Estimating the radiation dose to the fetus during prophylactic internal iliac occlusion in patients with abnormal placentation

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Aims. To evaluate the estimated fetal radiation dose during prophylactic internal iliac arterial occlusion in patients with abnormal placenta and to estimate the risk of radiation induced cancer in child age.

Methods. Prophylactic occlusion of the internal iliac arteries during Caesarean section was performed in 42 patients with placenta praevia and/or placenta accreta spectrum. Fogarty embolectomy catheters were used for prophylactic occlusion of the internal iliac arteries. All procedures were performed in the hybrid operating room using Philips Allura Xper FD 20 X-ray system. Low dose X-ray fluoroscopy (7.5 frames per second) was used. The CODE (Conceptus dose estimation) Software was used to estimate the fetal dose and the risk of radiation induced carcinoma.

Results. Fluoroscopy times required for insertion of Fogarty catheters were 0.5-4.2 min (mean: 1.7 min, median: 1.5 min). The estimated radiation dose to the fetus was 0.26-3.36 mGy (mean: 1.49 mGy, median: 1.25 mGy). The risk of radiation induced cancer in child age was 0.01-0.04% (mean 0.02%, median 0.01%). One patient developed thrombosis of a common femoral artery.

Conclusion. Prophylactic occlusion of the internal iliac arteries is a simple and safe procedure with minimal risk of complications and with a very low estimated radiation dose to the fetus.

Key words: placenta praevia, placenta accreta spectrum, prophylactic occlusion, internal iliac arteries, fetus radiation dose

Received: May 18, 2020; Revised: September 15, 2020; Accepted: October 2, 2020; Available online: November 26, 2020 https://doi.org/10.5507/bp.2020.046

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INTRODUCTION

Placenta praevia (complete or marginal) is defined as abnormal placentation near or covering the internal cervical os. Placenta accreta spectrum, previously known as morbidly adherent placenta, is defined as an abnormal trophoblast invasion of all or part of the placenta to the uterine wall. Placenta accreta spectrum includes placenta accreta, placenta increta, and placenta percreta.

Placenta praevia and accreta spectrum are associated with a high risk of maternal and fetal mortality and morbidity, especially when diagnosed during delivery. These placental disorders, in particular abnormal placenta invasion, are associated with a risk of massive bleeding^{1,2}. Prenatal diagnosis by ultrasonography and/or magnetic resonance imaging is crucial to reduce maternal blood loss and postpartum complications. Delivery by Caesarean section can be planned and performed in a specialized centre, where a multidisciplinary team is available^{3,4}.

Recently, efforts have been made in patients with placental disorders to avoid hysterectomy and preserve fertility⁵. Temporary prophylactic bilateral internal iliac artery occlusion may allow Caesarean delivery to be performed with a reduced risk of intraoperative bleeding and without hysterectomy. Prophylactic occlusion of the internal iliac

arteries is performed under fluoroscopic guidance with potential risks related to ionizing radiation. Nevertheless, the risks of fetal effects, including inducing childhood cancer, are thought to be negligible at fetal doses < 50 mGy (ref.⁶).

The aim of our retrospective study, from prospectively collected data, was to evaluate the estimated fetal radiation dose associated with prophylactic internal iliac occlusion during Caesarean section in patients with abnormal placenta (placenta praevia and placenta accreta spectrum) and to estimate the risk of radiation induced cancer in child age.

MATERIAL AND METHODS

From November 2015 to November 2019, we performed prophylactic occlusion of the internal iliac arteries in 42 pregnant patients of mean age 35 years (range 23-48 years). The combined procedure of prophylactic internal iliac artery occlusion and Caesarean section was indicated in pregnant patients with abnormal placentation. Prophylactic occlusion of the internal iliac arteries during Caesarean section was performed to decrease blood loss and avoid hysterectomy. The indication for prophylactic

occlusion of the internal iliac arteries in patients with placenta percreta was a reduction in blood loss during hysterectomy. At our hospital hysterectomy is primarily indicated in placenta percreta and attempts to remove placenta percreta are not performed. All consecutive patients with placenta previa or accreta spectrum were included in this study.

