Abstract. Computed Tomography (CT) procedures constitute the 5% of the total diagnostic radiology and provide more than the 40% of the total dose. Patient dose depends on many factors; most of them depend on the way the procedure is performed. All around the world, there is a growing interest in studying patient dose in CT procedures in order to optimize them. If the patient is pregnant, conceptus absorbed dose can be high and radiation risks during pregnancy are well established. Uruguay has 35 CT scanners and 70,000 procedures are performed per year in a total population of 3.1 million people. However, neither patient nor conceptus doses in CT procedures have still been evaluated. The main objective of this paper is to estimate fetus/embryo absorbed doses in abdomen-pelvis CT procedures in order to make radiologists and technicians realize their responsibility in CT procedures performance, especially in pregnant and females of childbearing age. The investigation was performed in the Radiology Department of the University Hospital “Dr. Manuel Quintela”. A 41 patient sample was taken to know average technical parameters used in abdomen and abdomen-pelvis CT procedures. Methods considering CT Dose Index (CTDI) in the centre of a head phantom were applied to estimate fetus absorbed dose. Results were 22 mGy in abdomen-pelvis procedure and 3 mGy in abdomen procedure. Real values may be higher if the procedures are performed with and without contrast media (barium or iodine). Results make necessary the establishing of a radiation protection protocol of the handling of pregnant patients and females of childbearing age. For this, it is essential that radiologists and technicians receive specific education in CT radiation protection.

1. Introduction

While the benefits of CT are well known in diagnosing diseases and trauma and in the guidance of interventional and therapeutic procedures, those benefits are not without risks because patient doses can be high. Nowadays, CT procedures perform the higher contribution to the collective dose due to all diagnostic radiology and all artificial sources. U.N.S.C.E.A.R. [1] shows that they are the 5% of the total diagnosis procedures, supplying more than the 40% of the total dose.

During the earlier CT scanners, explorations were made with small number of slices because of the low equipment performance and the extended times of sweepings and construction. This implied a significant patient dose reduction. However, technical equipment evolution has caused a rise in patient dose due to the variations in the acquisition techniques (number of slices, mA.t product, kV, filtrations, etc.). International and regional organisms of radiological protection are concerned about patient dose in CT procedures because of biological damage inferred by the ionizing radiation and the increment in the number and kind of CT procedures.

Many factors determine patient dose in CT procedures. Some of them are closely related on the protocols applied (given by manufacturers or modified by the radiologist or technologist), on the way they are use and, on the changes made for each patient taking into account his/ her individual size and specific pathology.

Technical parameters affecting patient dose in CT are the following [2] [3]:

- Study carried on with and without contrast media (iodine or barium)
- Slice thickness. The smaller the thickness of the slice is, the higher the number of photons required to obtain the image and then an increment in the dose. The thickness of the x-ray beam profile will determine the amount of scatter produced per rotation of the x-ray tube.
- Slice spacing or pitch. The slices may be performed in a contiguous way, separated by gaps or overlapped. In this case the dose could be increased in 20% to 30% without any further diagnostic information because of the rise of both direct and scatter radiation.
- **X-Ray Energy (kVp).** The output of an x-ray tube increases approximately with the square of the kVp if the filtration is not modified, increasing also beam penetration (number of photons reaching the receptor) and, as a consequence, producing less damage to the patient.

- **Beam filtration.** Leakage affects patient dose as well as in conventional radiology. Beam quality gets better by eliminating the low energy photons which increase patient dose. Usually, filtrations used barely reach the minimum value specified by the Food and Drug Administration of USA (FDA).

- **X-Ray Intensity (mA).** Output radiation (and patient dose) is directly proportional to tube current. Some manufacturers allow the tube current to vary during the scan, using lower currents to thinner anatomy.

- **mA .t product and kV** are factors previously set in the protocols of each equipment and do not take into account patient corporal differences. Due to this, the use of the parameters established in the protocols of the equipment could significantly increase the dose in children or small-sized patients.

