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Radiation Dose in Diagnostic and Therapeutic Procedures of Congenital Heart Diseases in Children

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Abstract

Background: There is concern about radiation dose in children during cardiovascular catheterization and many believe that the use of computerized tomography is much better than conventional catheterization and angiography. The aim of this study is to compare the radiation dose between diagnostic and therapeutic procedures in children.

Methods: 178 patients with congenital heart disease enrolled in this study. Patients have been divided into 3 groups of CT angiography, conventional angiography and intervention. Data include: sex, age, weight, fluoroscopy time, total radiation dose of CT angiography, the amount of reference point air Kerma (Ka, r) (reference dose) and kerma area product (Pka) of fluoroscopy machine. Peak skin dose (PSD) was calculated for intervention and conventional angiography patients using the following formula: PSD = 249 + 5.2 × P_{KA}. The data has been analyzed by SPSS version 20. In this study the P-value less than 0.05 was considered meaningful.

Results: The patients were similar in sex, age and weight in all the three groups. The mean reference point air kerma (ka,r) in intervention group was meaningfully higher than the other two groups (P < 0.001) , but in some patients of CT Angiography group the radiation dose was higher than conventional angiography group.

The mean kerma area product (p_{ka}) in intervention group was higher than angiography group, although this difference is less meaningful statistically (P = 0.049). The Fluoroscopy time (P = 0.035) in intervention group was meaningfully higher than angiography group. The mean calculated pick skin dose (PSD) was 437 ± 383 miligray and 213 ± 508 miligray for intervention and conventional angiography groups respectively (P < 0.001). In intervention group, Fluoroscopy time (P = 0.037), ka,r (P = 0.17) (and P_{ka} (P = 0.02) are more about VSD closure than other procedures.

Conclusions: Given the results of this study, the use of fluoroscopy for diagnosis and treatment of pediatric cardiovascular diseases is safe but with due attention to sensitivity of children to some side effects of X-ray compared to adults, considering safety advices in order to reduce fluoroscopy time, radiation dose and the use of standard protection to reduce X-ray absorption is necessary.

Keywords: Radiation, Congenital Heart Disease, Children

1. Background

Radiation exposure happens by two sources of natural and human made. Each of them contribute 50% of total radiation to people. The amount of radiation by medical sources for diagnostic purpose such as cardiovascular catheterization and computerized tomography is increasing, especially in children.

In these diagnostic procedures, X-ray (gamma ray) is required. X-ray has obviously got some harmful effects on human body (1-4).

Deterministic effects or tissue reactions are dose dependent. Stochastic effects may happen by any dose, otherwise, no amount of radiation can be safe or harmless.

During years, many interventions have been determined to reduce radiation dose in cardiovascular catheterization (4-7).

Also, many studies have been done in pediatric cardiovascular catheterization laboratory to improve the quality of Fluoroscopy and reduce radiation dose (8-13).

Still, these is concern about radiation dose in children during cardiovascular catheterization and many believe that utilization of computerized tomography is much better than conventional catheterization and angiography.

The aim of this study is to compare the radiation dose between diagnostic and therapeutic procedures in children.

2. Methods

This study was descriptive and retrospective.

About 178 patients with congenital heart disease enrolled in this study. 60 of them underwent angiography by computerized tomography (CT angiography) by Siemens 64 slice machine made by Germany and 118 of them underwent conventional angiography by Siemens Fluoroscopy machine made by Germany (axiom artis megalix).

Among 118 patients in the second group, 60 patients underwent cardiovascular catheterization and angiography and the remaining 58 people had interventional procedures too.

So these patients have been divided into 3 groups of CT angiography, conventional angiography and intervention.

Demographic and obtained angiographic data of diagnostic and interventional procedures consisted of: sex, age, weight, fluoroscopy time, total radiation dose of arterial and venous phases of CT angiography by miligray scale, the amount of reference point air Kerma (Ka, r) (reference dose) by miligray scale, kerma area product (Pka) by microgray scale per square meter witch was calculated by conventional fluoroscopy machine.

P (ka) changed to gray per square centimeter, and peak skin dose (PSD) was calculated for intervention and conventional angiography patients using the following formula: $PSD = 249 + 5.2 \times P_{KA}$.

The data has been analyzed by SPSS version 20 using descriptive statistic methods: (mean, standard deviation, frequency, percentage), Independent-samples T-test and Mann-Whitney Test for comparing quantitative mean, Kolmogrof-Smirnof test for determination of data distribution ,chi-square test (to compare qualitative data) and Kruskal-Wallis and ANOVA tests to compare the mean of the three groups.

In case of being meaningful, we used a suitable following test.

For determination of the correlation we used regression liner test.

In this study the P-value less than 0.05 was considered meaningful.

3. Results

In this study 178 patients in three groups of CT Angiography, conventional angiography and Intervention has been studied. There were 60 cases in both first and the second groups and 58 in the third group. The patients were similar in sex, age and weight in all the three groups and there wasn't any meaningful differences (Table 1).

The mean reference point air kerma (ka,r) in intervention group is meaningfully higher than the other two groups ($P < 0.001$), but in some patients of CT Angiography group the radiation dose is higher than conventional angiography group.

The mean kerma area product (p_{ka}) in intervention group is higher than angiography group, although this difference is less meaningful statistically ($P = 0.049$).

The Fluoroscopy time in intervention group is meaningfully higher than angiography group (Table 2).

The mean calculated pick skin dose (PSD) is 437 ± 383 miligray and 213 ± 508 miligray for intervention and conventional angiography groups respectively ($P < 0.001$).

