# *Radiation exposure of pregnant patients and pregnant employees in imaging departments: An overview of regulations and recommendations*


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II

*(Non-legislative acts)*

# DIRECTIVES

## COUNCIL DIRECTIVE 2013/59/EURATOM

**of 5 December 2013**

**laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom**

*Article 62*

## Special protection during pregnancy and breastfeeding

1. Member States shall ensure that the referrer or the practitioner, as appropriate, inquire, as specified by Member States, whether the individual subject to medical exposure is pregnant or breastfeeding, unless it can be ruled out for obvious reasons or is not relevant for the radiological procedure.

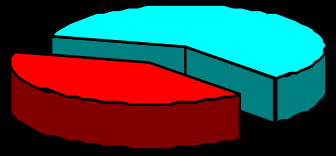
2. If pregnancy cannot be ruled out and depending on the medical radiological procedure, in particular if abdominal and pelvic regions are involved, special attention shall be given to the justification, particularly the urgency, and to the optimisation, taking into account both the expectant individual and the unborn child.

3. In the case of a breastfeeding individual, in nuclear medicine, depending on the medical radiological procedure, special attention shall be given to the justification, particularly the urgency, and to the optimisation, taking into account both the individual and the child.

4. Without prejudice to paragraphs 1, 2 and 3, Member States shall take measures to increase the awareness of individuals to whom this Article applies, through measures such as public notices in appropriate places.

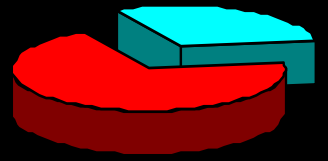
# A number of physicians recommend termination of pregnancy for women exposed to diagnostic X-rays

*Family physicians*



*40 %*

*Obstetricians*



*70 %*

*40% of family physicians and 70% of obstetricians recommended abortion for women exposed to diagnostic x-rays in early pregnancy*

*Fink D, Glick S. Harefuah 124:717-719, 1993*

Insights Imaging (2015) 6:133–139
DOI 10.1007/s13244-014-0365-x

ORIGINAL ARTICLE

# Radiation awareness among radiology residents, technologists, fellows and staff: where do we stand?

**Subramaniyan Ramanathan · John Ryan**

Received: 31 July 2014 / Revised: 20 October 2014 / Accepted: 27 October 2014 / Published online: 21 November 201


**Abstract**

*Objectives* To investigate and compare the knowledge of radiation dose and risk incurred in common radiology examinations among radiology residents, fellows, staff radiologists and technologists.

*Methods* A questionnaire containing 17 multiple choice questions was administered to all residents, technologists, fellows and staff radiologists of the department of medical imaging through the hospital group mailing list.

*Results* A total of 92 responses was received. Mean score was 8.5 out of 17. Only 48 % of all participants scored more than 50 % correct answers. Only 23 % were aware of dose from both single-view and two-view chest X-ray; 50–70 % underestimated dose from common studies; 50–75 % underestimated the risk of fatal cancer. Awareness about radiation exposure in pregnancy is variable and particularly poor among technologists. A statistically significant comparative knowledge gap was found among technologists.

*Conclusions* Our results show a variable level of knowledge about radiation dose and risk among radiology residents, fellows, staff radiologists and technologists, but overall knowledge is inadequate in all groups. There is significant underestimation of dosage and cancer risk from common examinations, which could potentially lead to suboptimal risk assessment and excessive or unwarranted studies posing significant radiation hazard to the patient and radiology workers.

*Main Messages*

- *Knowledge of radiation dose and risk is poor among all radiology workers.*
- *Significant knowledge gap amon*
  *to residents, fellows and staff rad*
- *Significant underestimation of r*
  *risk from common examinations.*

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**Keywords** Radiation dose · Radiat
Technologists · Cancer risk · Questi

## Introduction

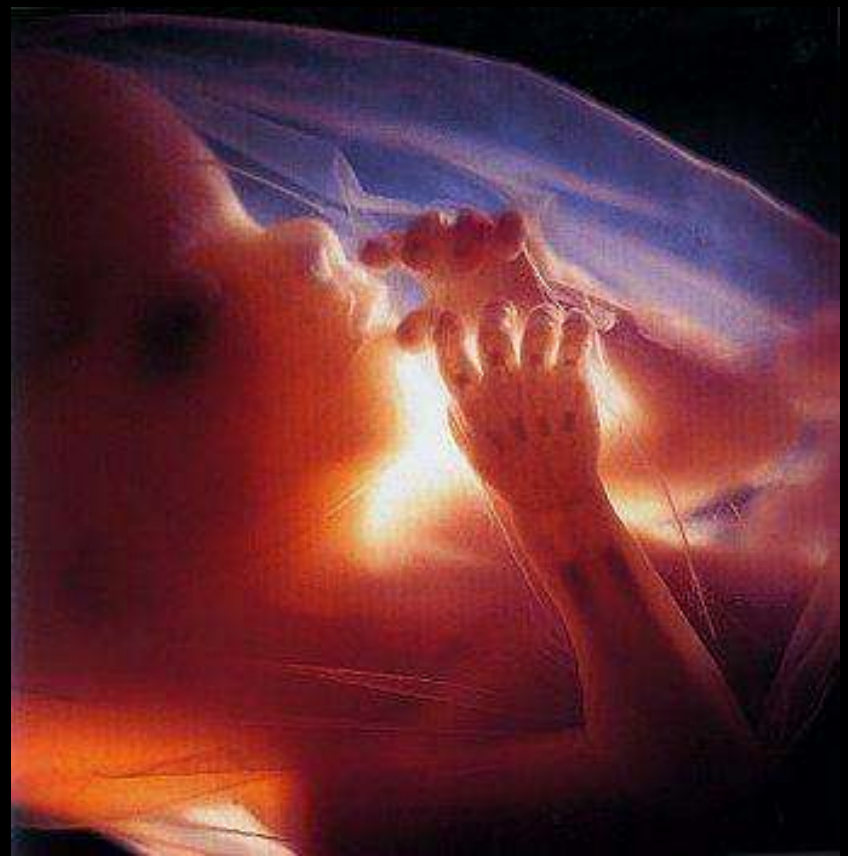
Radiology plays a prominent role i
of the diagnostic and interventio
involve exposure to ionising radiat
benefits of imaging outweigh the as
there is growing concern over the a
ionising radiation on living orga
Council on Radiation Protection a
tion, "Ionizing Radiation Exposur
United States", reported a seven
exposure to the population of the U
radiation since the early 1980s [1].
ation, especially the cancer risk, is
understood as it has no minimal
adverse outcomes take at least 1–2

Review of the published scien
knowledge of radiation dose and ri
examinations is very limited. Nur
performed, predominantly among p
cialties, medical students and traine
[5–13]. Surprisingly, there are very
ogy workers. Overall these studies i
in medical professionals about radiation risks incurred to patients during common imaging tests, and an inability to correctly answer the common questions raised by patients [9–12, 14–16]. It is important for the referring physicians to



Lastly, the subject of radiation exposure in pregnancy is complex and risk benefit ratio needs to be considered carefully before proceeding with the examination. Radiologists play a prominent role in deciding the appropriate imaging modality based on the trimester, clinical question and availability. In our study, though very limited, knowledge of radiation risk in pregnancy was assessed based on a single question (Appendix, question no. 17). Importantly, only 13 % of technologists gave the correct answer, and a significant proportion of the participants suggested medical termination of pregnancy as an option. The knowledge was variable among other groups (residents, fellows and staff radiologists) in the range of 60–85 %. This is highly important, as the technologists come into close contact with the patients in the radiology department and they should have adequate knowledge on radiation exposure during pregnancy and should ideally be trained enough for answering patients' concerns and arranging a discussion with the radiologist.

**A number of physicians DO NOT perform X-ray examinations on pregnant patients**



**The radiation risk for childhood cancer is only 0.06% if the embryo dose is 10 mGy**

*Photo by L. Nilsson*

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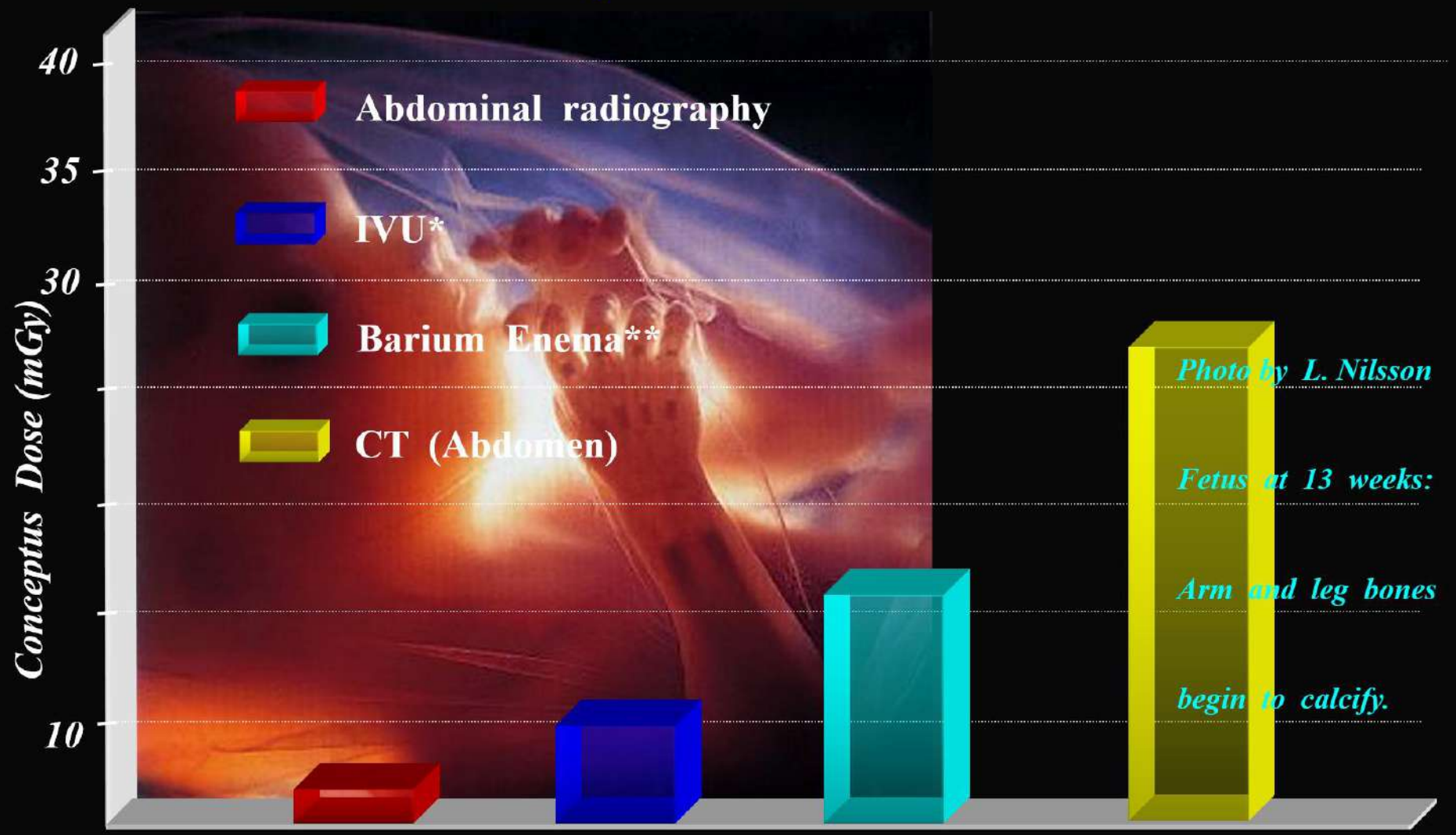
*Fetus at 13 weeks: Arm and leg bones begin to calcify.*

