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Evaluation of the Fetal-Maternal Radiation Doses in CT-Pelvimetry and Estimation of the Fetal Radiation Risks in 03 Radiology Departments in Douala-Cameroon

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Abstract

Background: CT in pregnant patients requires careful consideration of the radiation dose and corresponding radiation risks from ionizing radiation to the unborn child. The determination of foetal dose in diagnostic radiology is of interest as a basis for risk estimates from medical exposure of the pregnant patient. **Objective:** To evaluate the foetal-maternal radiation doses delivered during the CT-Pelvimetry procedure and to estimate the risk to the unborn child to develop a cancer in childhood and hereditary disease. **Materials and Methods:** We investigate the foetal-maternal radiation doses during CT-scan Pelvimetry in Douala (Cameroon). Data of 194 helical acquisition CT-Pelvimetry were collected between May 2017 and May 2019. An average DLP for the examination was established and the average effective dose was evaluated. The fetal dose was calculated and the FetDose V5 program was used for risk estimations. **Results:** The average dose length product (DLP) was 56.17 mGy·cm (range: 51.69 - 59.21 mGy·cm). The average effective dose received by women pregnant was 0.78 mSv. The mean individual fetal dose was 1.5 mGy (range: 0.76 - 1.87 mGy). The risk of Childhood Cancer calculated was: range 1 in 16,000 to 1 in 10,000 and 1 in 260,000 to 1 in 106,000 to the risk of Hereditary Disease, respectively. **Conclusion:** This study shows that the foetal-maternal doses delivered during CT-Pelvimetry examinations are very low and the risks of childhood cancers and hereditary diseases are derisory, the technology

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should be further investigated to ensure its full potential for optimal diagnostic accuracy.

Keywords

CT-Pelvimetry, Fetal-Maternal Radiation Dose, Fetal Radiation Risk

1. Introduction

Computed tomography (CT) is one of the most popular methods in medical imaging. During the past decades the number of CT examinations in pregnant patients has been growing constantly. However, CT in pregnant patients requires careful consideration of the radiation dose and corresponding radiation risks from ionizing radiation to the unborn child. The potential health risks make it important to estimate radiation dose absorbed by the fetus when a pregnant woman has a CT scan. Assessment of maternal pelvic dimensions is usually considered necessary where vaginal delivery is contemplated in a breech presentation or if fetal-pelvic disproportions are suspected in a current or previous pregnancy. Pelvimetry assesses diameters and indexes of a woman's pelvis aiming to depict fetal-pelvic disproportion. This can be done by clinical examination, conventional X-rays, digital fluorography, computed tomography (CT) scan, or magnetic resonance imaging (MRI) [1] [2]. Except the MRI, pelvimetry techniques result in a radiation dose to mother and fetus which, depending on how the technique is performed, can vary by up to 40-fold [3] [4].

Conventional X-ray pelvimetry was the initial method allowing indirect measurements and appreciation of the overall shape of the pelvis. However, CT of the pelvis is now the standard of reference [5]. Indeed, CT yields a better estimate of obstetrical diameters of the pelvic inlet, and reduces the radiation dose to the mother and fetus [6]. The helical acquisitions provided reliable measurements of pelvic diameters: the promonto-retro-pubic diameter, the transverse median and bi-spinous diameters. Magnetic resonance imaging (MRI) is a non-irradiating imaging technique that also yields reliable pelvic measurements [7], and although it seems to be a good alternative, the use of MRI remains limited by availability issues [8].

The aim of this study was to evaluate the radiation doses delivered to the fetus and their mothers during the CT-Pelvimetry examinations and estimation of the effective dose in order to estimate the fetal dose and risk in 03 radiology departments in Douala-Cameroon.

