Radiation and Pregnancy

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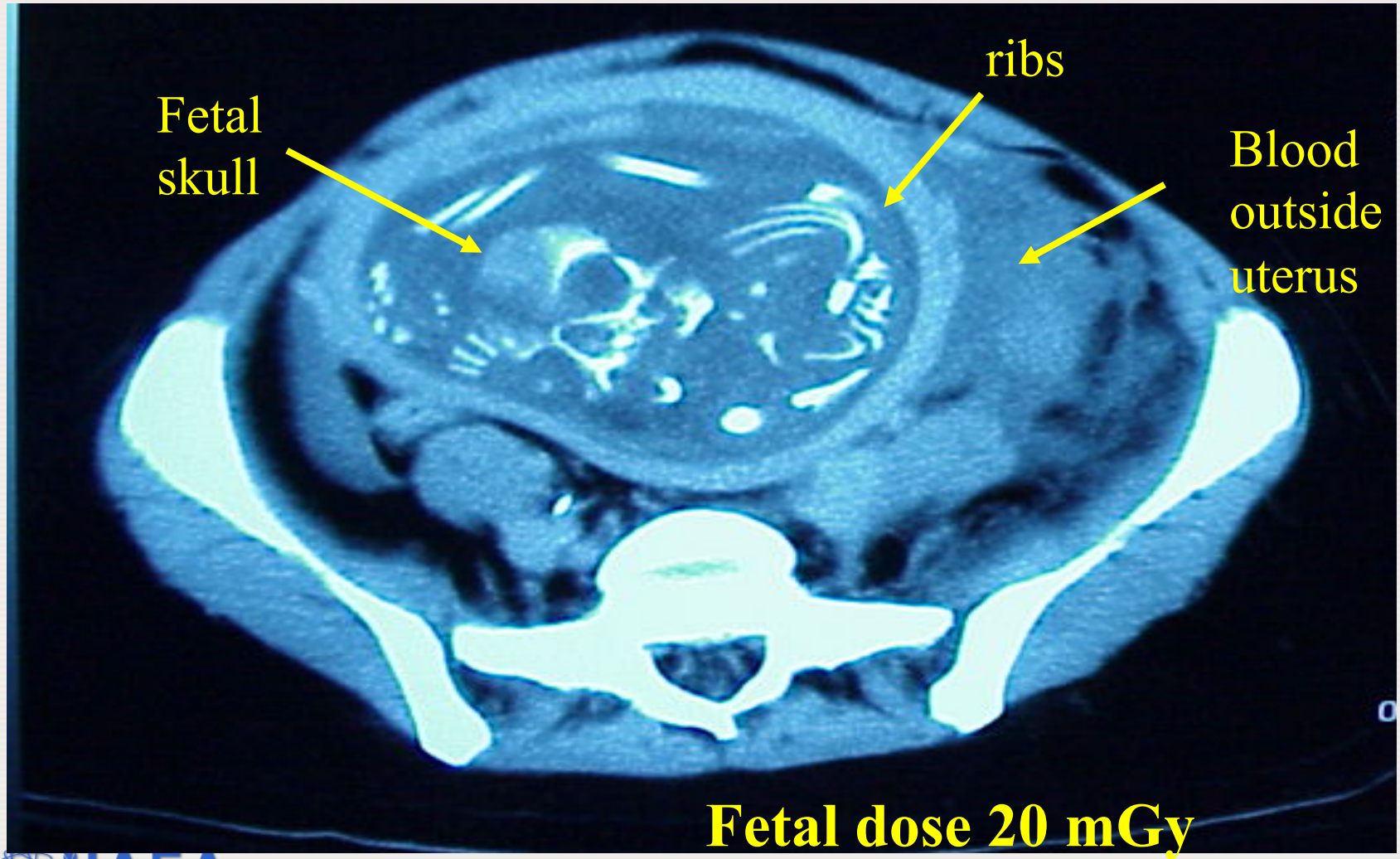
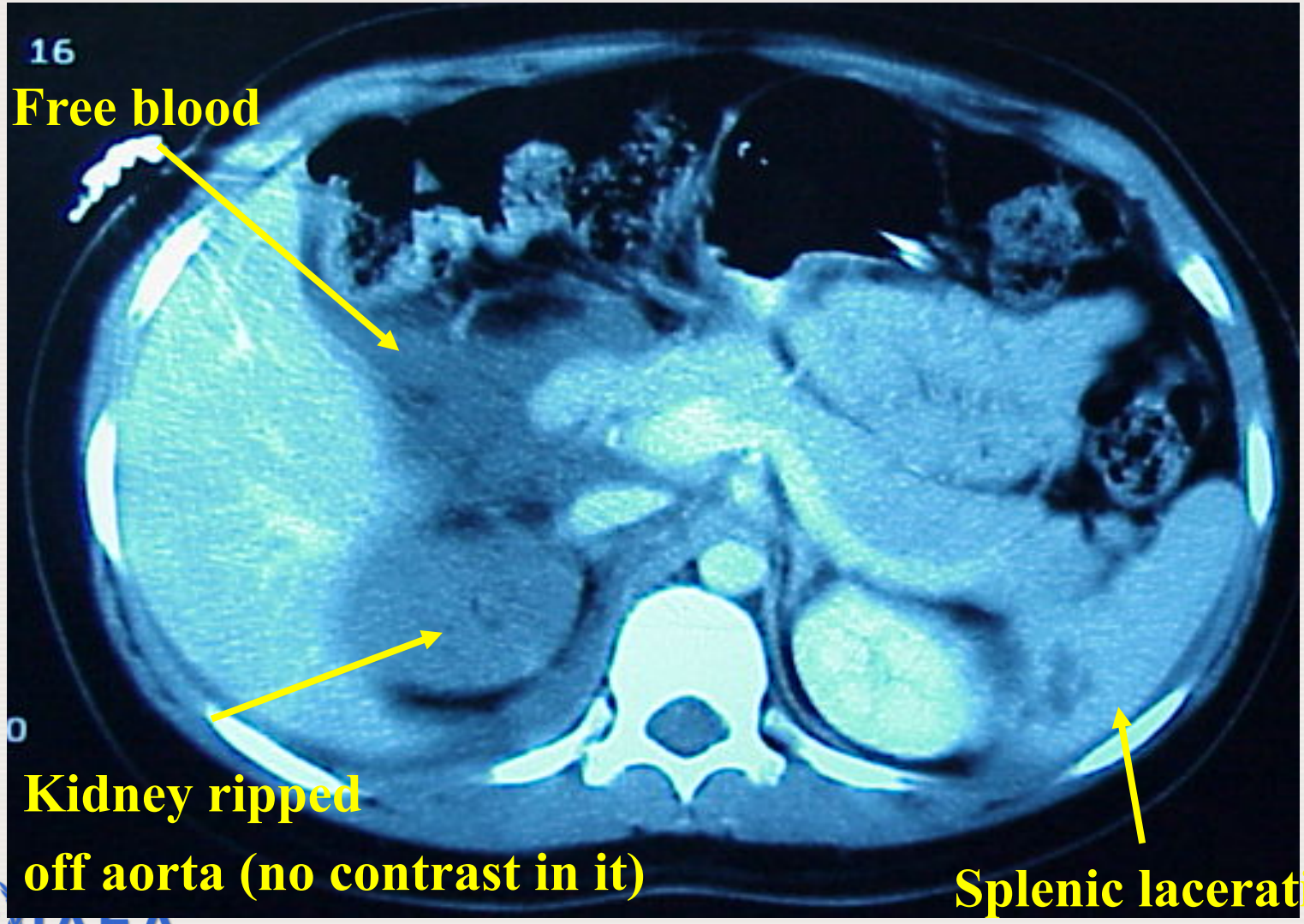
IAEA