# Conceptus dose from abdominal X-ray examinations




*J. Damilakis et al, Radiat Prot Dosim 1997, **J. Damilakis et al, Invest Radiol 1996

# Conceptus dose (1st trimester) from Tc-99m examinations

| *Examination* | *Conceptus dose (mGy)* |
|---|---|
| *Bone scan (phosphate)* | *~ 8* |
| *Liver colloid* | *~ 1* |
| *Renal DTPA* | *~ 4* |

*Photo by L. Nilsson*

*Fetus at 13 weeks:*

*Arm and leg bones*

*begin to calcify.*

# Physician's perception of risk associated with diagnostic x-rays

## Physicians' Perceptions of Teratogenic Risk Associated with Radiography and CT During Early Pregnancy

Savithiri Ratnapalan[1,2]
Nicole Bona[2]
Kiran Chandra[2]
Gideon Koren[2]

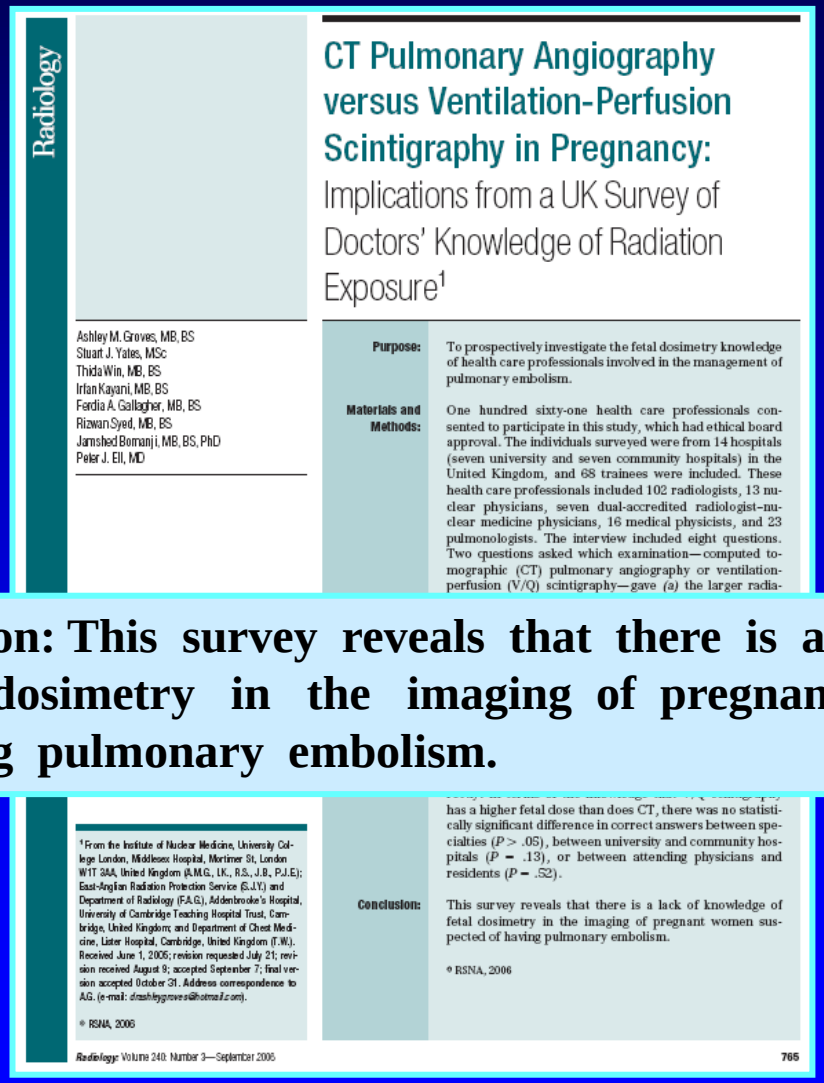
**OBJECTIVE.** The objective of our study was to determine family physicians' and obstetricians' perceptions of the risk of major fetal malformations associated with exposure to radiation from radiography and CT during early pregnancy.

**MATERIALS AND METHODS.** Structured questionnaires were sent to 400 family physicians and 100 obstetricians selected randomly across Ontario, Canada. The physicians were informed about the 1–3% baseline risk for major malformations and were asked about

**CONCLUSION.** Our survey shows that physicians who care for pregnant women perceive the teratogenic risk associated with an abdominal radiograph and an abdominal CT scan to be unrealistically high during early pregnancy. This misperception could lead to increased anxiety among pregnant women seeking counseling and to unnecessary terminations of otherwise wanted pregnancies. This perception of high teratogenic risk associated with radiation could also lead to a delay in needed care of pregnant women.

*S. Ratnapalan et al. AJR 182:1107-1109, 2004*

# Pregnancy and pulmonary embolism



Radiology

## CT Pulmonary Angiography versus Ventilation-Perfusion Scintigraphy in Pregnancy: Implications from a UK Survey of Doctors' Knowledge of Radiation Exposure[1]


Ashley M. Groves, MB, BS
Stuart J. Yates, MSc
Thida Win, MB, BS
Irfan Kayani, MB, BS
Ferdia A. Gallagher, MB, BS
Rizwan Syed, MB, BS
Jamshed Bomanji, MB, BS, PhD
Peter J. Ell, MD



**Purpose:** To prospectively investigate the fetal dosimetry knowledge of health care professionals involved in the management of pulmonary embolism.

**Materials and Methods:** One hundred sixty-one health care professionals consented to participate in this study, which had ethical board approval. The individuals surveyed were from 14 hospitals (seven university and seven community hospitals) in the United Kingdom, and 68 trainees were included. These health care professionals included 102 radiologists, 13 nuclear physicians, seven dual-accredited radiologist–nuclear medicine physicians, 16 medical physicists, and 23 pulmonologists. The interview included eight questions. Two questions asked which examination—computed tomographic (CT) pulmonary angiography or ventilation-perfusion (V/Q) scintigraphy—gave *(a)* the larger radia-

has a higher fetal dose than does CT, there was no statistically significant difference in correct answers between specialties ($P > .05$), between university and community hospitals ($P = .13$), or between attending physicians and residents ($P = .52$).

**Conclusion:** This survey reveals that there is a lack of knowledge of fetal dosimetry in the imaging of pregnant women suspected of having pulmonary embolism.





[1] From the Institute of Nuclear Medicine, University College London, Middlesex Hospital, Mortimer St, London W1T 3AA, United Kingdom (A.M.G., I.K., R.S., J.B., P.J.E.); East-Anglian Radiation Protection Service (S.J.Y.) and Department of Radiology (F.A.G.), Addenbrooke's Hospital, University of Cambridge Teaching Hospital Trust, Cambridge, United Kingdom; and Department of Chest Medicine, Lister Hospital, Cambridge, United Kingdom (T.W.).



Received June 1, 2005; revision requested July 21; revision received August 9; accepted September 7; final version accepted October 31.



Address correspondence to A.G. (e-mail: *drashleygroves@hotmail.com*).




**Conclusion: This survey reveals that there is a lack of knowledge of fetal dosimetry in the imaging of pregnant women suspected of having pulmonary embolism.**

*A. Groves, S. Yates et al.*
*Radiology 240: 765-770, 2006*


Photo by L. Nilsson: 26 weeks

# Determination of pregnancy before irradiation

- *Investigation of the reproductive status of a female of childbearing age prior to x-ray imaging.*

- *It is prudent to consider as pregnant any woman of reproductive age presenting herself for an X – ray examination at a time when a menstrual period is overdue, or missed, unless there is info – rmation that precludes a pregnancy.*

*(ICRP Publication 84, 2000)*

# Determination of pregnancy before irradiation

**Methods used for determination of pregnancy:**

- **Verbal questions**
- **Forms**
- **Urine and serum pregnancy tests**

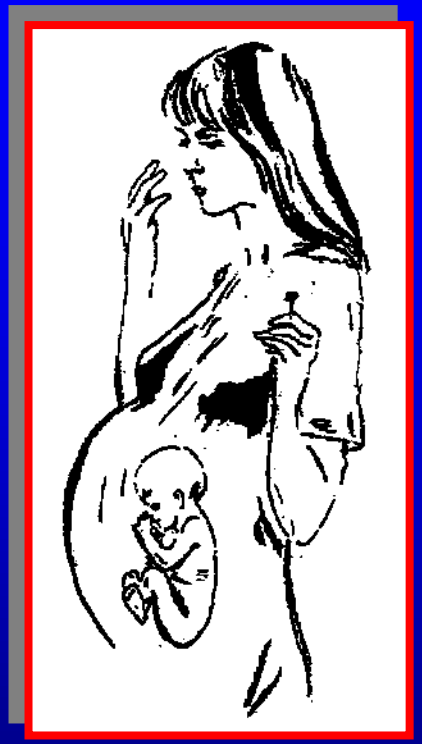
**Define your department's policy on how to screen pregnant patients!**

# Determination of pregnancy before irradiation

**Screening for pregnancy**

**- healthcare personnel is not trained to question patients about their pregnancy status**

**- no policy with 100% guarantee of detection**



*'PLEASE INFORM THE STAFF*

*BEFORE YOUR X-RAY EXAMINATION*

*IF YOU THINK YOU MAY BE PREGNANT'*


*Photo by L. Nilsson: 5-6 days, the clump has developed into a blastocyte, containing many more cells, and has entered the womb*

# Accidental irradiation of pregnant patients

‘1% of women of child-bearing age who underwent abdominal radiographs were unknowingly pregnant in their first trimester’