In intervention group, different procedures have been done in which more frequency was as bellow in sequential: PDA closure, COA angioplasty, ASD closure, pulmonary valvuloplasty by balloon and VSD closure. By paying attention to the lowest statistical difference (LSD), Fluoroscopy time ($P = 0.037$), ka,r ($P = 0.17$) (and P_{ka} ($P = 0.02$) are more about VSD closure than other procedures.

None of the cases in this study were affected by early and skin side effects of X-ray.

4. Discussion

The variety of congenital heart diseases in children require complicated diagnostic and therapeutic interventions which can be long and repeated. Sometimes it is necessary to use X-ray (gamma) to do these procedures.

To avoid the side effects of X-ray (1, 2) lots of studies has been done and by paying attention to the inevitable usage of X-ray in diagnostic and therapeutic procedures, a distinct amount of radiation dose and Fluoroscopy time has been defined (3-6).

With respect to this fact that there is no harmless level of radiation, lots of advices have been given to reduce the amount of radiation and standardization the radiation in cardiovascular catheterization laboratories (7-14).

It is needed to use dosimeter to assess the exact amount of received radiation by patient, but it is not possible all the time, and also it demands a lot of time and expenses. For this reason angiographic devices are armed to variable facilities that can estimate the received skin dose by patient. The maximum acceptable interventional reference dose is 2000 grays (3, 4).

Reference dose, is an estimation of total skin dose.

Pka is the total energy of X-ray which is emitted from X-ray source and contrary to reference dose, doesn't depend on the distance of energy sources to skin.

The Pka is a good index of total energy of X-ray which will be absorbed by patient (4). It can be used for controlling the amount of received radiation by patient during interventional procedures. In spite of that, because the skin dose depends on body size and patients position, and the above parameters won't consist of back scatter radiation, the real skin dose in patient may be 10% - 40% more than calculated.

One of the common advices for reducing the radiation dose in pediatrics is using CT angiography instead of conventional angiography, but there are some disadvantages:

1. It's not suitable for evaluating stenosis or insufficiency of heart valves.

Table 1. Demographic Data of The Patients of Three Groups[a]

Variables	Intervention (N = 58)	Angiography (N = 60)	P Value	CT Angiography (N = 60)	P Value
Gender			0.45*		0.12
female	34 (58.6)	24 (40.0)		25 (41.7)	
male	24 (41.4)	36 (60)		35 (58.3)	
Weight, kg	12.90 ± 8.15	13.02 ± 8.25	0.94**	12.88 ± 11.81	0.99
Range	2 - 45	3.5 - 38.0		2.80 - 47.0	
Age, mo	42.10 ± 33.61	45.95 ± 39.57	0.78**	41.88 ± 48.87	0.13
Range	2 - 126	1 - 144		2 - 146	

[a]Values are expressed as No. (%).

Table 2. Radiation Dose and Fluoroscopy Time of Three Groups

Variables	Intervention (N = 58)	Angiography (N = 60)	P Value	CT Angiography (N = 60)	P Value
Ka.r, mgy	30.71 ± 26.31	20.54 ± 14.25	< 0.001	8.61 ± 2.25	< 0.001
Range	6.00 - 126.00	3.00 - 58.00		5.22 - 20.22	
P_{KA}, Gy.cm^2	172.68 ± 151.28	84.27 ± 208.77	0.049		-
Range	10.60 - 646.00	2.60 - 351.80			
Fluoroscopy time, sec	658.09 ± 566.89	463.68 ± 235.15	0.035		-
Range	5.00 - 381.00	111.00 - 845.00			

Abbreviations: Ka.r, Reference Point Air Kerma (Reference Dose); P_{KA}, Kerma Area Product.

2. It's not applicable for measuring the pressures in the heart and vessels.

3. It's not useable as a guidance for cardiovascular intervention.

4. Not all CT-Angiography devices have enough accuracy in diagnosis of cardio-vascular anomalies.

5. Resulting interpretation is operator dependent.

In the present study the mean radiation dose in conventional angiography is 2.5 times as much, compared to CT angiography.

In intervention group it is about 1.5 times as much in comparison to conventional angiography, in spite of that, the pick skin dose, ka, r and p_{ka} in conventional angiography and even in interventional angiography is lower than the reference dose by the society of interventional radiology (SIR) and international commission on radiological protection (ICRP) (4).

In our study, Fluoroscopy time in some cases of intervention group is higher than the permitted level (3, 4).

In both groups of intervention and conventional angiography the radiation dose is correlated to fluoroscopy time.

In the present study the radiation dose in intervention group is higher for VSD closure procedure than the others, as the study of Onnasch DG and collegues (15).

The mean fluoroscopy time for intervention group is about 1.5 times as much in comparison to conventional angiography same as EL Sayed, MH and colleges study (16).

The mean fluoroscopy time at present study versus Asghar Mesbahi and Aslanabadi's study is more in conventional angiography group but is less in intervention group (17), also the radiation dose in present study is less than the above mentioned study, which can be due to increased quality of fluoroscopy machines.

4.1. Conclusion

With the results of this study, the use of fluoroscopy for diagnosis and treatment of pediatric cardiovascular diseases is safe but with due attention to sensitivity of children to some side effects of X-ray compared to adults (18), considering safety advices in order to reduce fluoroscopy time and radiation dose and the use of standard protective measures to reduce X-ray absorption is necessary.

Considering the efficiency and limitations of different diagnostic and therapeutic modalities for pediatrics cardiovascular diseases, we can improve the productivity of the modality, prevent repetitive radiation to the patient and reduce X-ray side effects.

Although none of the patient in this study were suffering from early and skin side effects of X-ray, but follow up is needed to assess the long-time side effects. For determining the exact pick skin dose, studies with more cases are required.

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