2. Materials and Methods

2.1. Study Design and Study Site

It was a cross-sectional study relating to the doses delivered in CT-Pelvimetry, carried out with 03 radiology departments in the city of Douala-Cameroon,

amongst which 01 in the public sector and 02 in the private sector; 02 Hitachi brand and 01 General Electric brand and having a 16-slice CT system commissioned in 2017 and 2018. The sample of 03 services was constituted after having solicited the 13 hospitals registered in the city of Douala with a functional CT scanner. One service did not respond to our request; two others were no longer operational after the beginning of the study because CT scan device were out of service. We did not have CT-Pelvimetry data in 7 other departments.

2.2. Duration and Study Procedure

The collection of data was done manually over a period of 24 months (from May 2017 until May 2019). Part of the data was collected daily during CT scan procedures and the other part was extracted from the picture archiving and communication system (PACS) of the radiology units and was entered into an Excel file and verified. Pelvic CT examinations were performed in supine position. A lateral scout view was obtained, followed by helical acquisition from the antero-superior iliac spine to the ischial tuberosity. Following CT manufacturer recommendations, images were acquired at a thickness of 5 mm with the constants held at 120 kV and 17.80 - 18.80 mAS (Hitachi brand); 52.68 mAs (GE brand) and pitch 1.5. The different obstetrical diameters of the pelvis were measured on a dedicated computer equipped with a picture and archiving communication system, using multiplanar reconstruction.

2.3. Study Population

In this study, we included all patients having benefited from a CT-Pelvimetry examination in the three services and providing required dosimetric data during the period of our study.

We carried out a sample of convenience, the total of 194 examinations was obtained during the period of the study. This examination exclusively concerning women of childbearing age.

2.4. Data of Interest

The studied variables were: CT device brand, model and number of detector, installation date, date of completion of the examination, patient's age, CT-Pelvimetry indication, pregnancy term, kilo voltage (kV), amperage (mA), time of tube rotation (s), tube current (mAs), the displayed CT dose index (CTDIvol) and the Dose Length Product (DLP). An average DLP for the examination was established to the DLP Data displayed on the CT console and the average Effective dose was evaluated using the International Commission on Radiological Protection (ICRP) conversion factor [9] [10].

$$\left(\text{mGy}\cdot\text{cm}\right) = \text{CTDIvol} \times \text{scan length} \quad (1)$$

The average Effective Dose (ED) doses associated with the CT-Pelvimetry exam studied were assessed from the calculated DLP using a region- and age-specific coefficient:

$$E(\mathrm{mSv}) = \mathrm{EDLP}_{\mathrm{region,age}} \times \mathrm{DLP} \quad (2)$$

where $\mathrm{EDLP}_{\mathrm{region,age}}$ (mSv (mGy·cm)$^{-1}$) is the normalized value of effective dose per dose-length product over a specific body region for a particular standard patient age [11] [12] [13].

2.5. Fetal Dose Calculations

The fetal dose was calculated by the online software, called "Dose Fetal" Web [14] to estimate the radiation dose received by the fetus from CT. The algorithm employed by the tool is based on Monte Carlo simulations performed on computational phantoms and real data of pregnant patients at different gestational stages. The vendor-independent tool, can be used to calculate radiation dose exposure for any scanned body region, scan length and CT protocol. Its pull down-menu allows users to select gestational age and tube voltage. Additionally, users need to enter the volume CT dose index (CTDIvol), and select the upper and lower positions of the scan. The users can also add the maternal abdominal perimeter in millimetres to improve the accuracy of calculations, and the patient ID for their records. Calculations can be saved in PDF format.

2.6. Consequence of Fetal Irradiation

The possible cancer risks caused by ionizing radiation doses of ~1 mSv or less are too small to be estimated directly from epidemiological data. The linear no-threshold (LNT) approach to estimating such risks involves using epidemiological data at higher (but still low) doses to establish an "anchor point", and then extrapolating the excess cancer risk linearly down from this point to the low dose of interest [15].

We used FetDose program to calculate the risk to the fœtus [16] [17].

According to Osei *et al.*, the fetal radiation risk (R) is calculated as

$$R = Df \times \mathrm{RC} \quad (3)$$

where RC is the risk coefficient for the consequence of interest (Osei, *et al.*, 2003). The risk of childhood cancer induction: risk coefficient used is 8.0×10^{-5} per mGy and hereditary effects: risk coefficient used is 0.5×10^{-5} per mGy [18] [19] [20].