Mossman KL et al, Obstet Gynecol 1982;60:237-242

‘2.9% of trauma patients were pregnant and the unidentified pregnancy rate was 0.3%’

Bochicchio GV et al, J Am Coll Surg 2001;192:566-569

# Acronym: CONCERT


**CONCEptus RadiaTion Doses and Risks from Imaging with Ionizing Radiation**

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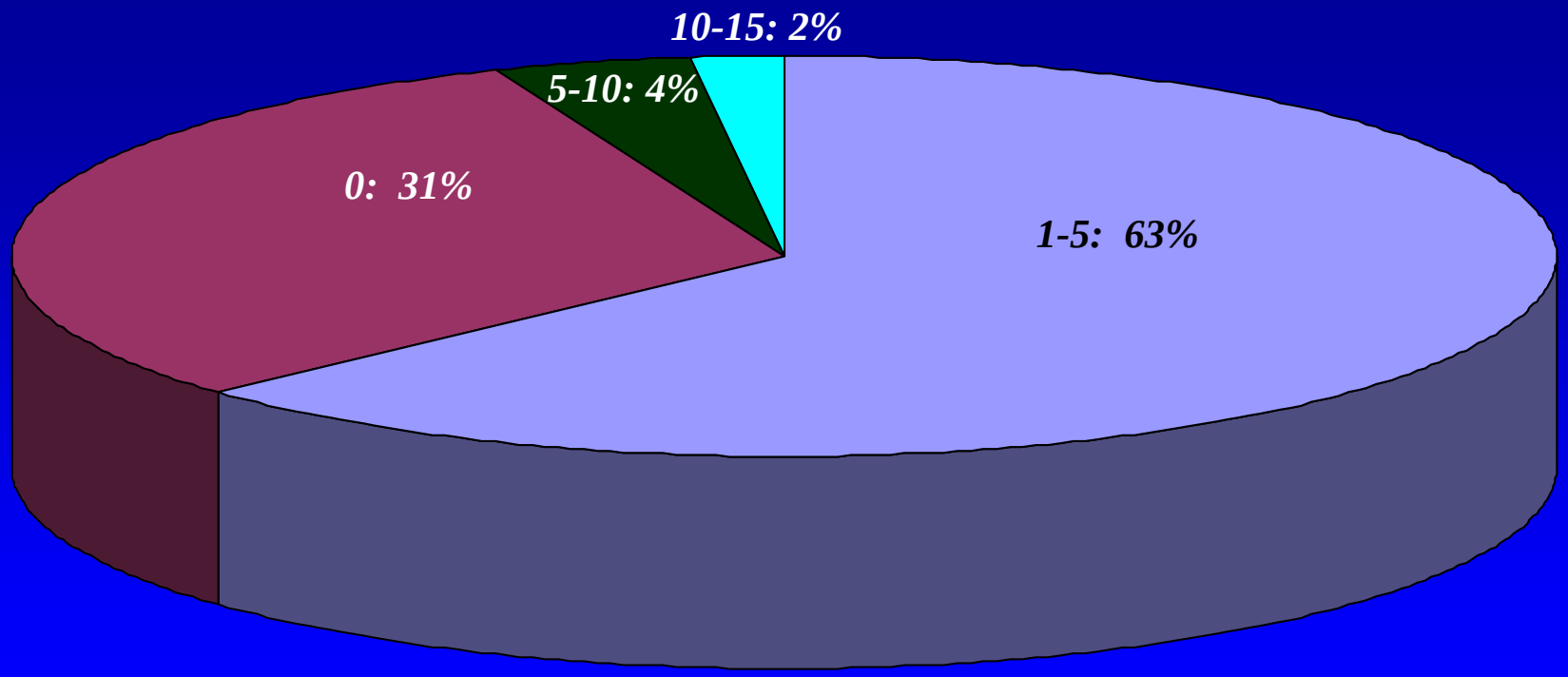
**Duration: 36 months**

# Accidental irradiation of pregnant patients

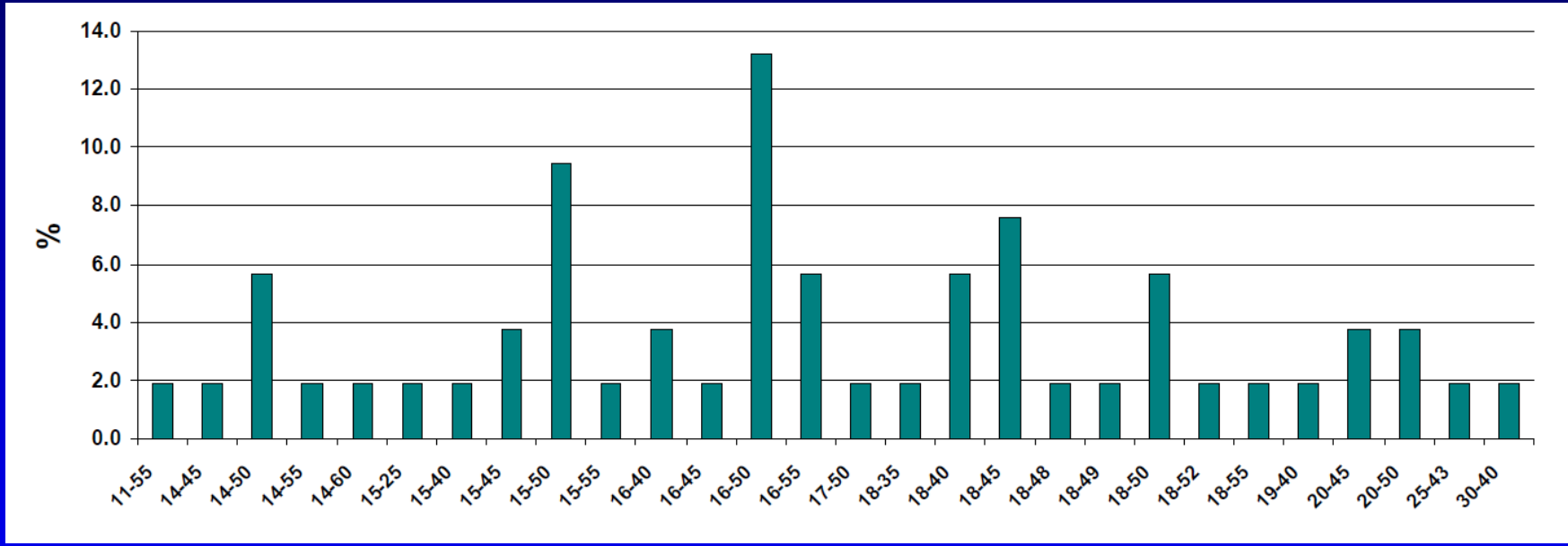
*Question to Obstetricians:*

*How many pregnant patients exposed accidentally to diagnostic X-rays visited you during the last 12 months to ask advise about the biological effects of radiation to the conceptus?*



# Physicians referring patients to X-rays

**Question to interventional cardiologists:**
**What is the minimum and what the maximum age you use for questioning a patient about pregnancy?**