Placental abnormalities were diagnosed prenatally, in all 42 patients by ultrasonography. In 31 patients magnetic resonance imaging was also performed. Placenta previa was diagnosed in 21 patients, placenta praevia and adherens in 3, placenta praevia and placenta accreta in 13 patients, and placenta praevia and percreta in 5 patients.

Endovascular technique

All procedures were performed in a hybrid operating room with a Philips Allura Xper FD 20 X-ray system.

The cross-over technique was used for placement of introducers and occlusion balloons. Introducer sheaths used were 55 cm hydrophilic, shaped 6F introducers (Flexor Touhy-Borst Side-Arm Introducer, Ansel modification 2 - Renal Double, Cook, Bloomington, IN). The shape of these introducers allows easy cross-over catheterisation, almost always without requiring preshaped catheter. The correct position of introducers was verified by injection of contrast medium. For temporary occlusion of the internal iliac arteries, 5.5F over-the-wire Fogarty thru-lumen embolectomy catheters were used (Edwards Lifesciences, Irvine, CA, USA). An advantage of these catheters is the ability to occlude arteries of different diameters and the possibility to flush the internal iliac arteries and catheters through the lumen of the embolectomy catheter. Successful occlusion of the internal iliac arteries by the inflated Fogarty balloons was tested with contrast medium and the volume of contrast medium in the balloons was recorded. Introducers were continuously flushed with saline by pressure infusion to minimize the risk of thrombosis. Introducers and Fogarty balloons were firmly fixed to the surgical drape to prevent migration. Thereafter, Caesarean section was performed under general anaesthesia. After delivery of the neonate and umbilical cord clamping, the balloons were blindly inflated to reduce bleeding in the operating field, and delivery of the placenta and uterine suture were completed or hysterectomy in case of placenta percreta was done. After surgery, the femoral arteries were percutaneously closed using a nitinol clip (StarClose SE, Abbott Vacular, Santa Clara, CA, USA).

We used low dose X-ray fluoroscopy (7.5 frames per second) for Fogarty embolectomy catheter insertion to minimise radiation dose (Fig. 1). Digital subtraction angiography record was not performed in any patients.

This study used prospectively collected data from all patients for calculation of the fetal dose. The data were recorded during every procedure. The data needed to estimate the fetal dose are stage of pregnancy, fluoroscopy time, X-ray tube voltage, study area including projection, zoom, total DAP (dose area product), distance FSD (focus-to-skin distance), filtration (Al/Cu) (Table 1). The CODE (Conceptus dose estimation) Software was used to estimate the fetal dose and the risk of radiation induced

cancer in child age. The software was developed for the calculation of fetal dose for different stage of pregnancy.

RESULTS

The technical success rate of Fogarty catheter insertion was 100%. Fluoroscopy times required for the insertion of Fogarty catheters were 0.5-4.2 min (mean: 1.7 min, median: 1.5 min) (Table 1). The mean estimated radiation dose to the fetus was 1.49 mGy, the median was 1.25 mGy (0.26-3.36 mGy) (Table 1).

The risk of radiation induced cancer in child age was 0.01-0.04% (average risk: 0.02%, median risk: 0.01%) (Table 1). One patient developed thrombosis of a common femoral artery and this complication was successfully managed by surgical thrombectomy.

Hysterectomy was performed in 6 patients, five patients with placenta percreta and one patient with placenta accreta. The indication for hysterectomy in the patient with placenta accreta was massive bleeding during an attempt to remove of the placenta. We did not observe dislocation of the occlusion balloons during the hysterectomy.

Embolisation of the uterine arteries with spongostan (Gelita-Spon standard, Gelita medical, Eberbach, Germany) was successfully performed in 7 patients during the procedure because of postoperative bleeding.