2.7. Data Analysis

Data analysis was carried out, first per service, then for all the 3 services. The dose metrics were analyzed and the proposed dose levels were established at 50th and 75th percentile of dose distribution. Our data were compared with other previous studies from France [21]; Sweden [22], and Canada [17]. The FetDose program was used to calculate all risk estimations.

2.8. Ethical Statement

This study was authorized by the Institutional Research Ethics Committee for

Human Health at the University of Douala and by the Regional Health Delegation of the littoral Region of Cameroon. In order to respect confidentiality, all the data collected was studied anonymously, the services were coded by numbers (from 1 to 3).

3. Results

A total of 194 CT-Pelvimetry data produced using a helical acquisition was collected. The different radiology services, the characteristics of the CT scan devices and the number of data collected per CT scan device is shown in Table 1. Table 2(a) and Table 2(b) show the Patient's age range, gestational age and clinical indications. Table 3 shows the CT-Pelvimetry acquisition parameters, delivered

Table 1. Radiology services, characteristics of the CT scan devices included in the study and the number of data collected per CT scan device.

Site	Characteristics of CT-machine					Number of CT-exams
	CT-machine	Mark	Model	Number of detectors of CT-machine	Year of installation	
1	A	Hitachi	Supria	16	2017	**90**
2	B	General Electric	Revolution	16	2017	**80**
3	C	Hitachi	Supria	16	2018	**24**
			Total			**194**

Table 2. (a) Patient's age range, gestational age and clinical indications; (b) Clinical indication by service.

(a)

Indications	Gestational age (weeks)	Age range				
		[19, 24]	[25, 29]	[30, 34]	[35, 40]	Total
Scarred Uterus	36	0.52%	10.82%	15.46%	11.86%	38.66%
Clinically contracted pelvis	36	13.40%	11.34%	4.12%	1.03%	29.89%
Breech presentation	36	0.52%	7.73%	13.92%	6.19%	28.36%
Short stature (<1.50 m)	36	0.00%	2.58%	0.00%	0.52%	3.10%
Total		14.44%	32.47%	33,50%	19.60%	100%

(b)

Services	Indications									
	Scarred uterus		Clinically contracted pelvis		Breech presentation		Short stature (<1.50 m)		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%
1	35	38.89	27	30.00	25	27.78	3	3.33	90	0.47
2	31	38.75	23	28.75	24	30.00	2	2.50	80	0.41
3	9	37.50	8	33.33	6	25.00	1	4.17	24	0.12
Total	75	38.66	58	29.90	55	28.35	6	3.09	194	100

Table 3. Acquisition parameters and doses.

Services	Acquisition parameters				Doses			Fetal absorbed dose
	kV	mA	Time of Tube Rotation (s)	mAS	CTDIw (mGy)	DLP (mGy·cm)	E (mSv)	Mean foetal dose (mGy)
1	120	23.67	0.75	17.80	1.79	54.67	0.76	1.36
2	120	53.75	0.98	52.68	2.46	59.21	0.83	1.87
3	120	25.00	0.75	18.80	1.00	51.69	0.72	0.76
	120	**36.24**	**0.84**	**32.31**	**1.97**	**56.17**	**0.78**	**1.5**

doses and estimated mean of radiation dose and effective dose. Table 4 shows a summary of the mean and range of fetal absorbed dose and the fetal radiation risk of childhood cancer and hereditary effects.

3.1. Radiology Departments

03 radiology departments in Douala yielded information on a total of 194 CT protocols performed. 46.4% were collected in the first site, 41.2% in the second and 12.4% in the third. The CT machines were 16 multidetectors (General Electric Revolution and Hitachi Supria) (Table 1).