- **Scan rotation time.** This factor (analogous to exposure time in conventional radiology) determines how long the x-ray beam directly irradiates a tissue. Radiation dose is directly proportional to it because both primary and scattered radiations increase with beam rotation times.

- **Arch Rotation.** 360 degrees exploration arches will double patient dose in relation with procedures performed with 180 degrees or partial rotations.

- **Exploration modes.** High quality modes (HQ) use lower mA.s than those of high speed (HS). However, patient dose in HQ will be higher than in HS because the foremost operates with slice overlapping.

In 1981, the FDA introduced the CTDI and the Multiple Scan Average Dose (MSAD) as physical dose quantities to describe the absorbed dose delivered by CT [4]. CTDI is defined as the integral of a single-scan dose profile along an infinite line perpendicular to the tomographic plane divided by the nominal slice thickness:

\[
CTDI_{\text{theoretical}} = \frac{1}{T} \int_{-T/2}^{T/2} D(z) dz
\]  

(1)

Where: \( T \) is the nominal slice thickness and \( D(z) \) is the dose as a function of position along the z-axis.

The MSAD is defined as the integral of a multiple scan dose profile along a line with a length of one slice distance, divided by the incremental distance between slices. MSAD is equal to CTDI when the slice distance is equal to the nominal slice thickness:

\[
MSAD = \left( \frac{1}{I} \right) CTDI_{\text{theoretical}}
\]  

(2)

Where: \( I \) is the slice distance.

CTDI is determined with a pencil ionization chamber with an active length of 10 cm.

\[
CTDI_{10cm} = \frac{1}{T} \int_{-5cm}^{5cm} D(z) dz
\]  

(3)

CTDI is measured within a cylindrical PMMA (polymethylmethacrylate) phantom, 16 cm-diameter (CTDI head) or 32-diameter cm (body CTDI) with a length of 14 cm or more, according to FDA specifications [5].

Weighted CTDI (CTDI\(_W\)) is a single parameter used to describe the dose associated with a scan series. It is obtained combining CTDI in the centre of the phantom (CTDI\(_c\)) with the average CTDI (CTDI\(_{ap}\)) obtained in the four positions of the periphery of the phantom (CTDI\(_c\)):

\[
CTDI_W = \frac{1}{3} \left( CTDI_c + 2 CTDI_{ap} \right)
\]  

(4)
Another dosimetric quantity is the dose free-in-air on the rotation axis ($D_{air}$). Numerically, $D_{air}$ is equal to CTDI. Because of this, CTDI is often used to express $D_{air}$. It can be measured by ionization chamber, thermoluminescent or film dosimeters free in air without any absorber between focus and x-ray detector. $D_{air}$ is an important physical dose quantity which can be used for calculating organ dose by conversion factors and permit assessment of the radiation risk.

Dose length product (DLP) is a quantity also related with the effective dose and radiation risk [4]. For a whole CT exploration:

$$DLP = \sum CTDI_{100,air} \times T_i \times N_i$$

Where: $T$: thickness of the slice and $N_i$ the number of slices of the whole CT procedure.

In Uruguay there are 35 CT scanners all around the country and there are performed 70.000 CT procedures per year for a total population of 3.1 million people [6]. However, patient doses in CT procedures have not still been evaluated. In addition to this, radiologists and technologists have neither a worrying lack of information on those factors affecting patient and dose nor the knowledge of the possible changes that can be made of the protocols provided by manufacturers in order to adapt them to patient morphology and pathology.

For all these reasons, most radiologists and technicians do not know the way that technical factors affects embryo/fetus absorbed dose and Radiology Departments do not have protocols considering the pregnancy (or its possibility) in patients undergoing CT procedures. In head, cervical spine and chest CT explorations only scattered radiation reaches the embryo/fetus. However, in abdomen, pelvis, and lumbar spine CT procedures, the embryo/fetus is exposed both to primary and scattered radiation and his/her absorbed dose and radiation risks can be high. Radiation protection societies and organisms recommend that issues should be taken in order to balance the benefit to the mother (or the child, or both) and the risks. This evaluation should take into account embryo/fetus absorbed dose and its age. If the procedure must be made, radiologists and technicians need to know how to reduce embryo/fetus absorbed dose without lose of diagnostic information.