DISCUSSION

Prophylactic occlusion of the internal iliac arteries is indicated in pregnant women with placental abnormalities (placenta praevia and accreta spectrum) to reduce blood loss during Caesarean section and to avoid hysterectomy and preserve fertility⁷⁻¹¹.

Prophylactic temporary occlusion of the internal iliac arteries is a fluoroscopically guided procedure. The use of fluoroscopy is associated with potential adverse effects to the fetus due to the use of ionizing radiation. The probability of inducing cancer increases with the radiation dose. Estimated radiation doses to the fetus during prophylactic occlusion of the internal iliac arteries are low^{12,13}. Some risk of radiation inducted cancer exists and the risk is not zero at doses of the order of 10 mGy (ref. 14). The risk of radiation induced fatal cancer in childhood is about 0.06% per 10 mGy (1/1700) (ref. 15). According to practice guidelines of ACOG (The American College of Obstetricians and Gynecologists), the risk of fetal effects, including childhood cancer induction, are thought to be negligible at fetal doses < 50 mGy (ref.6). According to ICRP (The International Commission on Radiological Protection), a fetal dose of 100 mGy has a small individual risk of radiation-induced cancer. There is over a 99% chance that the exposed fetus will not develop childhood cancer¹⁶.

Various aspects of the procedure, namely the medical devices used, the mode of fluoroscopy, and use of collimation contribute to a reduce fluoroscopy time and thus the fetal dose. The use of hydrophilic coated preformed sheaths allows easy crossing of the aortic bifurcation di-

Table 1. The parameters and results of patients.

Patient	Voltage (kV)	Fluoroscopic time (s)	FSC (cm)	Zoom	Filtration Cu/Al (mm)	DAP (mGy.cm ²)	Fetal dose (mGy)	Risk of radiation induced cancer (%)
1	111.00	130.0	81.3	48	0.9/1	4464.0	2.94	0.04
2	107.37	133.0	90.4	48	0.9/1	4500.0	2.24	0.03
3	117.01	148.0	79.1	48	0.9/1	4500.0	3.36	0.04
4	82.00	160.0	81	48	0.9/1	7841.0	2.81	0.03
5	94.45	79.0	92.7	48	0.9/1	1917.0	0.42	0.01
6	86.00	106.0	88.9	48	0.9/1	1317.0	0.38	0.01
7	105.67	254.0	86.9	48	0.9/1	4278.0	2.38	0.03
8	94.45	105.0	87.4	48	0.9/1	2714.0	0.94	0.03
9	102.48	182.0	80.4	48	0.9/1	4711.0	2.61	0,03
10	103.00	110.0	80.5	48	0.9/1	4411.0	2.66	0.03
11	98.00	169.0	80.7	48	0.9/1	4114.0	2.42	0.03
12	117.40	94.0	82.1	48	0.9/1	3874.0	2.34	0.03
13	111.00	117.0	85.1	48	0.9/1	4229.0	2.67	0.03
14	96.36	113.0	81.7	48	0.9/1	3403.0	1.7	0.02
15	104.61	161.0	82.1	48	0.9/1	4030.0	2.57	0.02
16	104.01	68.0	84.9	48	0.9/1	2634.0	1.25	0.03
17	80.00	201.0	81	48	0.9/1	4532.0	1.23	0.01
18	100.00	130.0	80.3	48	0.9/1	2455.0	1.26	0.02
19	101.00	85.0	82.7	48	0.9/1	2913.0	1.22	0.02
20	80.00	79.0	81	48	0.9/1	2588.0	0.75	0.01
21	107.60	72.0	84.4	48	0.9/1	2317.0	1.29	0.02
22	119.87	97.0	85.5	48	0.9/1	4962.0	2.98	0.02
23	111.00	104.0	83.1	48	0.9/1	2751.0	1.4	0.02
24	99.00	117.0	81	48	0.9/1	1948.0	0.6	0.02
25	110.60	124.0	80.3	48	0.9/1	2457.0	1.23	0.01
26	102.00	77.0	84.3	48	0.9/1	1517.0	0.59	0.01
27	80.00	75.0	81.4	48	0.9/1	2524.2	0.75	0.01
28	83.00	129.0	81.4	48	0.9/1	3000.0	1.24	0.01
29	83.00	107.0	81	48	0.9/1	2500.0	0.83	0.01
30	90.00	144.0	81	48	0.9/1	1266.0	0.83	0.01
31	80.00	83.0	85.1	48	0.9/1	2615.0	0.49	0.01
32	80.00	83.0	81.8	48	0.9/1	2601.0	0.75	0.01
33	80.00	155.0	81.8	48	0.9/1	3190.0	1.13	0.01
34	100.00	90.0	81	48	0.9/1	4467.0	2.45	0.03
35	85.00	83.0	84.7	48	0.9/1	2475.0	0.81	0.03
36	99.00	44.0	81	48	0.9/1	1903.0	0.6	0.01
37	89.00	129.0	81	48	0.9/1	6143.0	2.9	0.03
38	91.00	99.0	81	48	0.9/1	3995.0	1.52	0.03
39	82.00	56.0	84.9	48	0.9/1	1463.0	0.37	0.01
40	80.00	118.0	81	48	0.9/1	2721.1	0.75	0.01
41	83.00	98.0	81	48	0.9/1	970.0	0.75	0.01
42	89.00	50.0	80	48	0.9/1	1208.0	0.26	0.01