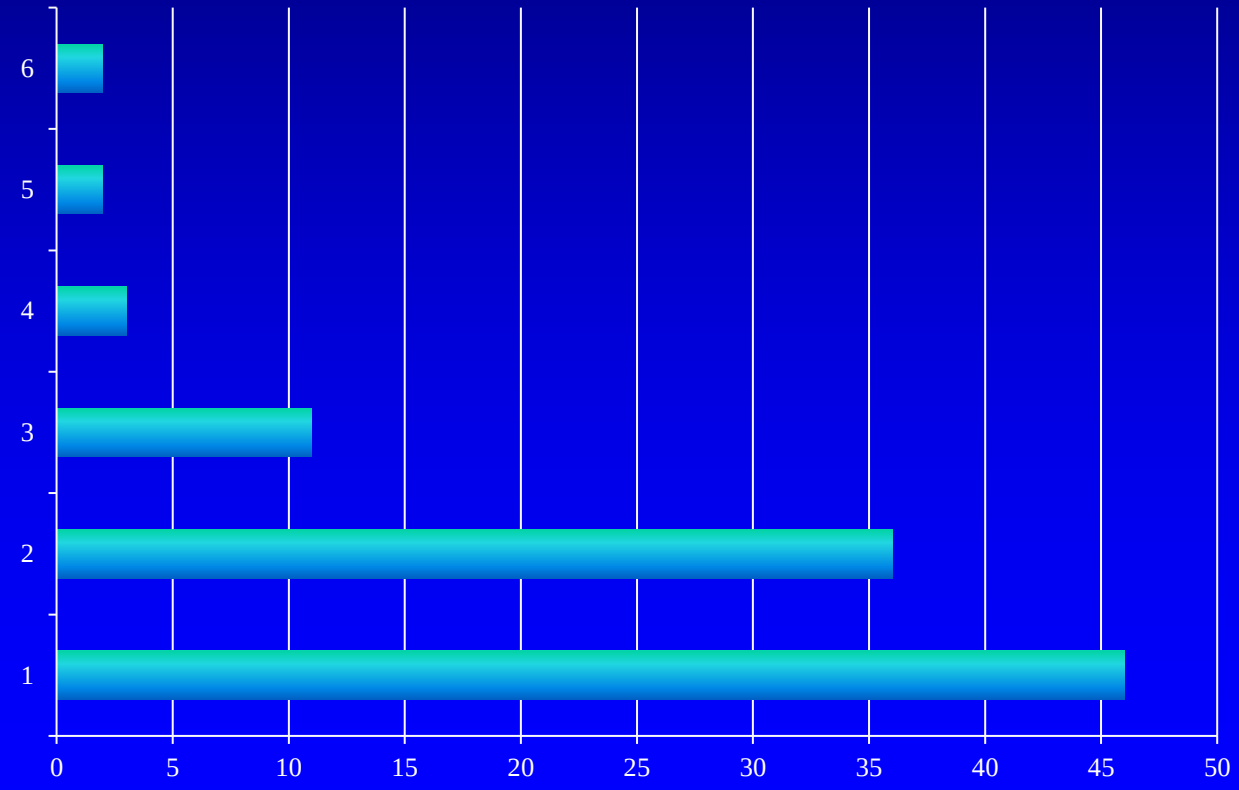

**43.4 % did not include minors in the age range**

**16 % did not include patients older than 40 y in the age range**

# Pregnant patients in Radiology dpts

**Question to Radiologists:**

**How many pregnant patients are subjected to diagnostic X-ray examinations in your department every year?**


*>20: 2%*

*16-20: 2%*

*11-15: 3%*

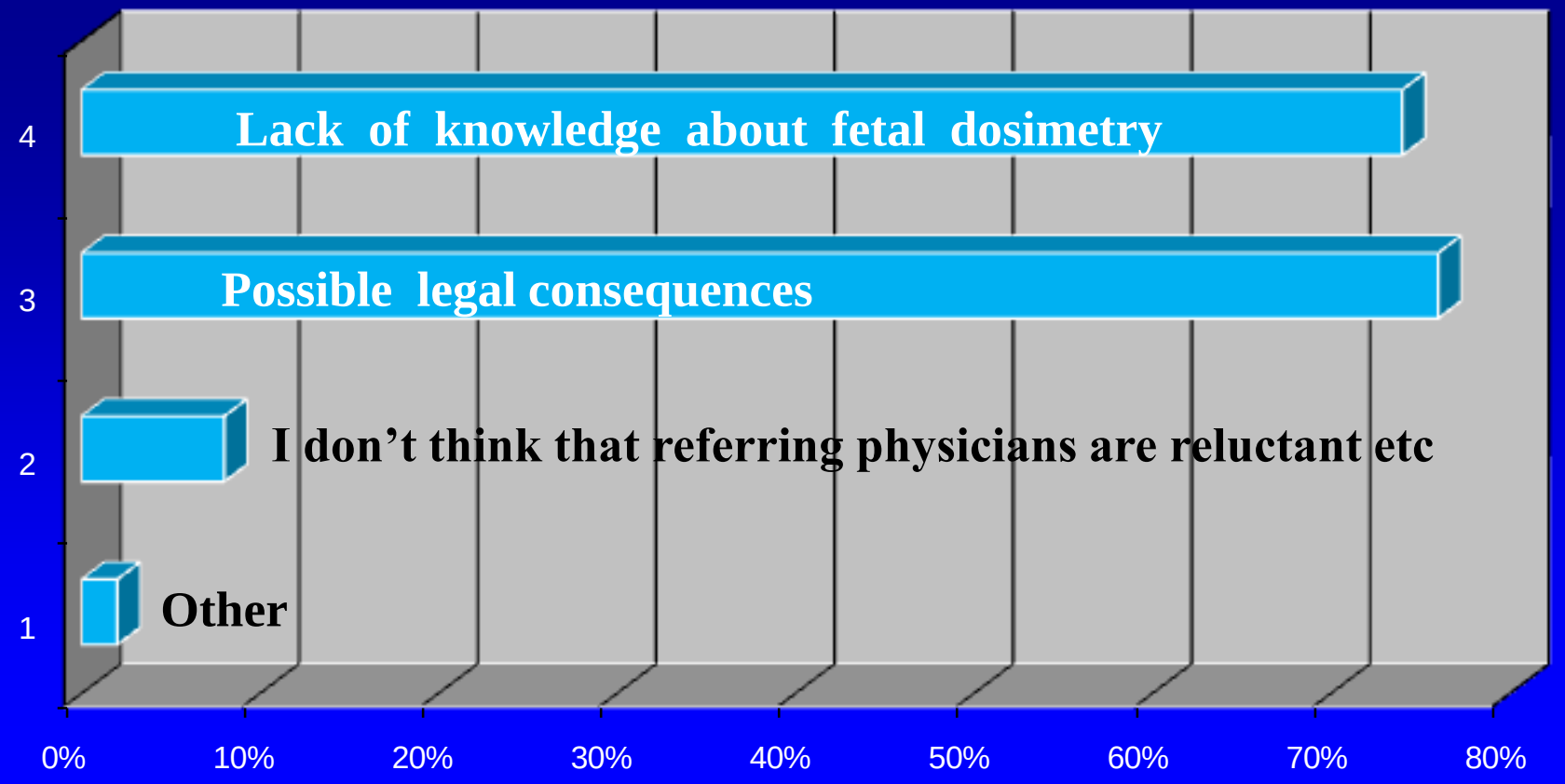
*6-10: 11%*

*1-5: 36%*

*0: 46%*

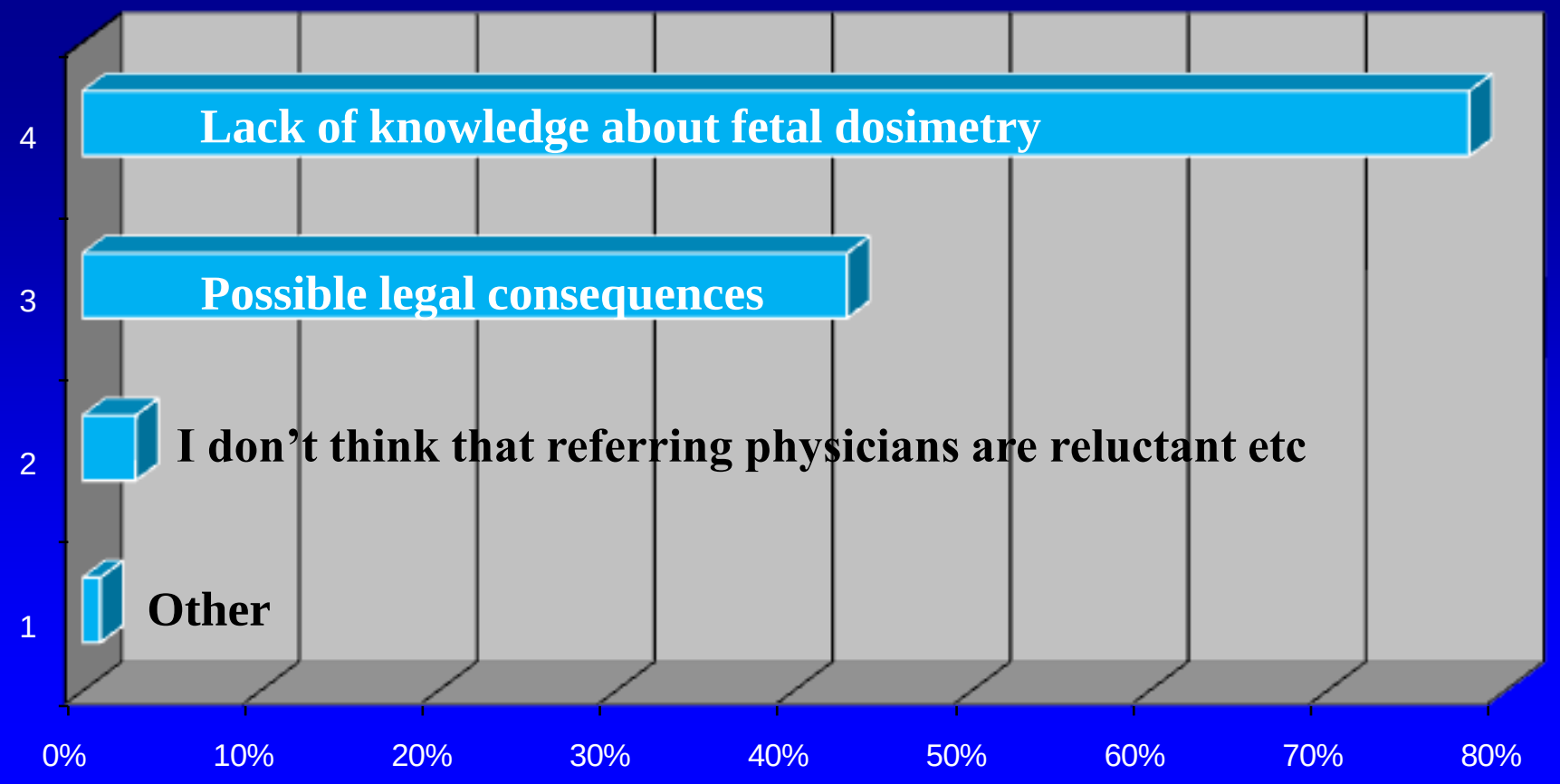
# Physicians referring patients to X-rays

**Question to radiologists:**
**What makes referring physicians reluctant to send pregnant patients to X-ray imaging departments even for extra abdominal exams?**
**(you can choose more than 1 answers)**



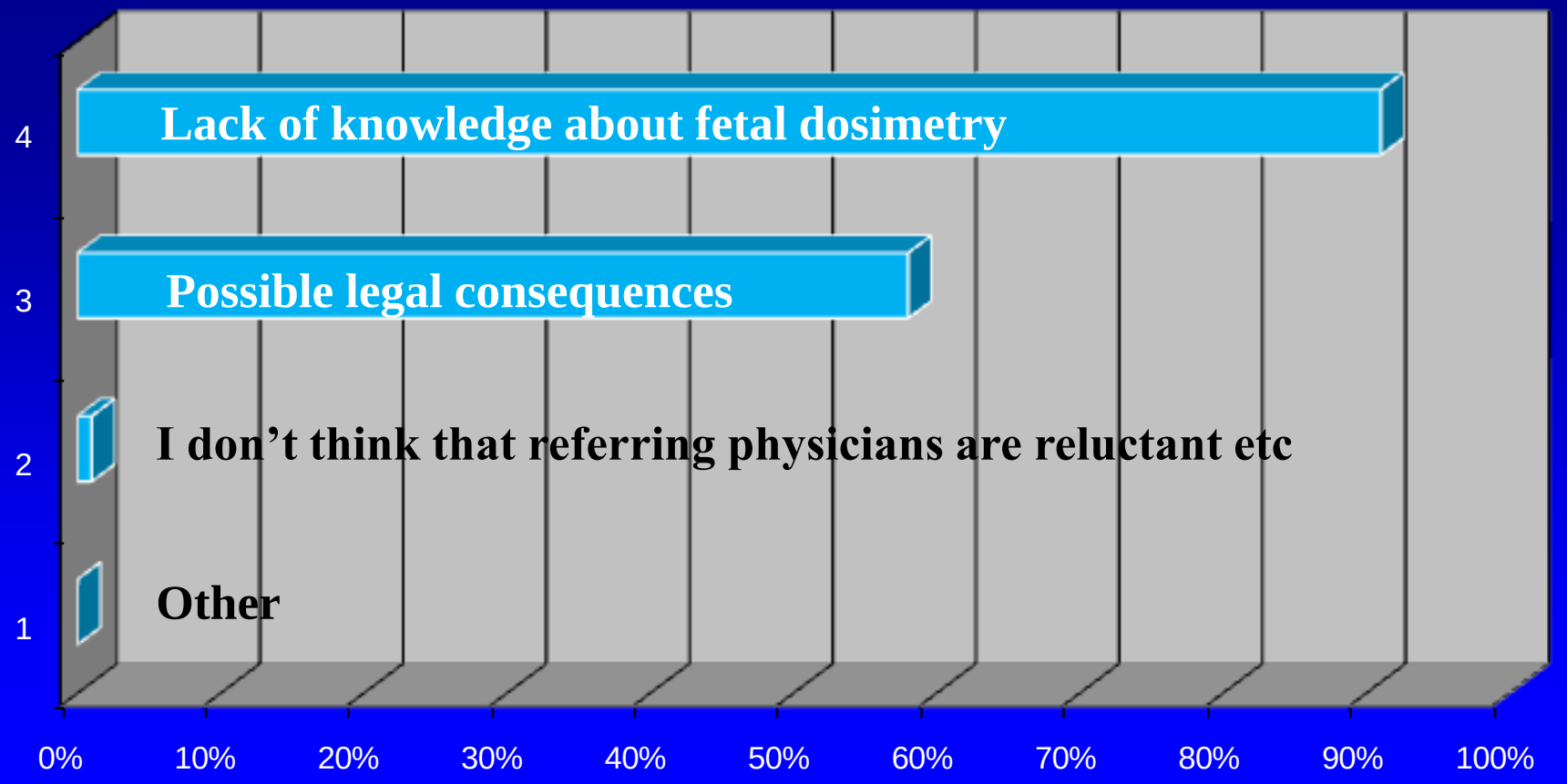
# Physicians referring patients to X-rays