3.2. Age Frequency Distribution and Clinical Indications

Of the 194 examinations, 38.66% were for scar uterus; 29.9% were for clinically contracted pelvis; 28.35% were for breech presentation and 3.09% were for deformation of the pelvis indication. Mean age of pregnant women was 30 years (range: 19 - 40 years, median = 30 years). The mean term and the time of imaging examinations was 36 weeks of amenorrhea (Table 2(a), and Table 2(b)). All these clinical indications were justified [23].

3.3 Acquisition Parameters and Delivered Doses

In the three services, all protocols were performed according helical acquisition with a voltage of 120 kV, 32.31 mAs average. The mean radiation dose of helical acquisitions, CTDIw and DLP were 1.97 mGy (range: 1.00 - 2.46 mGy) and 56.17 mGy·cm (range: 51.69 - 59.21 mGy·cm) respectively. The mean effective dose was 0.78 mSv (Table 3).

3.4. Fetal Dose and Consequence of Foetal Irradiation

The mean fetal dose calculated was 1.5 mGy (range: 0.76 - 1.87). The risk of Childhood Cancer calculated was 1 in 16,000 - 1 in 10,000 and 1 in 260,000 - 1 in 106,000 to the risk of Hereditary Disease, respectively (see Table 4).

3.5. Comparison between Doses

CT-Pelvimetry doses and fetal dose from our work were compared with others studies (Table 5).

Table 4. Fetal dose-averaged and risk of childhood cancers and hereditary effects for the 194 fetuses exposed during CT-Pelvimetry examinations of their mothers.

Fetal dose range (mGy)		Risk of childhood cancer (risk coefficient: 8.0×10^{-5} per mGy)	Risk of hereditary effects (risk coefficient: 0.5×10^{-5} per mGy)
Min.	0.76	6.08×10^{-5}	0.38×10^{-5}
Averaged	1.5	12×10^{-5}	0.75×10^{-5}
Max.	1.87	14.96×10^{-5}	0.935×10^{-5}

Table 5. Comparison between doses.

Dosimetry	Our study (MDCT 16 slices, Hitachi Supria 16 and General Electric Revolution 16)	Thibaut *et al.* (MDCT Brilliance 40) [21]	Slimane *et al.* (SIEMENS Somatom Sensation 64 CT) [24]	Phexell *et al.* (standard spiral) [22]
CTDIw (mGy)	1.97	0.9	2.15	0.61
DLP (mGy·cm)	56.17	37.9	55.97	14.7
E (mSv)	0.78	0.53	0.84	0.21
Mean fetal dose	1.50		2.36	

4. Discussion

4.1. Comparison between Results from Our Work and Others Studies

The mean fetal dose (1.50 mGy) equivalent to 5 chest X-rays examination if we consider the minimum dose of 0.3 mGy for a frontal chest X-ray. Doses, CTDI-vol and DLP from our study were 1.97 mGy (range: 1.00 - 2.46 mGy) and 56.17 mGy·cm (range: 51.69 - 59.21 mGy·cm) respectively, the mean effective dose was 0.78 mSv. These doses were globally higher than those in other studies [21] [22]. The DLP value from our pelvimetry examinations was 1.5 to 3.8 higher compared to these studies. Thibaut *et al.* doses were estimates generated by CT scan software while the measurements in the Phexell *et al.* study were executed on an anthropomorphic phantom and thermos-luminescent dosimeters (TLD) were used for the dose measurements, and bags of sodium chloride were chosen for simulation of the pregnancy in the third trimester, especially lower than 36 weeks. But CTDIvol, effective dose and fetal dose from our study was lower than that value found by Slimane *et al.* [24] (**Table 5**).

These doses were the same as those in our previous study [25].

The fetal dose and risks from our work concerning CT-Pelvimetry exclusively are lower compared to the E.K. Osei *et al.* study which concerned CT-pelvis examination.

4.2. Fetal Absorbed Dose and Risk

The radiation doses received by the 194 foetuses ranges from 0.76 to 1.87 mGy

(1.5 mGy mean foetal dose) from CT-Pelvimetry examination (see **Table 3**, **Table 4** and **Table 6**). According to the conclusions of the studies carried out by the ICRP, there is no deterministic effect of practical importance in humans below a dose of at least 100 mGy [26]. Doll and Wakeford showed that radiation doses of the order of 10 mGy received by the fetus in utero produce a consequent increase in the risk of childhood cancer. The excess absolute risk coefficient at this level of exposure is approximately 6% per gray [27].