**The main purpose** of the present research is to estimate embryo/fetus absorbed dose in abdomen and pelvis CT procedures in order to justify the importance of establishing a protocol to handle pregnant patients and females of childbearing age as a first step in CT radiation protection.

### 2. Material and Methods

The research was performed in the Radiology Department of the University Hospital “Dr. Manuel Quintela”, in Montevideo. The scanner is Picker CT Twin Flash. Data of the technical parameters used in CT procedures was taken during August and September, 2002.

A 41 patient sample was taken. Patient data collected was: age, height, sex and weight. Technical parameters collected were: kV, mA.t product, slice thickness, distance between slices, number of slices, pitch, filtration, arch angle, use or not of the CT scanner protocol and if the study was performed with contrast media, without it, or with and without it. Data was classified according to the CT exploration (abdomen and abdomen-pelvis) and patient sex.

### 2.1. Patient Dose

In order to obtain patient dose in abdomen and abdomen-pelvis explorations DLP and weighted CTDI were determinate with the following:

-Body PMMA phantom for adult patient (76-415 Victoreen): 32 cm diameter, with FDA performance standards for adult patients. The phantom has five long holes: one in the centre and four at the periphery (90° apart and 1 cm from the phantom surface). Diameter inside each hole is 1.31 cm, especially designed to host a CT ionization chamber.
-Pencil shaped ionization chamber, 3.2 cm$^3$ (Victoreen, 6000-200 model, number 106484, calibration date 10/12/01, Victoreen laboratory).
-Electrometer (Victoreen, 4000 + SI- model, number 107545, calibration date 08/27/01, Victoreen Laboratory).

To obtain CTDI, body phantom was placed on the patient table of the CT scanner so its symmetry matches the axis with the tomography sweeping “z” axis. Lectures of the pencil ionization chamber were obtained within the phantom at the centre and periphery at 12, 3, 6, 9 and 0’clock positions (each position separated by a 90º angle). In each measure, the other four holes must have inserted plastic rods. In each position many measures were made to obtain average readings.

CTDIw was obtained for each one of the CT explorations (abdomen, abdomen-pelvis) data, using an average of the technical parameters employed (slice thickness, kVp and mA. t product) according with (4). The scanner laser light was used to position the middle of the chamber length. Before the measurements, a scan survey was made in order to verify that both the hole and the ionization chamber were located in the axis of the rotation axis of the CT scanner. For each position of the ionization chamber CTDI is calculated with the following equation:

$$CTDI = R \times f_c \times f_f \times f_{t,p} \times L \div nT$$  \hspace{1cm} (6)

Where: R is the ionization chamber reading, $f_c$ is the chamber ionization factor, $f_f$ is the exposure to dose conversion factor (or phantom conversion factor), $f_{t,p}$ is the pressure and temperature correction factor, L is the chamber length$^1$, T is the slice thickness and n is the number of simultaneously acquired sections$.^2$. The exposure to dose conversion factor ($f_f$) for the appropriate effective energy (usually 70 keV) is 7.8 mGy/ R for acrylic (usually used by manufacturers) and 9.4 mGy/R for muscle (that should be use for patient dosimetry) [7].

To obtain CTDIw, equation (4) is applied. And then, with (5) DLP for each whole examination (abdomen and abdomen-pelvis) is determined.

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$^1$ Note that some ionization chamber calibration factors include the chamber length. In these cases $f_f \times L$ is the chamber correction factor.

$^2$ n=1 for single row detector machine, and more for multislice machines.
2.2. Embryo/fetus absorbed dose estimation.