**Question to cardiologists:**
**What makes referring physicians reluctant to send pregnant patients to X-ray imaging departments even for extra abdominal exams?**
**(you can choose more than 1 answers)**



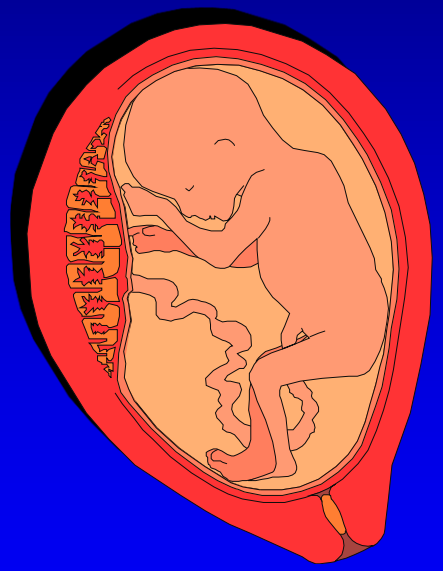
# Physicians referring patients to X-rays

**Question to obstetricians:**
**What makes referring physicians reluctant to send pregnant patients to X-ray imaging departments even for extra-abdominal exams?**
**(you can choose more than 1 answers)**



# Justification of an X-ray examination

*To justify an x-ray study the risks to the unborn child should be known*



# Conceptus radiogenic risk

***AGE***

***What is the conception age ?***

***DOSE***

***What is the estimated conceptus dose ?***

# Is a detailed dose assessment always needed?

*No if:*

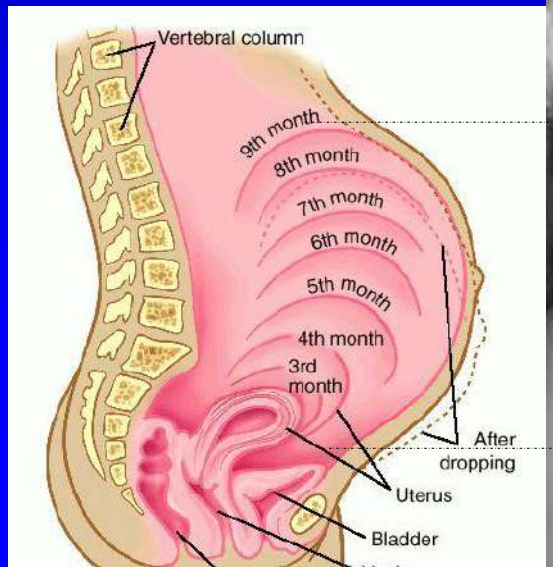
- *age less than 2 weeks*
- *conceptus dose is low*

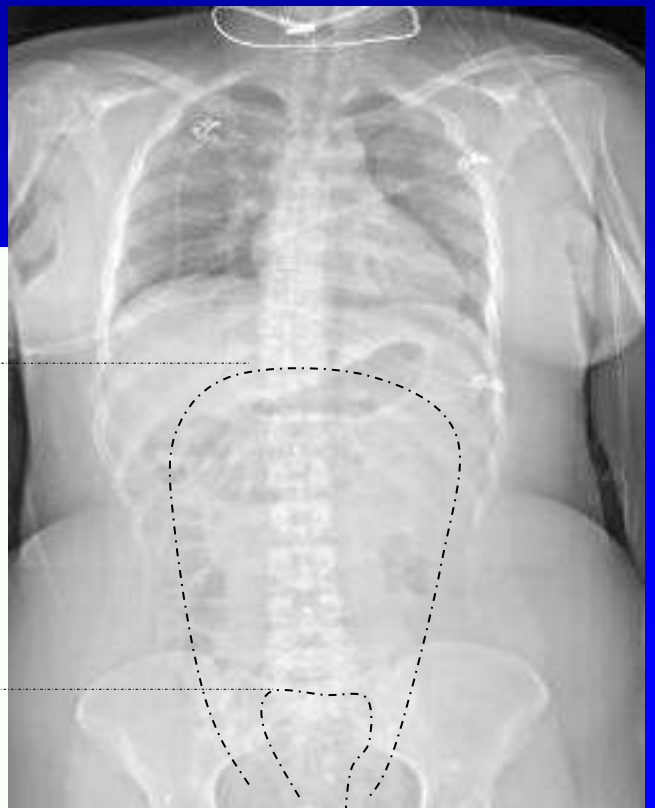
# Justification

**Justification depends on the stage of pregnancy**

**- organogenesis: 3-15 weeks post conception**

**- size and position of uterus**

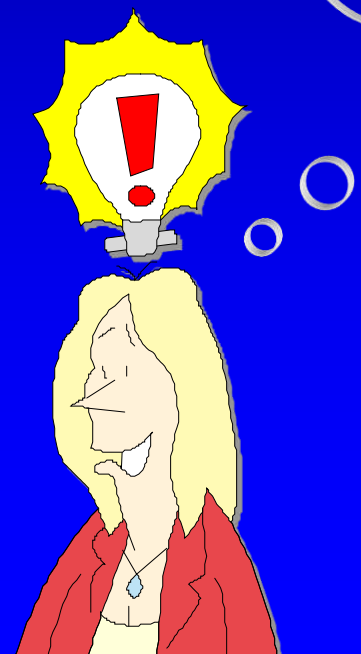


# Communication

**PREGNANT ??**

***What is the dose received by my baby?***

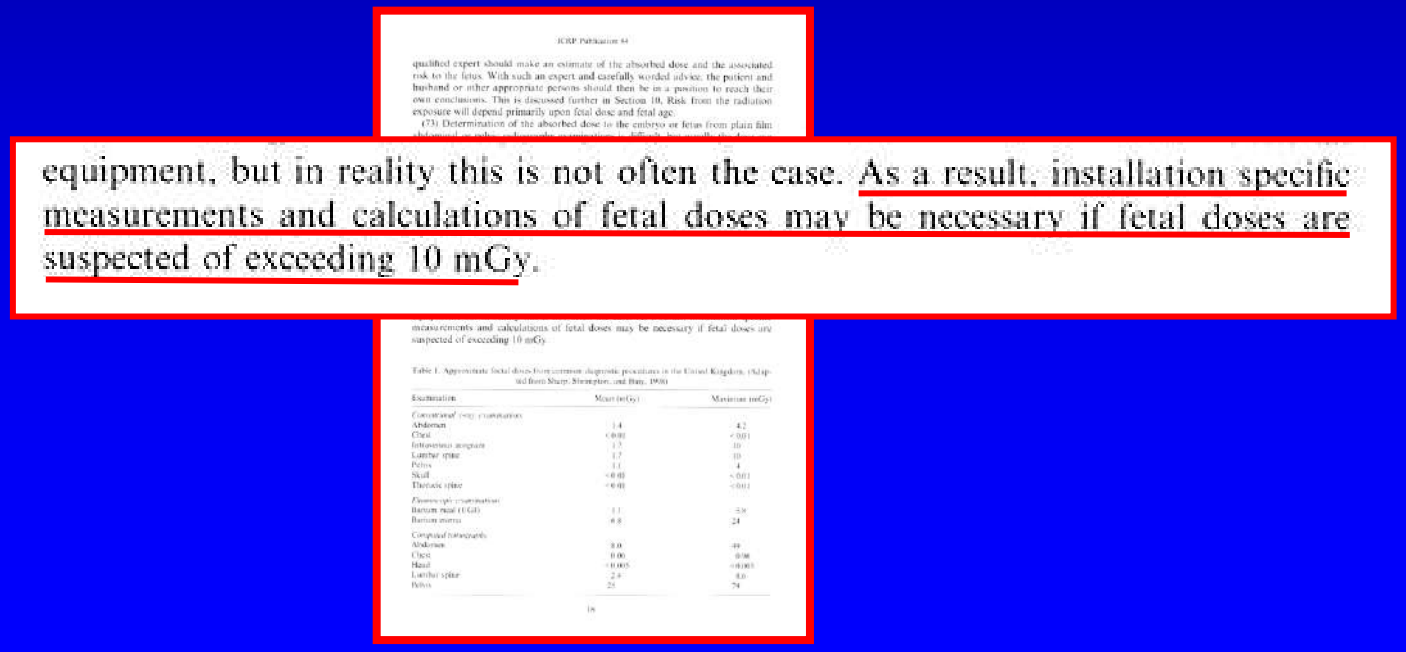


# Conceptus Dose (mGy)

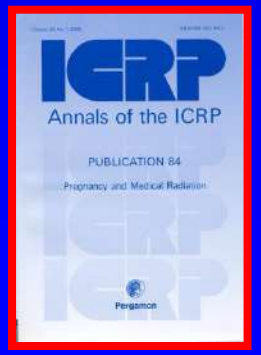
10 50 100

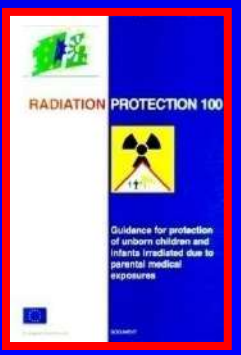
*Conceptus doses below 100 mGy should not be considered a reason for terminating a pregnancy*