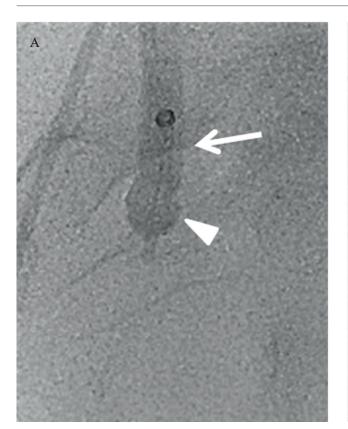
rectly into the internal iliac arteries in pregnant women, usually without needing another preshaped catheters. Our experience and the literature record slightly different morphology of the aortic bifurcation in pregnant women (almost always obtuse angle) which makes cross-over catheterisation of the internal iliac artery very easy¹⁷. Digital subtraction angiography is not used. Low dose pulse fluoroscopy should be used during the procedure to reduce X-ray exposure ¹⁸⁻²⁰.

These combined procedures, Caesarean section and prophylactic occlusion of the internal iliac arteries should

be performed in a hybrid operating room to avoid transporting patients from the angiography suite to the operating room which also avoids the need to reconfirm the position of the balloons and thus reduces the fluoroscopy time and fetal radiation dose¹².

An experienced interventional radiologist with good knowledge of arterial anatomy can perform the procedure with low dose fluoroscopy and a short fluoroscopy time and consequent low radiation dose^{13,21}.

The fluoroscopy time can be shortened by occlusion of the common iliac arteries or aorta, which is an alter-



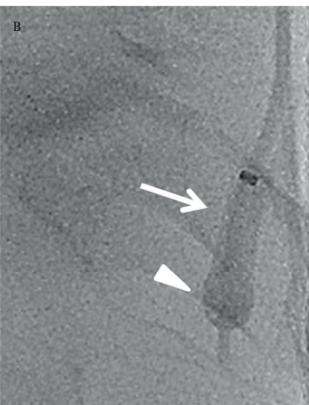


Fig. 1A,B. The record of fluoroscopy during catheter insertion. Test injection of contrast medium through the introducers to verify the occlusion of blood flow in the internal iliac arteries. Inflated Fogarty balloons (>) and stagnation of contrast medium proximally from balloons (→).