The use of body CTDI is not a reliable model for conceptus dose estimation. Body CTDI tends to underestimate this dose because:

- The cylindrical 32 cm diameter phantom does not represent the real shape of the abdomen. The usual patient has an ellipsoidal transverse shape with axes on the order of 20 cm by 35 cm.
- Phantom material has a mass density of 1.19 g cm\(^{-3}\). This value is 20% bigger than soft tissue density. For this, phantom attenuation will be higher.
- The phantom might not have enough length to simulate full backscatter effects when great volumes are explored.
- CTDI is sometimes determined for 14 slices of 10 mm thickness for a 14 cm long exanimate section.
- Dose is measured in the centre or in the periphery of the phantom and doesn’t represent the true depth of the embryo or fetus.

Embryo/fetus dose estimation can be determined using different approaches. One of them is used by the National Radiation Protection Board in the United Kingdom (Reports 248, 249, and 250). It relates CTDI measurements in a phantom to Monte Carlo dose estimations.

A second method is the one described by Panzer and Zankl [8]. It is based on free in air dose. It has the following limitations: a) is based on a standard patient (height 1.6 m; weight 60 kg, 190 mm body thickness and 3.80 mm wide); b) the embryo is assumed to be at a fixed depth; c) the embryo is no more than 2 months old; d) no beam shaping filters are used; e) it is necessary to interpolate between different effective filtrations to formulate a table of reference dose factors [9]. In consequence, the method doesn’t take into account neither patient size nor embryo/fetus location. In addition, the method also required that the beam quality (Half Value Layer) must be known [10].

A third method is that of Felmlee et al [11]. The method is based on measures performed on an anthropomorphic phantom and on the CTDI at the centre (CTDIc) of a 16 cm diameter PMMA head phantom. This phantom is a better approach to size and shape of the abdomen. In addition, the method tends to minimize beam filtration effect and is less sensitive to those uncertainties related with the position of the sensitive volume of the ionization chamber. Moreover, the method allows some corrections for different fetus/embryo depth [9] [10].

Because of all the reasons exposed above, the method based on the CTDI measured on the centre of a 16 cm-diameter PMMA phantom is the one chosen in this paper. Some authors describe methods based in this quantity.

Felmlee et al. present a reference dose factor as integral dose [11]. Embryo/fetus absorbed dose due to a scan located “d” cm away is:

\[
D = CTDI \times INFDR_E
\]  
(7)

Where: CTDI is obtained for the centre of the 16 cm-diameter phantom in the exploration conditions (kVp and mA.s) and applying the exposure to dose conversion factor for muscle; and INFDR\(_E\) is the Integral Normalized Fetal Dose Ratio. INFDR is the fetal-dose contribution for a group of CT scans. Felmlee et al. calculated INFDR from the Normalized Fetal Dose Ratio (NFDR) and assuming 1-cm scan thickness and 1-cm table increment. The INFDR for a specific examination is determined by a combination of the proper INFDR values found in Felmlee et al. charts [11].

\[
INFDR_E = INFDR_0 + INFDR_{SUP} + INFDR_{INF}
\]  
(8)

Where INFDR\(_0\) is the INFDR at 0-cm distance (is the examination includes a scan positioned directly over the embryo/fetus) and INFDR\(_{SUP}\) and INFDR\(_{INF}\) are the INFDR for scan locations superior and
inferior to the embryo/fetus location. INFDR\textsubscript{0} is obtained from Felmlee et al. table that present it in function of embryo/fetus depth. Due to tissue attenuation, INFDR\textsubscript{0} increases when the depth increases.

\[\text{INFDR}_{\text{SUP to INF}} = (T/I)[\text{INFDR}(M) - \text{INFDR}(N-1)] \] (9)

Where T is the scan thickness (cm); I is the incremental distance between slices (cm); INFDR (M) is the INFDR at the maximum distance from the fetus location and INFDR (N-1) is the minimum distance N (cm) minus 1 cm from the fetus location (both INFDR obtained in Felmlee et al. charts [11]).

As seen, this method allows the estimation of embryo/fetus absorbed dose considering the irradiated volume for all kind of CT exploration (axial, spiral and multislice).