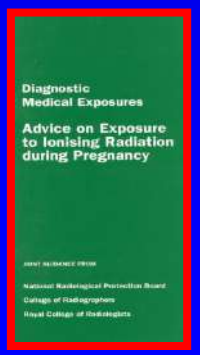
*ICRP Publ. 84*



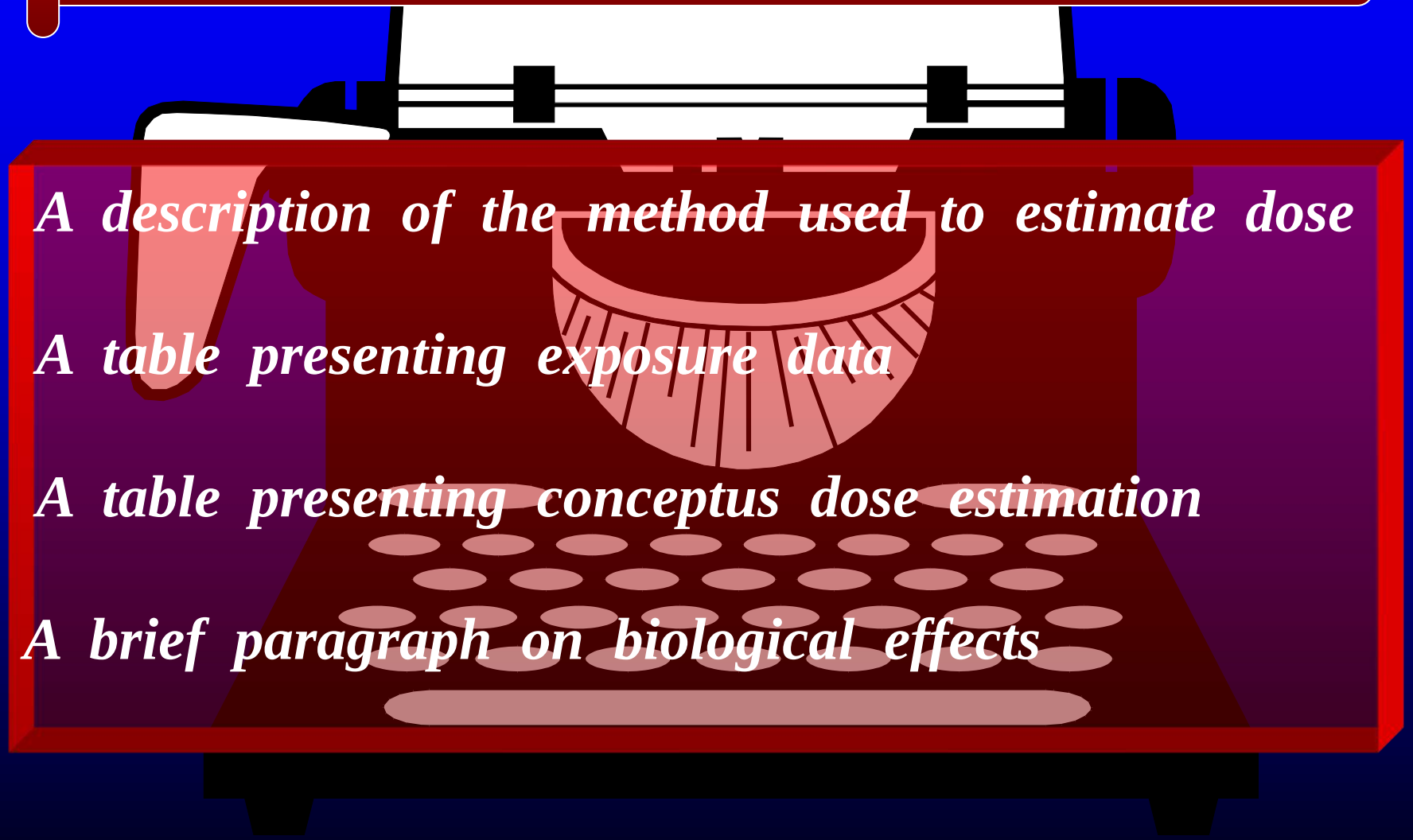
equipment, but in reality this is not often the case. As a result, installation specific measurements and calculations of fetal doses may be necessary if fetal doses are suspected of exceeding 10 mGy.



# *Reporting dose results*



*A description of the method used to estimate dose*

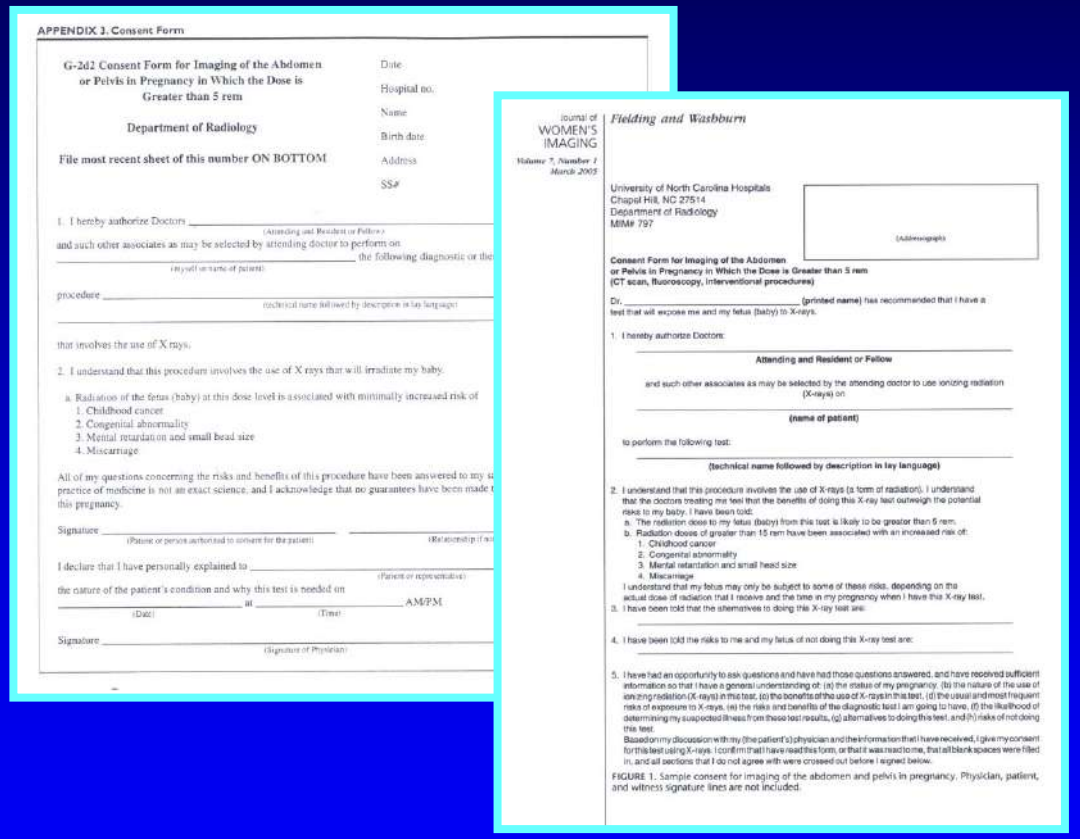
*A table presenting exposure data*

*A table presenting conceptus dose estimation*

*A brief paragraph on biological effects*

*THERE IS A CHANCE THAT A WOMAN WILL GIVE BIRTH TO CONGENITALLY MALFORMED CHILDREN, REGARDLESS OF ANY EXPOSURE TO RADIATION*

# Informed consents



APPENDIX 3. Consent Form

G-2d2 Consent Form for Imaging of the Abdomen or Pelvis in Pregnancy in Which the Dose is Greater than 5 rem

Department of Radiology

File most recent sheet of this number ON BOTTOM

Date
Hospital no.
Name
Birth date
Address
SS#

1. I hereby authorize Doctors _____ (Attending and Resident or Fellow)

and such other associates as may be selected by attending doctor to perform on _____ (my/self or name of patient) the following diagnostic or the

procedure _____ (technical name followed by description in lay language)

that involves the use of X rays.

2. I understand that this procedure involves the use of X rays that will irradiate my baby.

a. Radiation of the fetus (baby) at this dose level is associated with minimally increased risk of
1. Childhood cancer
2. Congenital abnormality
3. Mental retardation and small head size
4. Miscarriage

All of my questions concerning the risks and benefits of this procedure have been answered to my s
practice of medicine is not an exact science, and I acknowledge that no guarantees have been made t
this pregnancy.

Signature _____ (Patient or person authorized to consent for the patient) _____ (Relationship if no

I declare that I have personally explained to _____ (Patient or representative)

the nature of the patient's condition and why this test is needed on _____ (Date) at _____ (Time) AM/PM

Signature _____ (Signature of Physician)

Journal of WOMEN'S IMAGING
Volume 7, Number 1
March 2005

*Fielding and Washburn*

University of North Carolina Hospitals
Chapel Hill, NC 27514
Department of Radiology
MIM# 797

(Addressograph)

**Consent Form for Imaging of the Abdomen or Pelvis in Pregnancy in Which the Dose is Greater than 5 rem (CT scan, fluoroscopy, interventional procedures)**

Dr. _____ **(printed name)** has recommended that I have a test that will expose me and my fetus (baby) to X-rays.

1. I hereby authorize Doctors:

**Attending and Resident or Fellow**

and such other associates as may be selected by the attending doctor to use ionizing radiation (X-rays) on

**(name of patient)**

to perform the following test:

**(technical name followed by description in lay language)**

2. I understand that this procedure involves the use of X-rays (a form of radiation). I understand that the doctors treating me feel that the benefits of doing this X-ray test outweigh the potential risks to my baby. I have been told:
a. The radiation dose to my fetus (baby) from this test is likely to be greater than 5 rem.
b. Radiation doses of greater than 15 rem have been associated with an increased risk of:
1. Childhood cancer
2. Congenital abnormality
3. Mental retardation and small head size
4. Miscarriage
I understand that my fetus may only be subject to some of these risks, depending on the actual dose of radiation that I receive and the time in my pregnancy when I have this X-ray test.
3. I have been told that the alternatives to doing this X-ray test are:

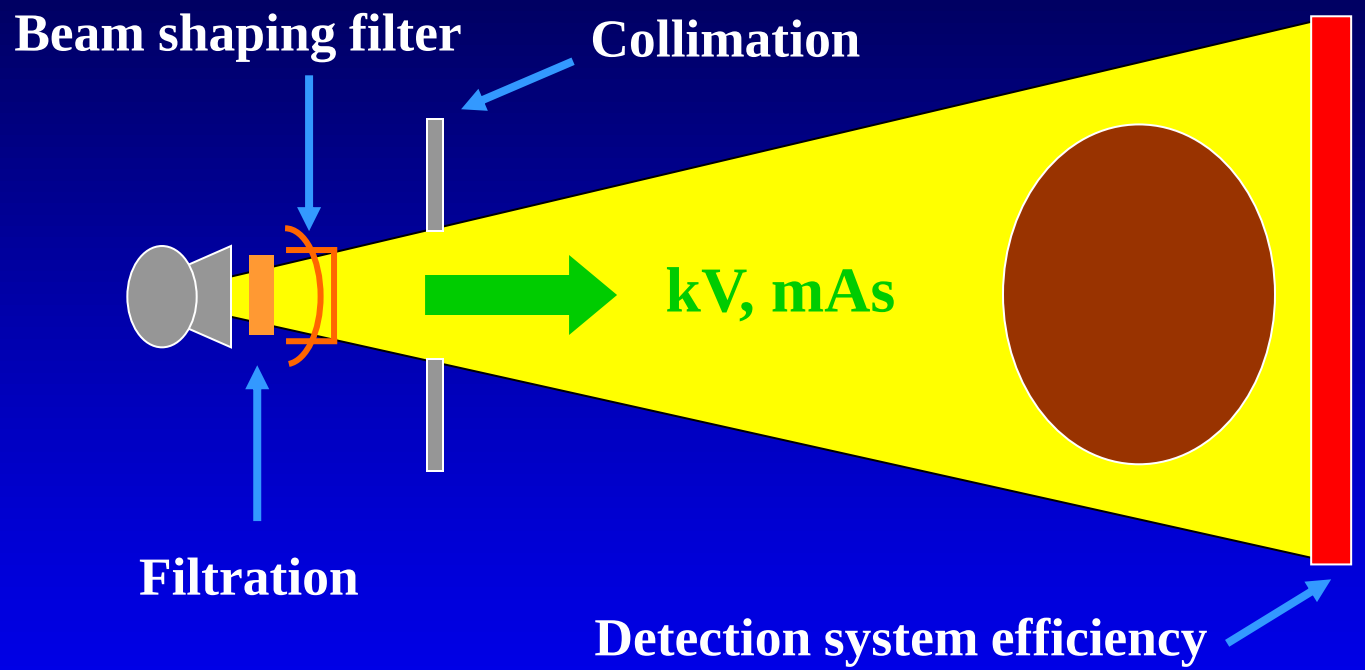
4. I have been told the risks to me and my fetus of not doing this X-ray test are:

5. I have had an opportunity to ask questions and have had those questions answered, and have received sufficient information so that I have a general understanding of: (a) the status of my pregnancy, (b) the nature of the use of ionizing radiation (X-rays) in this test, (c) the benefits of the use of X-rays in this test, (d) the usual and most frequent risks of exposure to X-rays, (e) the risks and benefits of the diagnostic test I am going to have, (f) the likelihood of determining my suspected illness from these test results, (g) alternatives to doing this test, and (h) risks of not doing this test.
Based on my discussion with my (the patient's) physician and the information that I have received, I give my consent for this test using X-rays. I confirm that I have read this form, or that it was read to me, that all blank spaces were filled in, and all sections that I do not agree with were crossed out before I signed below.

FIGURE 1. Sample consent for imaging of the abdomen and pelvis in pregnancy. Physician, patient, and witness signature lines are not included.

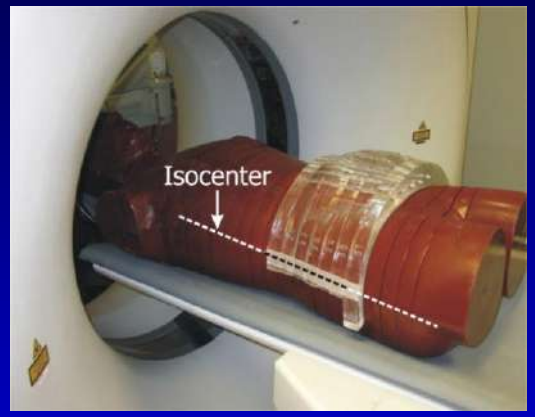
*J. Fielding and D. Washburn, Journal of Women's Imaging 7:16-21, 2005*
*G. El-Khoury, M. Madsen, M. Blake, J. Yankowitz, AJR 181:335-340, 2003*

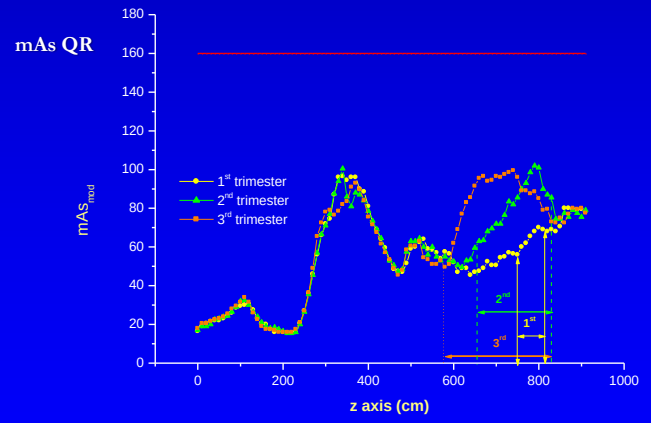
# Dose optimization: Parameters that affect CT dose




Scanning length, Reconstruction slice width, Scanner geometry
Pitch, Algorithms, Dose reduction tools

# CT: Patient centering & AEC



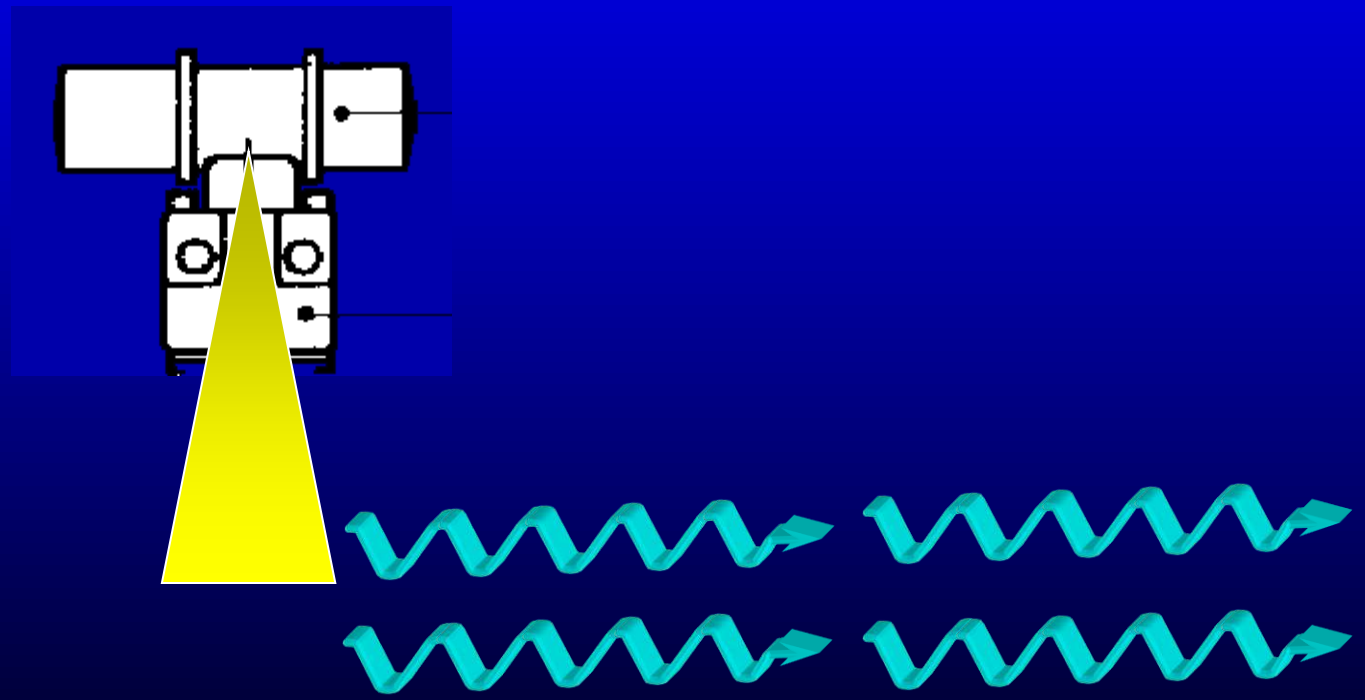

# Interventional Radiology

**Practical actions to control dose to the patient**

**Keep beam-on time to a minimum**
**Keep the x-ray tube at maximal distance from the patient**
**Keep the image receptor as close to the patient as possible**
**Do not overuse geometric magnification**
**Collimate as tightly as possible**
**Use low dose rate pulsed fluoroscopy**

*Damilakis J, Investigative Radiology 56:62-68, 2021*

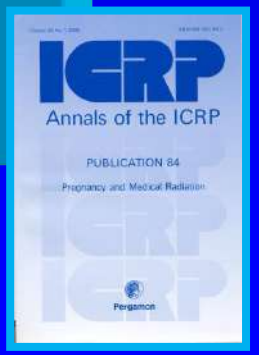
# *Pregnant (or potentially pregnant) employees working in imaging departments*



# Conceptus dose limit for pregnant workers
# ICRP Publication 84

**‘The working conditions of a pregnant worker, after the declaration of pregnancy, should be as such to make it unlikely that the additional dose to the conceptus will exceed about 1 mGy during the remainder of pregnancy.’**

***Annals of the ICRP, Publication 84, 2000***



# Voluntary declaration of pregnancy

*A FEMALE WORKER SHOULD, IN BECOMING AWARE THAT SHE IS PREGNANT, NOTIFY THE EMPLOYER IN ORDER THAT HER WORKING CONDITIONS MAY BE MODIFIED IF NECESSARY*