native to the most commonly used approach of prophylactic occlusion of the internal iliac arteries²². But it is necessary to consider that pregnant women have a higher risk of thrombembolic complications relating to higher artery compliance and hypercoagulation status during pregnancy^{23,24}. Occlusion of the common iliac arteries or aorta has a higher risk of these thrombembolic complications^{7,22,25-28}. Furthermore, occlusion of the infrarenal aorta can be associated with aortic dissection, aortic rupture, and peripheral ischemia^{29,30}. Additionally, supraphysiological increases in blood pressure proximal to the occluded aorta can contribute to cardiac failure³¹. Aortic balloon deflation and subsequent reperfusion can lead to potential cardiovascular complications²⁹. The radiation dose can be decreased with aortic occlusion but with an associated risk of severe complications³². Placement of the occlusion balloons in the common iliac arteries can be performed even without X-ray exposure under ultrasound guidance, but with a higher risk of thromboembolic complications and risks of retrograde flow into the internal iliac arteries³³. Another disadvantage is an inability to continue with uterine artery embolization in indicated cases compared with the selective catheterization of the internal iliac arteries. In our opinion, occlusion of the internal iliac arteries is easy, fast, and has a low risk of complication. In our group of patients, we had only one complication, thrombosis of common femoral artery.

In the literature we found only five articles which reported fetal radiation doses during prophylactic temporary occlusion of the internal iliac arteries. Bodner et al.³⁴ had 6 patients with placenta accreta/percreta who underwent prophylactic temporary balloon occlusion. The fluoroscopy time for placement of occlusion balloons into the anterior division of the hypogastric arteries was recorded in 3 cases. The average time was 4 min 20 sec. The average estimated fetal radiation dose was 32 mGy. Levine at al.³⁵ reported the fetal radiation dose during prophylactic pelvic artery balloon catheterization in 5 patients with placenta accreta, the median estimated fetal radiation exposure was 61 mGy. Kai et al.¹² reported the mean fetal radiation dose during prophylactic temporary occlusion of the internal iliac arteries before Caesarean section to be 21 mGy in 3 patients with placenta praevia/ accreta. The mean fluoroscopic time was 4.86 min. Yi et al.³⁶ published one case of a patient with placenta increta. The fetal radiation dose was 55 mGy. The fluoroscopic time was 2 min and 10 s. Semerado et al.¹³ reported the fetal absorbed radiation dose in 34 patients with morbidly adherent placenta during prophylactic occlusion of internal iliac arteries in Caesarean delivery. The median of fetal radiation dose was 4.65 mGy. The mean fluoroscopic time was 7.31 min.

The mean estimated radiation dose to the fetus in our group of patients was 1.49 mGy, the median was 1.25 mGy. The mean fluoroscopy time was 1.7 min, the median was 1.5 min. The fetus dose in our study was lower in comparison with literature and the fluoroscopic time was shorter. The risk of radiation induced cancer in child age

in our study was 0.01-0.04%, the average risk was 0.02%, and the median was 0.01%.

It is important to note that, albeit small, some risk of adverse events from fluoroscopy during prophylactic occlusion of the internal iliac arteries in pregnant women with placenta abnormalities exists. To minimise this procedure should be performed by an experienced interventional radiologist in a hybrid operating room with the appropriate equipment and material. The use of low dose fluoroscopy without digital subtraction angiography is our standard practice.

CONCLUSION

We found that prophylactic temporary occlusion of the internal iliac arteries in patients with an abnormal placenta is simple and effective with minimal risk of complications and very low estimated fetal radiation dose. The technique requires appropriate endovascular device, and an experienced team working in a hybrid operating room. Although the risk of complications is small and the dose to the fetus is low, it is necessary to develop an approach which minimises the fetal radiation dose.

Acknowledgement: Supported by: IGA_LF_2020_01. Author contribution: MC: data collection, study design, literature search, manuscript writing and final approval; KH: data collection, literature search; MK: critical reading, final approval; LJ: data analysis, data interpretation; TM: data interpretation; VP: figures, critical reading. Conflict of interest statement: The authors state that there are no conflicts of interest regarding the publication of this article.

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