Wagner et al. present the reference dose factor as integral dose but also as normalized reference dose factor [10]. The authors define fetus/embryo absorbed dose (\(D\)):

\[D = D_{\text{prim}} + D_{\text{scat}}.\] (10)

Where \(D_{\text{prim}}\) is the embryo/fetus absorbed dose due to the primary beam, and \(D_{\text{scat}}\) is the embryo/fetus absorbed dose due to scattered radiation. It is important to note that \(D_{\text{prim}}\) will exist only if the embryo is inside the imaging volume, depending on the embryo age (and volume) and the CT procedure (in the present paper in abdomen-pelvis procedure). However, \(D_{\text{scat}}\) will exist always. In some procedures the embryo will receive only scattered radiation, but all the times that receive primary radiation will also receive scattered radiation.

In order to determine \(D_{\text{prim}}\), the following equation is applied:

\[D_{\text{prim}} = (T/I) \times D_{\text{ref}} \times F(0)\] (11)

Where: \(D_{\text{ref}}\) is the reference dose (CTDI\textsubscript{c}, measure in the centre of the head phantom, as was described above), T and I are the same defined for Felmlee et al. method (9), and \(F(0)\) is the “reference dose factor” in the “position 0”. “Position 0” is defined as the “slice” where the embryo or fetus is found in the CT exploration. \(F(0)\) is available in Wagner et al. tables adapted from Felmlee et al. tables and depends on embryo/fetus depth too [10]. \(F(0)\) and INFDR\textsubscript{0} values are the same.

If the point where the dose needs to be determined is not exposed to the primary beam, the contribution to the absorbed dose (\(D\)) is only from the scatter radiation (\(D_{\text{scat}}\)). \(D_{\text{scat}}\) from all such remote slices is the sum of the contributions from individual slice, and it is calculated as follows:

\[D_{\text{scat}} = (T/I) \times D_{\text{ref}} \times \sum F(zi)\] (12)

Where: \(D_{\text{ref}}\) and \(T/I\) are the same as in (11) and \(\sum F(zi)\) is the sum of the “reference dose factors”. Each \(F(zi)\) depends on the distance \(zi\) from each individual slice to the centre of the volume of the embryo/fetus (“Position 0”) and is obtained in Wagner et al. tables adapted from Felmlee et al charts.

It is important to note that all the slices performed will contribute with scatter radiation to the embryo/absorbed dose. Wagner et al. tables adapted from Felmlee et al. [10].show \(F(zi)\) for \(zi\) from 10 to 180 mm, each 10 mm. That means that in some cases it will be necessary to interpolate. As it is expected, \(F(zi)\) decreases with the increase of \(zi\) and for slices more than 15 cm from the

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3 The pitch is the table travel per rotation divided by the total nominal scan width, and in consequence is \((I/T)\). Some authors recommend not using the pitch done by manufacturers because they have different ways to obtain it [9].
embryo/fetus, the dose contribution from the CT scan is generally less than 50 µGy and no calculation is warranted.

![Figure 2. The picture shows top of the uterus position according to embryo/fetus age (in weeks). (From Rzeszotarski, M. [9])](image)

Unfortunately, some CT exploration shows the embryo/fetus. In these situations it is easy to identify the position. However, if the embryo is small or if he/she is not seen in the CT scan (because it is outside the imaging volume) it will be necessary to ask for assistance. This stage shall be performed with a gynaecologist. Some times (if it is available) an ultrasound or a magnetic resonance exploration can give this information. Other possibility is to locate the embryo/fetus with the help of the information given by the gynaecologist examination or using tables and figures that provides uterus size and/or fetus location depending on the gestation age [9].

The embryo/fetus age is reported in several ways, and the physician should be clear on what is meant by this. Age may be reported as the number of weeks since the last menstrual period (LMP), which is about two weeks longer than the time since conception. However, the physician indicates the number of weeks since conception.