# Dose monitoring

Conventional dosimeters

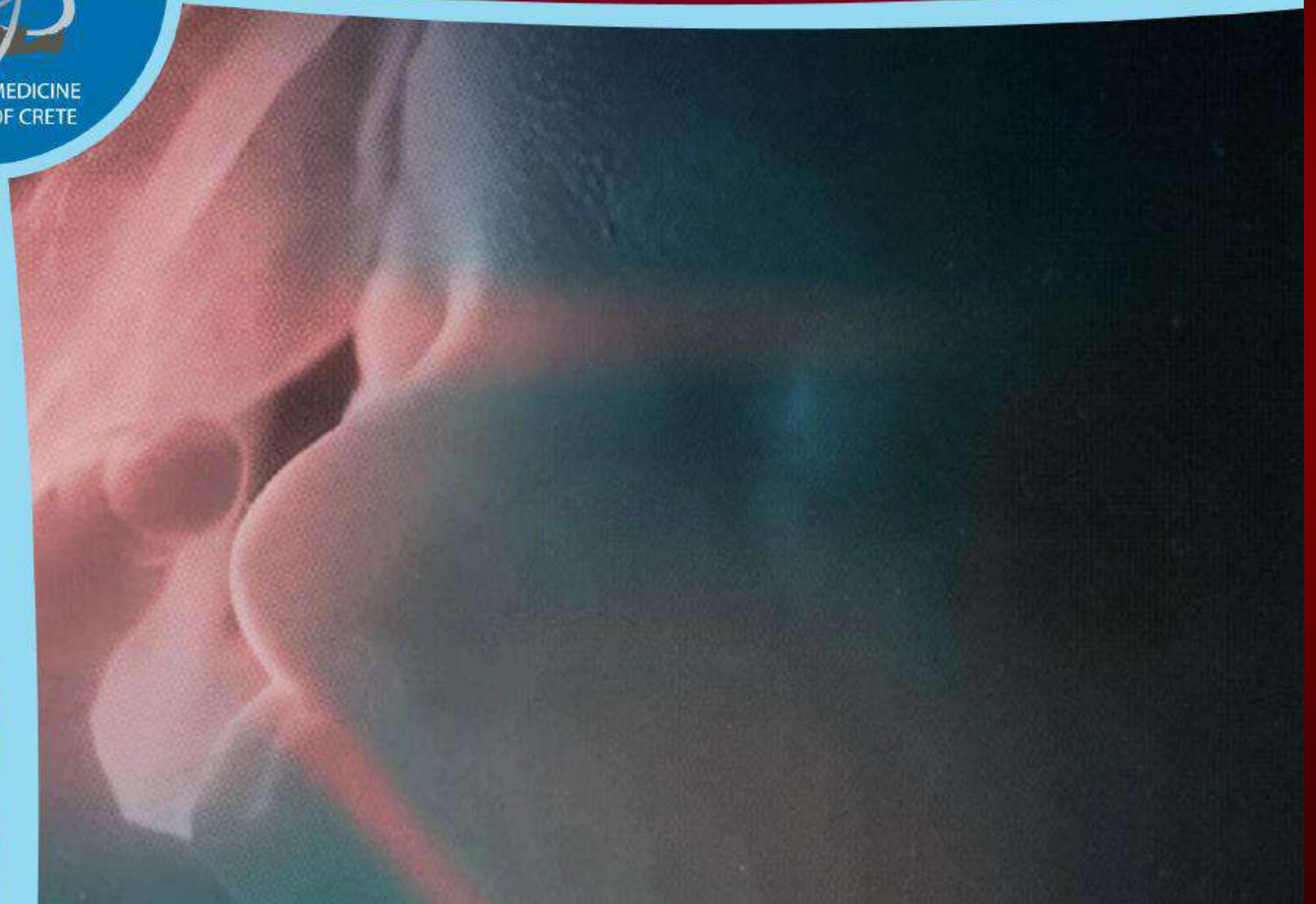
Real-time dose monitoring

Supplemental dosimetry

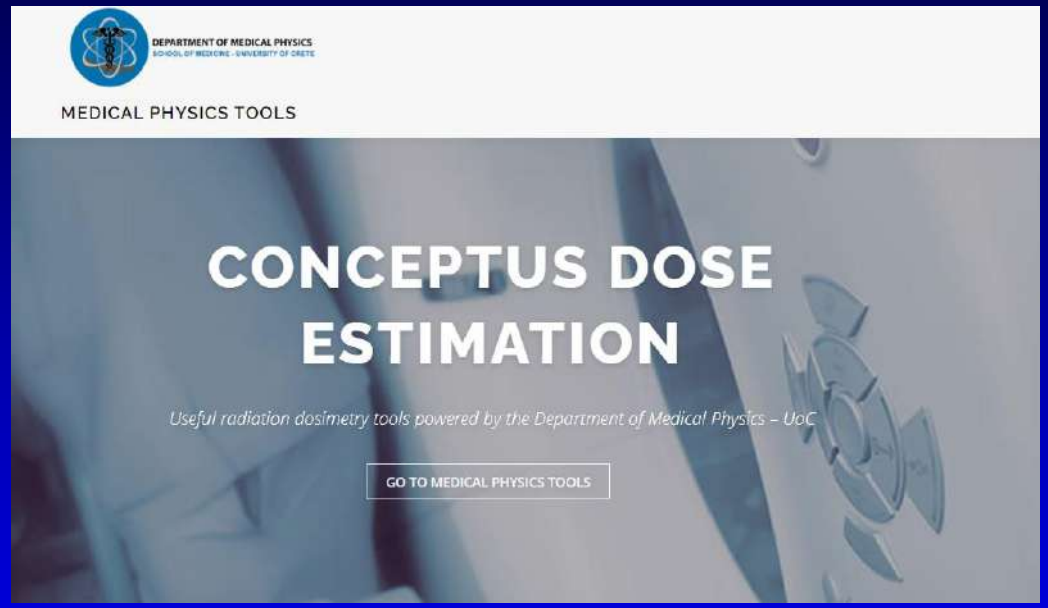
DEPARTMENT OF MEDICAL PHYSICS

FACULTY OF MEDICINE
UNIVERSITY OF CRETE

# Conceptus Dose Estimation tool



# Tools for medical dosimetry




http://ctdose-iqurad.med.uoc.gr/

**CoDE**

**Co**nceptus Radiation **D**oses and Risks **E**stimation from Imaging with Ionizing Radiation

**CT-RAD Tool**

Personalized Computed Tomography Organ Dose Estimation

COMING SOON

**AutoWED**

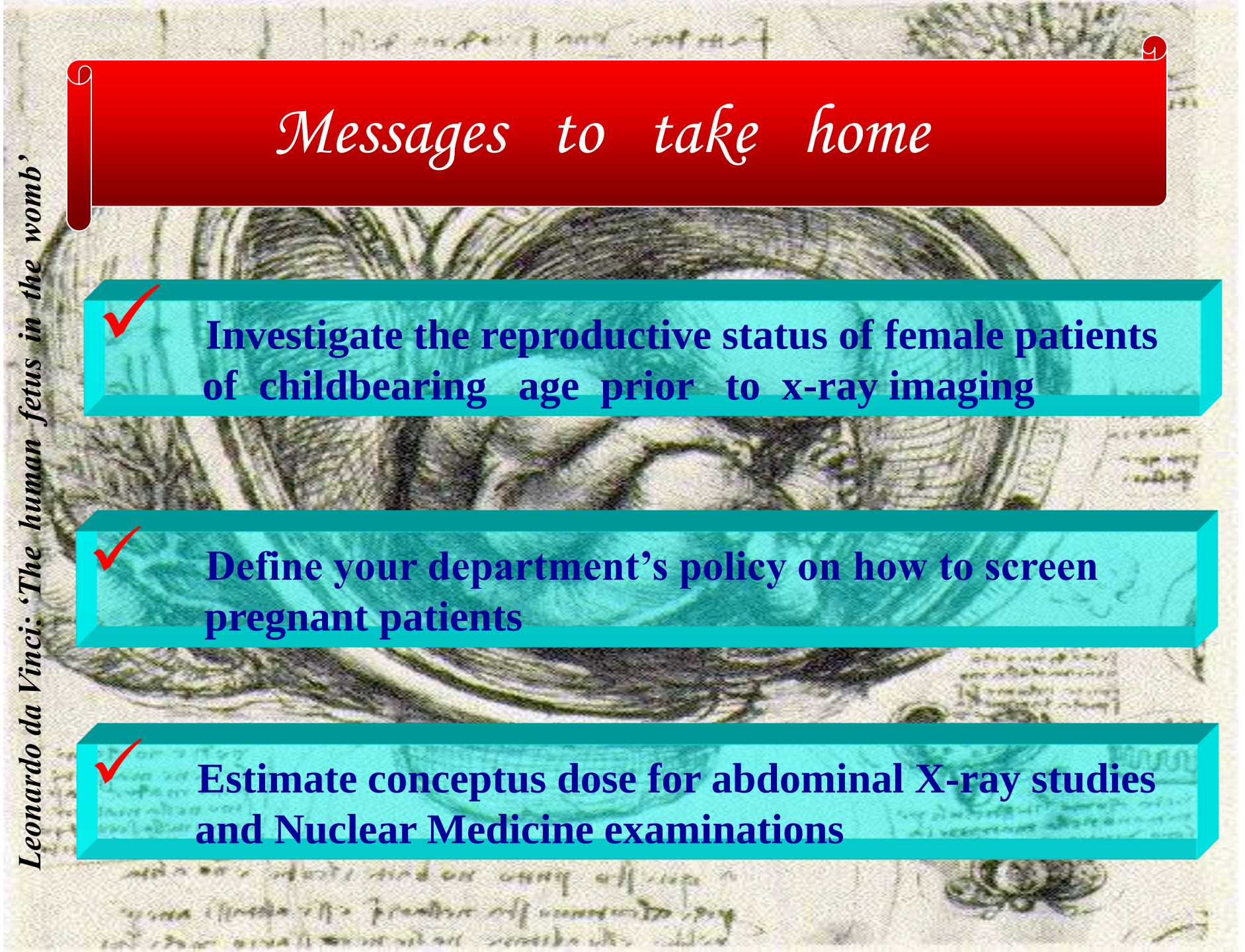
NEW!

Automated Calculation of Water-equivalent Diameter based on AAPM TG220 report

**XSG**

NEW!

X-ray spectrum generator for MC dosimetry



# *Messages to take home*

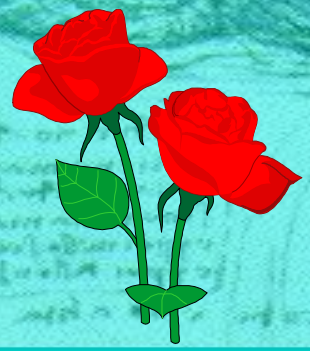
- ✓ **Investigate the reproductive status of female patients of childbearing age prior to x-ray imaging**
- ✓ **Define your department's policy on how to screen pregnant patients**
- ✓ **Estimate conceptus dose for abdominal X-ray studies and Nuclear Medicine examinations**

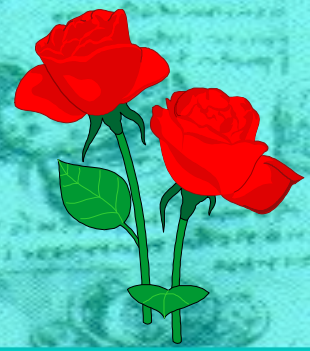
***Leonardo da Vinci: 'The human fetus in the womb'***

# *Messages to take home*

- **Situations that may lead to radiation doses higher than 100 mGy are very rare in diagnostic radiology**
- **Abortion due to a diagnostic x-ray examination is not justified in the vast majority of cases**

***Thank you !***





*Leonardo da Vinci: 'The human fetus in the womb'*