = 294)	Mono-plane (n = 148)	Biplane (n =146)	p value
Age (yrs)	61 ± 14	53 ± 12	< 0.001
Weight (kg)	72 ± 3	68 ± 2	0.009
Male sex (%)	60 (40)	32 (22)	< 0.001
Diabetes mellitus (%)	31 (24)	37 (25)	0.4
Hypertension (%)	61 (41)	86 (59)	0.005
Hyperlipidemia (%)	58 (39)	85 (58)	0.002
Prior PCI (%)	22 (15)	38 (26)	0.013

Values are mean ± SD or n (%). * p < 0.05 with significance.
PCI, percutaneous coronary intervention.
Hyperlipidemia defined as receiving lipid-lowering therapy or either total cholesterol > 200 mg/dl or serum triglycerides > 150 mg/dl.

Table 2. The lesion characteristics of patients under mono or biplane imaging

Total number (n = 294)	Mono-plane (n = 148)	Biplane (n = 146)	p value
Insignificant lesion (%)	37 (25)	36 (24)	0.62
1-V-D (%)	48 (32)	47 (32)	0.9
2-V-D (%)	35 (23)	35 (25)	0.53
3-V-D (%)	28 (20)	28 (19)	0.48
Left main lesion	2 (1.3)	3 (2)	0.53
Bifurcation lesion	6 (4)	8 (5.4)	0.64

Values are mean ± SD or n (%). * p < 0.05 with significance.
1-V-D, one vessel disease; 2-V-D, 2-vessel disease; 3-V-D, 3-vessel disease.

Table 3. The dose-area product (DAP), radiation exposure, contrast medium doses and fluoroscopy time in patients receiving mono- or biplane imaging for only diagnostic angiography

Parameters	Monoplane (N = 37)	Biplane (N = 36)	p value
DAP ($cGycm^2$)	15660 ± 1324	30800 ± 1708	< 0.001
Radiation exposure	173.3 ± 14.7	322.6 ± 17.0	< 0.001
Contrast medium doses	53 ± 3.1	51.2 ± 2.8	0.6
Fluoroscopy time(sec)	67.2 ± 9.7	80.2 ± 20.7	0.57
Procedure time (min)	11.2 ± 0.5 (6-20)	12.1 ± 0.6 (6-24)	0.3

Values are mean ± SD or n (%).
* p < 0.05 with significance. Abbreviation as Table 1. SD, standard deviation.

Table 4. The dose-area product (DAP), radiation exposure, contrast medium doses and fluoroscopy time in patients receiving mono- or biplane imaging stratified by the severity of coronary artery disease in patients receiving percutaneous coronary intervention (PCI)

Parameters	Lesion type	Monoplane	Biplane	p value
DAP (cGycm^2)	1-V-D	37460 ± 1972	119000 ± 8622	< 0.001
	2-V-D	78840 ± 6503	209900 ± 8273	< 0.001
	3-V-D	133100 ± 16280	321400 ± 34910	0.008
Radiation exposure	1-V-D	381.7 ± 19.6	1293 ± 66.8	< 0.001
	2-V-D	825 ± 66.3	2256 ± 103	< 0.001
	3-V-D	1459 ± 80.7	5446 ± 125.4	0.004
Contrast medium doses	1-V-D	131.4 ± 6.7	130.9 ± 7.4	0.96
	2-V-D	186 ± 7.9	206 ± 10.7	0.15
	3-V-D	273.9 ± 12	266.7 ± 49.7	0.9
Fluoroscopy time (sec)	1-V-D	141.4 ± 13.6	255.4 ± 22.2	< 0.001
	2-V-D	205.7 ± 24.4	492.4 ± 69.5	0.01
	3-V-D	491.3 ± 44.21	547.3 ± 89.3	0.6
Procedure time (min)	1-V-D	24.8 ± 1.1 (13-46)	25.3 ± 1.2 (16-53)	0.8
	2-V-D	33.8 ± 1.5 (20-67)	32.4 ± 1.2 (19-44)	0.5
	3-V-D	54.1 ± 2.5 (42-103)	50.3 ± 2.4 (38-95)	0.3

