Reducing ionizing radiation doses during cardiac interventions in pregnant women

Elizabeth Orchard MA MRCP, Sarah Dix MD, Neil Wilson MD, Lucy Mackillop MA, MRCP and Oliver Ormerod DM, FRCP

Department of Cardiology, John Radcliffe Hospital, Oxford OX3 9DU, UK

Summary

Background: There is concern over ionizing radiation exposure in women who are pregnant or of child-bearing age. Due to the increasing prevalence of congenital and acquired heart disease, the number of women who require cardiac interventions during pregnancy has increased. We have developed protocols for cardiac interventions in pregnant women and women of child-bearing age, aimed at substantially reducing both fluoroscopy duration and radiation doses.

Methods: Over five years, we performed cardiac interventions on 15 pregnant women, nine postpartum women and four as part of pre-pregnancy assessment. Fluoroscopy times were minimized by simultaneous use of intracardiac echocardiography, and by using very low frame rates (2/second) during fluoroscopy.

Results: The procedures most commonly undertaken were closure of atrial septal defect (ASD) or patent foramen ovale (PFO) in 16 women, coronary angiograms in seven, right and left heart catheters in three and two stent placements. The mean screening time for all patients was 2.38 minutes (range 0.48–13.7), the median radiation dose was 66 (8.9–1501) Gy/cm². The median radiation dose to uterus was 1.92 (0.59–5.47) μ Gy, and the patient estimated dose was 0.24 (0.095–0.80) mSv.

Conclusions: Ionizing radiation can be used safely in the management of severe cardiac structural disease in pregnancy, with very low ionizing radiation dose to the mother and extremely low exposure to the fetus. With experience, ionizing radiation doses at our institution have been reduced.

Keyword: cardiology

INTRODUCTION

The use of ionizing radiation has traditionally been avoided in pregnant women since it was established in 1956 that its use was associated with an increased rate of childhood malignancy.¹ Ionizing radiation can have a deterministic effect, where damage is induced above a dose threshold; this can produce congenital malformations of the fetus, mental and growth retardation or embryonic death.² Radiation can also have a stochastic effect where even the smallest exposure increases the probability of an effect in an individual, for example, malignancy. Due to these concerns, many radiological procedures are avoided in pregnancy.

Pregnancy is a unique physiological state where both cardiac output and stroke volume can increase by as much as 50%. Women with either pre-existing structural heart disease or ischaemic heart disease may be unable to adapt to these haemodynamic changes when pregnant. Pregnancy is also a hypercoagulable state that can predispose to the formation of venous thromboemboli.³ In the presence of either an ASD or PFO, venous thromboemboli can result in ischaemic stroke with potentially catastrophic outcome.

We have noted that women are now being referred more frequently for assessment of cardiovascular problems presenting in pregnancy or for pre-pregnancy assessment of their known cardiovascular disease. Therefore, we have developed protocols for cardiac interventions in pregnant women and women of child-bearing age, aimed at substantially reducing both fluoroscopy duration and radiation doses. We have reviewed our cardiac catheterization procedures performed for pre-pregnancy assessment, those performed in pregnant women, and those in postpartum period, to compare trends in ionizing radiation dose.

METHODS

Consecutive patients undergoing cardiac catheterization were included in the study. Women who were pregnant at the time of cardiac catheterization, were up to one-year postpartum, or who were undergoing pre-pregnancy assessment of their cardiac disease, were included. Cardiac interventions were only undertaken in pregnancy for severe cardiac conditions requiring urgent diagnosis and treatment to prevent major morbidity or mortality to mother.

The type of cardiac catheterization performed, radiation doses used, gestation of pregnancy and body surface area of the women were measured. The radiation doses required for different procedures were reviewed over the duration of the study to evaluate any reduction in radiation doses with time.

Correspondence to: Elizabeth Orchard
Email: elizabethorchard@hotmail.com

We used a single-plane Coroskop TOP Hicor system (Siemens, Munich, Germany). Dose area product measurements were performed with transmission ionization chamber DAP meter, attached to the X-ray tube collimeter. We calculated a retrospective estimation of dose to the uterus taking into account gestation, and thus an estimate of fetal dose and the overall patient effective dose (using the latest ICRP103 definitions). The radiation doses used were calculated for three projections, PA (posterior–anterior), LAO 30 (left anterior oblique) and RAO 30 (right anterior oblique), using a maximum tube potential of 80 kV and an average field size of 25 cm (diagonal).