4.3. Risk of Hereditary Disease

The probability of induced hereditary effect on the basis of the doses received by the fetuses (**Table 4** and **Table 6**) in this study shows that the risk to the individual fetuses was 1 in 140,000 (range: 1 in 260,000 - 1 in 106,000) from CT-Pelvimetry examination. The risks values are very low compared to the natural incidence. The natural frequency of genetic disorders and congenital abnormalities occur in about 2% - 5% of all live births [28]. Thus, the increased genetic risk of 1 in 10,714 for an individual fetus associated with the fetal dose in this study is very small compared with the natural risk of genetic disease.

4.4. Risk of Childhood Cancer

The risk of 1 in 9000 (range: 1 in 16,000 - 1 in 10,000) associated with the mean absorbed dose of 1.5 mGy from our study is very law comparable to the natural baseline risk of childhood cancer 1 in 650 (1.5×10^{-3}) [20] [29]. The BM estimated 360,114 total childhood cancers occurring worldwide in 2015; 54% in Asia and 28% in Africa. BM estimated standardised rates ranged from ~178 cases per million in Europe and North America, through to ~218 cases per million in West and Middle Africa [30].

The risk for the fetus to develop cancer after the mother has undergone any kind of radiological examination during pregnancy has been investigated and found to be minimal by Bailey *et al.* [32], and has also been reported in ICRP 84 (**Table 7**). The radiation dose in the spiral method was lower than 1.97 mGy. The absorbed mean radiation dose to the fetus (1.50 mGy) using the spiral method is considered low, especially when the dose is related to the 99.7% probability that a child (0 - 19 years) will not develop a malignancy from the absorbed doses ≤5 mGy [32]. Consequently, all such CT-Pelvimetry examination can be carried out on pregnant women, as long as they have been clinically justified and the dose is kept to minimum consist with the diagnostic requirement.

Our study had some limitations. The CTDIvol or its derivative the DLP data were estimates generated by CT scan software, which depend on scan acquisition parameters. They should be taken as an index of radiation output by the system for comparison purposes. We do not have gold standard direct dosimetry data to compare. Perhaps, the next step is to compare our data with CTDIvol and DLP estimates using an anthropomorphic phantom with dosimeters (phantom study).

Table 6. Comparison between fetal dose and risk.

Study	Fetal dose range (mGy)	Fetal dose-averaged (mGy)	Risk of childhood cancer	Risk of hereditary effects
Our Study (CT-pevimetry examination)	0.76 - 1.87	1.50	1 in 16,000 - 1 in 10,000	1 in 260,000 - 1 in 106,000
E.K. Osei *et al.* study (CT-pelvis examination) [17]	1.32 - 17.06	10.64	1 in 10,000 - 1 in 1000	1 in 140,000 - 1 in 11,000

The fetal dose and risks from our work concerning CT-Pelvimetry exclusively are lower compared to the E.K. Osei *et al.* study which concerned CT-pelvis examination.

Table 7. Probability of bearing a healthy child as a function of dose according to ICRP 84. [31].

Dose absorbed by the embryo or fetus, in mGy, in addition to natural radiation	**Probability that the child does not present malformation, %**	**Probability that the child does not develop Cancer (0 - 19 years), % 1)**
0	97	99.7
0.5	97	99.7
1.0	97	99.7
2.5	97	99.7
5	97	99.7
10	97	99.6
50	97	99.4
100	(near 97)	99.1

5. Conclusion

The fetal-maternal dose levels from CT-Pelvimetry examinations are very low and the risks of childhood cancers and hereditary diseases are derisory. Since the absorbed dose to the fetus, using CT technology, is a low level, the technology should be further investigated to ensure its full potential for optimal diagnostic accuracy.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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