Values are mean ± SD or n (%).
* p < 0.05 with significance. Abbreviation as Table 1. SD, standard deviation.
Monoplane imaging — 1-V-D (N = 48); 2-V-D (N = 35); 3-V-D (N = 28). Biplane imaging — 1-V-D (N = 47); 2-V-D (N = 35); 3-V-D (N = 28).

group with 2-V-D (BP: 2256 Gycm^2 vs. MP: 825 Gycm^2) and the group with 3-V-D (BP: 5446 Gycm^2 vs. MP: 1459 Gycm^2) (Table 3).

No significant differences in contrast volume and procedure time but longer fluoroscopy time with biplane in one- and two-vessel disease groups

There were no significant differences in contrast volume with monoplane imaging or biplane imaging between all groups including the group who received only diagnostic angiography (BP: 53 vs. MP: 51 ml, p = 0.6) (Table 3), the group with 1-V-D (BP: 131 vs. SP: 130 ml, p = 0.6), the group with 2-V-D (BP: 206 vs. MP: 186 ml, p = 0.15) and the group with 3-V-D (BP: 267 vs. MP: 273 ml, p = 0.9) (Table 4). Likewise, the procedure time was similar between monoplane imaging or biplane imaging in the patients who received either diagnostic angiography (Table 3) or coronary interventions (Table 4). The fluoroscopy times in the patients with biplane or monoplane imaging were not statistically different in the groups of only diagnostic angiography and 3-V-D (BP: 67 second vs. SP: 80 second, p = 0.58; BP: 491 s vs. MP: 547 s, p = 0.6) (Table 3, 4). However, the average fluoroscopy time in the patients with biplane imaging was significantly longer than in those with monoplane imaging in the groups with 1-V-D and 2-V-D (BP: 255 s vs. MP: 141 s, p < 0.0001; BP: 482 s vs. MP: 205 s, p < 0.0001, respectively) (Table 4).

Higher radiation exposure in biplane imaging independently of the number of coronary lesions or interventions

To differentiate the effect of coronary interventions on the use of contrast medium and radiation exposure, we analyzed the patients who underwent diagnostic angiography only or PCIs separately. Notably, the contrast medium usage was similar between the patients who received either diagnostic angiography only or PCIs. Among the patients who received diagnostic angiography only, the radiation exposure was significantly higher in those who underwent biplane imaging compared to those who underwent monoplane imaging (Table 3). Likewise, there was also a significant increase in radiation exposure in the patients with biplane imaging among those who received PCIs (Table 4). Since the complexity of angioplasty may influence the usage of contrast medium and radiation exposure, we further divided the patients who underwent angioplasty into 1-V-D, 2-V-D and 3-V-D groups to compare the impact of monoplane and biplane imaging. Not surprisingly, the use of contrast medium increased with the number of coronary lesions. However, the use of contrast medium was similar between those who received monoplane and biplane imaging independently of the number of coronary interventions. In contrast, in the patients who received coronary intervention for either 1-V-D or multiple-V-D, the radiation exposure was significantly higher in those who received biplane imaging compared to those who received monoplane imaging.

DISCUSSION

In this study, there were significant increases in DAP and skin dose in the patients who received biplane imaging compared to those who received monoplane imaging, and this was independent of the number of lesions. In addition, using biplane imaging failed to reduce the volume of contrast medium and procedure time. Conversely, it increased the fluoroscopy time in patients with one- and two-vessel diseases. To the best of our knowledge, few studies have focused on comparisons of mono- and bi-plane imaging, and our findings shed light on the issue of radiation exposure.