The dose to the uterus, and therefore the estimated fetal dose, was calculated using the methods and factors used by the Health Protection Agency as published in their document 'Protection of pregnant patients during diagnostic medical exposure to ionizing radiation – RCE-9'. The Body surface area of the patient and fetal gestation were factored into the calculation. The risk given is the excess risk of cancer induction derived using the risk factor of 10^{-4} mGy^{-1} .

STATISTICAL ANALYSIS

Data are shown as median (25th–75th centile). Non-normally distributed data were log transformed where necessary. Analyses were performed using Kruskal–Wallis test and Mann–Whitney *U* test, corrected by using Bonferroni *post hoc* test for two comparisons.

RESULTS

Over a five-year period, we performed cardiac interventions on 28 patients, 15 pregnant women, nine postpartum women and four women as part of prepregnancy assessment (Table 1). Of the 15 pregnant women, one was in her first trimester, 11 were in their second trimester and three were in their third trimester. The procedures most commonly undertaken were closure of ASD or PFO in 16 women, coronary angiograms in seven, right and left heart catheters in three and two stent placements (1 SVC stent in a patient with transposition of the great arteries and an atrial switch with baffle obstruction and 1 aortic stent in a patient presenting with coarctation during pregnancy).

The mean screening time for all patients was 2.38 minutes (range 0.48–13.7), the median radiation dose was 66 (8.9–1501) Gy/cm². The median radiation dose to uterus was 1.92

(0.59–5.47) μGy , and the patient estimated dose was 0.24 (0.095–0.80) mSv.

The median radiation dose to uterus for pregnant women was 0.73 (0.43–1.96) μGy , postpartum was 5.21 (2.08–40.96) μGy and prepregnancy was 4.3 (3.24–7.8) μGy . There was a significant difference between the pregnant women's dose to uterus and the postpartum and prepregnancy women ($P < 0.01$; Figure 1).

The median patient estimated dose for pregnant women was 0.11 (0.058–0.18) mSv, postpartum was 1.08 (0.32–4.04) mSv and prepregnancy was 0.5 (0.3–1.08) mSv. There was a significant difference between the pregnant women's estimated patient dose and the postpartum and prepregnancy women ($P < 0.01$ and $P < 0.05$, respectively, Figure 2).

The radiation dose to uterus and patient estimated dose were analysed for ASD/PFO closures, coronary angiograms, right and left cardiac catheters and stent procedures. The median radiation dose to uterus for ASD/PFO closures was 0.90 (0.41–3.78) μGy , coronary angiograms was 1.9 (0.96–4.58) μGy , right and left cardiac catheters was 2.1 (1.33–2.91) μGy and stent procedures was 30.9 (25.9–35.9) μGy (Figure 2).

The median patient estimated dose for ASD/PFO closures was 0.11 (0.05–0.80) mSv, coronary angiography was 0.28 (0.14–0.36) mSv, right and left cardiac catheters 0.32 (0.28–0.33) mSv and stent procedures was 4.21 (3.95–4.47) mSv (Figure 2).

The risk to the fetus ranged from one in 130,000 to one in 3,344,000, indicating very small risks. The range of patient dose risks varied more widely than for fetal dose risks with one in 1000 to one in 18,000, which are acceptable in the context of cardiac catheterization techniques.

The dose of radiation used throughout the study period was also analysed by year of procedure (Figure 3). There was a marked reduction in procedural ionizing radiation exposure during the study period.

Figure 1 Box and whisker plot of dose to uterus (μGy) and patient estimated dose (mSv) for pregnant, postpartum and women undergoing prepregnancy assessment. Overall significance test by Kruskal–Wallis test. * $P < 0.05$, ** $P < 0.01$ versus pregnant (Mann–Whitney *U* test, corrected by using Bonferroni *post hoc* test for two comparisons)

Table 1 Demographics of women undergoing cardiac catheterization

	Pregnant	Postpartum	Prepregnancy
<i>n</i> =	15	9	4
Mean age (range)	33.4 (21–43)	31.3 (25–37)	29.0 (21–38)
Trimester			
1	1		
2	11		
3	3		
Procedure			
ASD/PFO	11	4	1
Angiography	4	1	2
Right and left heart catheter	0	2	1
Coarctation Stent	0	1	0
SVC stent	0	1	0