In the present paper it is assumed an average size woman with 8 weeks of pregnancy and with the top of the uterus located 6 cm over the pubis symphysis and 5 cm under the iliac crest. That will suppose that the embryo location is in the middle of the uterus (3 cm from the pubis). In abdomen CT procedure, the “worst situation” will be the one considering the embryo in the top of the uterus (5 cm under the iliac crest). Embryo absorbed dose will be estimated in both CT procedures (abdomen and abdomen-pelvis) performed with the average technical parameters and in average clinical conditions performed in our hospital. Abdomen CT exploration begins in the xiphoid appendix and finishes in the pubis symphysis. Abdomen-pelvis CT exploration begins in the same anatomic structure but finishes in the pubis symphysis.

3. Results

3.1. Technical parameters.

Results show that the 85.7 % of the abdomen-pelvis explorations and the 76.0 % of the abdomen explorations were performed with 120 kV, 265 mA.s, 8.8 mm slice thickness each 8.0 mm and pitch 0.7. In average, abdomen scanner is performed with 31 slices, and abdomen pelvis with 50 slices. In most of the explorations radiologists and technicians use the CT scanner protocols. Measurements and calculus will be carried out with the average technical parameters obtained.
3.2. Patient Dose

Weighted CTDI (CTDI \(_W\)) is determined for both explorations with the same technical parameters. CTDI for each one of the five positions of the ionization chamber in the body phantom is obtained. In each case was applied equation (6) using exposure to dose conversion factor for muscle. The electrometer calibration factor was 1571.7160 nC / Gy and the ionization chamber calibration factor was 3.118 Rcm/ nC. In the last case, chamber length is included. Then CTDIW was obtained using equation (4).

\[
CTDI_W = 16.4 mGy
\]

Dose Length Product for each whole exploration was obtained applying equation (5). For Abdomen DLP number of slices was 31 and for abdomen-pelvis number of slices was 50.

For abdomen CT exploration:
\[
CTDI = 461 mGy/cm
\]

For abdomen-pelvis CT exploration:
\[
CTDI = 744 mGy/cm
\]

3.3. Embryo/fetus absorbed dose

First, CTDIc was measured using average technical parameters (120 kV, 265 mA.s, the same in both CT explorations as it was said) and applying (6):

\[
CTDIc = 34.2 mGy
\]

### 3.3.1. In abdomen CT procedure

Average exploration conditions are 31 slices with 8.8 mm thickness each 8.0 mm and pitch 0.7. Only scattered radiation reaches the embryo because the scan begins in xiphoid appendix and finish in iliac crests. In this paper it is assumed that the closer slice to the embryo (top of the uterus) is 5 cm.

Applying Felmlee et al. Integral Normalized Fetal Dose Ratio from tables, and combining (7), (8) and (9):

\[
D = 34.2 \times (8.8/8.0) \times (0.480 - 0.475) = 2.8 mGy
\]

Applying Wagner et al. normalized reference dose factors from tables in (12) according to the distance between each slice and the top of the uterus:

\[
D_{scat} = (8.8/8.0) \times 34.3 \times (0.079) = 3.0 mGy
\]

### 3.3.2. In abdomen-pelvis CT procedure

From the research it was found that this exploration is performed in average with 50 slices of 8.8 mm thickness each 8.0 mm and pitch 0.7, beginning in xiphoid appendix and finishing in pubis. We suppose that embryo depth is 9.0 cm.