For operational convenience, biplane angiography imaging is often preset for angles that are commonly used in individual vessel regions.[11] However, from a clinical perspective, the preset angle does not seem ideal for all clinical situations, depending on the patient's pathology and the anatomy of coronary arteries. Test injections are typically performed from a preset angle and then corrected for angiographic projections to achieve a minimum geometric distortion for a particular coronary lesion and minimal overlap with other blood vessels.[11] Nevertheless, if the operator is not familiar with the use of a biplane, the time for programing will be extended. In contrast, an operator who chooses to use a monoplane (with no pre-programmed angle) will be more likely to operate it during coronary angioplasties. Fang et al. concluded that biplane imaging could not decrease procedural time, fluorescence time, or contrast volume in retrograde interventions for chronic total occlusive lesions.[12] Correspondingly, we also found that there were no significant differences in contrast volume between monoplane imaging or biplane imaging independently of the number of lesions. Although the fluoroscopy time in the patients with biplane versus monoplane imaging was similar in the groups who received only diagnostic angiography and 3-V-D, in the patients with 1-V-D and 2-V-D the fluoroscopy time with biplane imaging was significantly longer. Different from Fang's study which focused only on chronic total occlusion, we analyzed the impact of monoplane and biplane imaging separately with regards to the severity of lesions. Even though only a few of the enrolled cases had complex coronary lesions such as bifurcation of left main lesions, we believe that the prolonged fluoroscopy time in this study was due to the complexity of individual procedures.

Given that the application of biplane imaging includes the diagnosis and treatment of coronary artery disease and also arrhythmia, most hospitals adopt biplane imaging due to economic reasons.[11] Also, biplane imaging is generally used to treat patients with impaired renal function and those with higher radio-sensitivity, such as children and the critically ill.[1-3] Therefore, most operators believe that the use of biplane imaging reduces the radiation dose, contrast medium load and shortens the procedure.[2,4] However, our results challenge this concept and suggest that the preferred imaging modality for diagnostic coronary angioplasties should be monoplane rather than biplane imaging.

Interestingly, we found that the rate of biplane imaging was lower in the patients who were older, male and had a higher body weight. However, using biplane imaging may result in a greater number of angiographic examinations in these patients due to the poor resolution of lateral projection. In particular, adjusting the angles during the examination may be difficult in intubated or obese patients given the limited space. Conversely, in the patients with cardiovascular risks and those who had previously undergone a PCI, the operators were more likely to choose biplane imaging. Also, the tilt angle selection was a major factor associated with radiation exposure, and CRA LAO 60°/20° and CAU 30° DAP have been reported to increase the radiation exposure by up to 2.5 times.[7-9] Clinically, most of these angles are set within the regular preset angles and are used to fine-tune and set the photography. Although it is well known that reducing the amount of intraoperative contrast medium, minimizing the angiographic frames and using smaller sizes of catheters are crucial for diagnostic and interventional procedures, this is difficult in the practice because these interventions are highly dependent on the techniques of the operators and also the clinical situation.

Limitations

There are some limitations to this study. First, it lacks a randomized allocation in the use of biplane or monoplane imaging, including the image receiver sizes, field of view size and collimation, which may have affected the results. Second, the radiation measurements recorded in the examination data (dose rate, skin dose and DAP) were not corrected for attenuation. Therefore, the patients' actual DAP and skin doses may have been lower than the reported values. Third, when grading the complexity of coronary lesions, SYNTAX scores may be more representative than QCA-defined severity of coronary lesions. Also, performing either mono- or biplane imaging was determined by the operators according to the patients' conditions. Thus, selection bias may have interfered with the accuracy of our result. We attempted to further the divide patients who received only diagnostic angiography according to the number of coronary lesions, however given the small number of patients, the statistical significance was diminished. Collectively, in diagnostic angiography or interventions for relatively simple lesions, monoplane imaging, which provides adequate information and reduces radiation exposure, may be superior to biplane imaging. Nevertheless, in complex or chronic total occlusion lesions, the net benefit of biplane imaging should be judged by the operator on an individual basis. Further randomized control studies may help to verify our findings.

CONCLUSIONS

Our findings indicated that biplane imaging technology resulted in greater radiation exposure and required a longer fluoroscopy time. There were no significant differences in the dose of contrast medium and procedure time between the biplane and monoplane angioplasty procedures.

CONFLICT OF INTEREST

All the authors declare no conflict of interest.

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