SVC, superior vena cava

Figure 2 Box and whisker plot of log transformation of total radiation dose, dose to uterus and patient estimated dose. ED, estimated dose

Figure 3 Procedural X-ray dose by year of procedure. The graph shows individual procedures carried out in women either pre-pregnancy, during pregnancy or immediately post-pregnancy by year of procedure (2005–2010). There was a marked reduction in procedural ionizing radiation exposure during the study period

Pregnancy produces profound changes in maternal haemodynamics. Circulating blood volume increases by 50%, and cardiac output also increases due to a rise in heart rate and stroke volume. Due to the increase in plasma volume, cardiac output and decrease in peripheral vascular resistance, women with structural or congenital heart disease may struggle to adapt to these changes in physiology and therefore present in pregnancy with cardiac symptoms.⁷ We know from CMACE data that ischaemic heart disease is an increasing cause of maternal morbidity and mortality.^{8,9} Due to the increased cardiovascular demands of pregnancy, women with ischaemic heart disease may require diagnosis or treatment during pregnancy.

Pregnancy is also a hypercoagulable state that predisposes to the development of venous thrombosis. Recent evidence suggests that thromboembolism across a patent foramen ovale may be an important cause of ischaemic stroke in pregnancy.¹⁰ As there is a substantial mortality associated with stroke presenting in pregnancy, the prevention and treatment of stroke are paramount.^{11,12} This includes anticoagulation; however, recurrent strokes, despite adequate anticoagulation in the presence of a known PFO/ASD, may require percutaneous PFO/ASD closure.^{11,13,14}

All these factors together have increased the number of pregnant women requiring cardiac catheterization and emphasized the need for pre-pregnancy and post-pregnancy assessment of these women.

Precautions were taken to reduce both maternal and fetal exposure to ionizing radiation. In venous-accessed catheter procedures over half of the fetal radiation exposure is generated during catheter insertion in the groin and advancement to the heart. By using exchange length wires, access can be confirmed by supra-diaphragmatic fluoroscopy only and the use of long venous sheaths enables the advancement of an intracardiac echocardiogram catheter (for ASD/PFO closures) to the heart without needing pelvic fluoroscopy.¹⁰ Radiation doses can also be further reduced by using intracardiac echo instead of fluoroscopy for visualizing the device and for device deployment. The fluoroscopy doses may also be further reduced by using very low frame rates (2/second), small collimated beam sizes, minimal angulation of X-ray source and not by taking

DISCUSSION

Ionizing radiological procedures for many years have been avoided in pregnant woman due to the perceived risks to the fetus. However, this risk has to be compared with the risk of an adverse clinical outcome in the mother. Most data regarding the use of ionizing radiation in pregnancy come from data on the diagnosis of pulmonary embolism using either ventilation perfusion scanning or computed tomography scanning. The risk of venous thromboembolism (VTE) during pregnancy is estimated at 0.5–3/1000 pregnancies, and untreated VTE has a mortality rate of about 15%.⁴ Studies have reviewed the outcome of ionizing radiation and demonstrated that there is a small increased relative risk in childhood cancer; however, fetal outcome is good.^{5,6}

acquisition runs. From our data it can be seen that there was a reduction in radiation dosimetry over time as our expertise in this area improved. In our institution expertise is concentrated with a single operator who has an interest in this area and with experience, we found that less fluoroscopic screening was required over time. In order to minimize radiation dose to the fetus, these techniques should only be performed by the most experienced operators.

There was a significant difference not only in radiation doses between pregnant and non-pregnant women, as would be expected, but also in types of procedure performed, with ASD/PFO closures, cardiac angiography and right and left heart catheters using significantly less radiation, than a stent insertion. However, both the patients were postpartum at the time of stent insertion.

CONCLUSION

By employing techniques to minimize fluoroscopy time and the resultant reduction in radiation dose that this produces, it is possible to deliver a low ionizing radiation dose to pregnant woman with very low exposure to the fetus. Therefore, where there is clear clinical need, pregnant women can safely undergo procedures requiring ionizing radiation.

DECLARATIONS

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Contributorship: EO, LM, OO conceived study. SD, EO analysed data, SD wrote the first draft. All authors reviewed and edited the manuscript and approved final version.

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