Applying Felmlee et al. Integral Normalized Fetal Dose Ratio from tables, and combining (7), (8) and (9):

\[
D = 34.2 \times (8.8/8.0) \times [(0.250) + (0.221) + (0.103)] = 21.8 mGy
\]

Applying Wagner et al. normalized reference dose factors from tables, and (11):

\[
D_{prim} = (8.8/8.0) \times 34.2 \times 0.250 = 9.4 mGy
\]

To estimate D_{scat}, the first three slices (of the 50) contribute in the same way that scattered dose (upper and under the Position 0). Applying tables and (12):

\[
D_{scat} = (8.8/8.0) \times 34.2 \times [(2 \times 0.091) + 0.203] = 14.5 mGy
\]

Finally, \(D_{total} = 9.4 + 14.5 = 23.9 mGy\)
4. Discussion

First of all, results shows that both methods based on CTDI in the centre of a 16-cm phantom, give similar embryo absorbed doses. Results show that in a CT procedure where the embryo/fetus is directed exposed to x-ray, it is possible that the absorbed dose reaches values higher than 20 mGy. However, results can still be higher because:

- Not only they are estimations but also they are based in an average size female phantom; in consequence, uncertainty can be high.
- Mistakes in the determination of the embryo/fetus depth may introduce differences between 20 and 300 % for the same CT procedure conditions [10]
- In most modern scanners collimation and patient table movements are excellent. However, these factors may introduce an important uncertainty if the scanner does not have strict quality controls.
- Procedures are usually performed with and without contrast media and embryo/fetus absorbed dose will be affected by a factor of 2. In this case, only due to scatter, embryo dose may be higher than 6 mGy
- In multislice CT scanners embryo/fetus absorbed dose may reach higher values

Risk evaluations must be performed taking into account absorbed dose and embryo/fetus age. Malformations have a threshold of 100-200 mGy. In addition, during the period of 8-25 weeks post conception fetus dose higher than 100 mGy may result in a verifiable decrease of IQ [12].

Childhood cancer relative risk of 1.4 (a 40 % increase over the background risk) may be reach with 10 mGy fetus absorbed dose [12]. This dose may also produce serious mental slowness of 4%, when radiation takes place between the 8th and 15th week (the most radiosensitive period) [12] [13]. Compared with natural rate risk (1%), risk increment due to that dose is small and the exploration could be acceptable if patient (mother) benefit is important.

During the same period a fetus absorbed dose between 10 and 100 mGy or more, the risk of serious mental slowness could overcome the 2-4%, number which could duplicate the natural rate. So, risk increment is enough to apply Radiation Protection issues [13].

Since fetus absorbed dose depends on patient size, technical parameters, specific characteristics of the CT equipments (CTDI) and on the exploration conditions (for example with and without contrast media), it is very feasible that in a similar explorations to those done in this research, the embryo/fetus could receive more than 10mGy (due to scattered radiation) or more than 40 mGy (due to direct and scattered radiation), increasing radiation risks.

As it is seen in the calculus, the biggest contribution to the embryo/fetus absorbed dose is due to the scattered radiation which cannot be attenuated by screening with lead apron. This means that if the procedure is justified, optimization must be done through the application of parameters and protocols which involve dose reduction techniques.

Nevertheless, many extreme situations could be avoided by performing the examinations within the first period days (“10 days rule”). Besides, two simple questions should be made before the examination: “Are you pregnant?” and “Have you missed a period?” If the patient is not sure, no urgent examination should be delay until pregnancy possibility can be confirmed.

If the clinical indication is an emergency and the study is immediately needed, referring physician and radiologist should discuss all diagnostic imaging possibilities such as ultrasound and magnetic resonance procedures taking into account the clinical evaluation and the pregnancy stage. If a woman requires an emergency CT examination, there should be no hesitation to do it. If the study can not be delayed all radiology departments should have pregnancy tests to confirm or discard pregnancy. If it is not possible to know the date of the last menstrual period, an ultrasound study will give this
information. In consequence, taking into account the embryo/fetus age and radiation risks, dose reduction issues must be applied according to the diagnosis information that the physician and radiologist need for each specific clinical situation.

5. Conclusions

Embryo/fetus absorbed dose in abdomen and abdomen-pelvis CT explorations can conduce the pregnant patient to consider the possibility or take the decision to terminate the pregnancy. Many times these extreme situations can be avoided with protocols on the management of pregnant and females of childbearing age. Protocols should be included in a radiation protection program with dose reduction education in CT procedures for radiologists and technicians.

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7. References