Atoms for Peace: The First Half Century
1957–2007

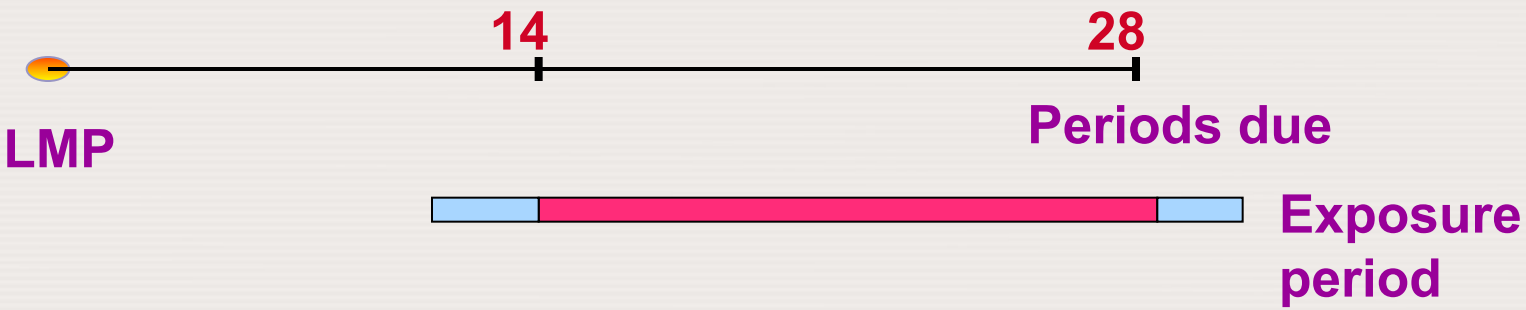
Example of justified use of CT in a pregnant female who was in a motor vehicle accident



3 minute CT exam and taken to the operating room. She and the child survived

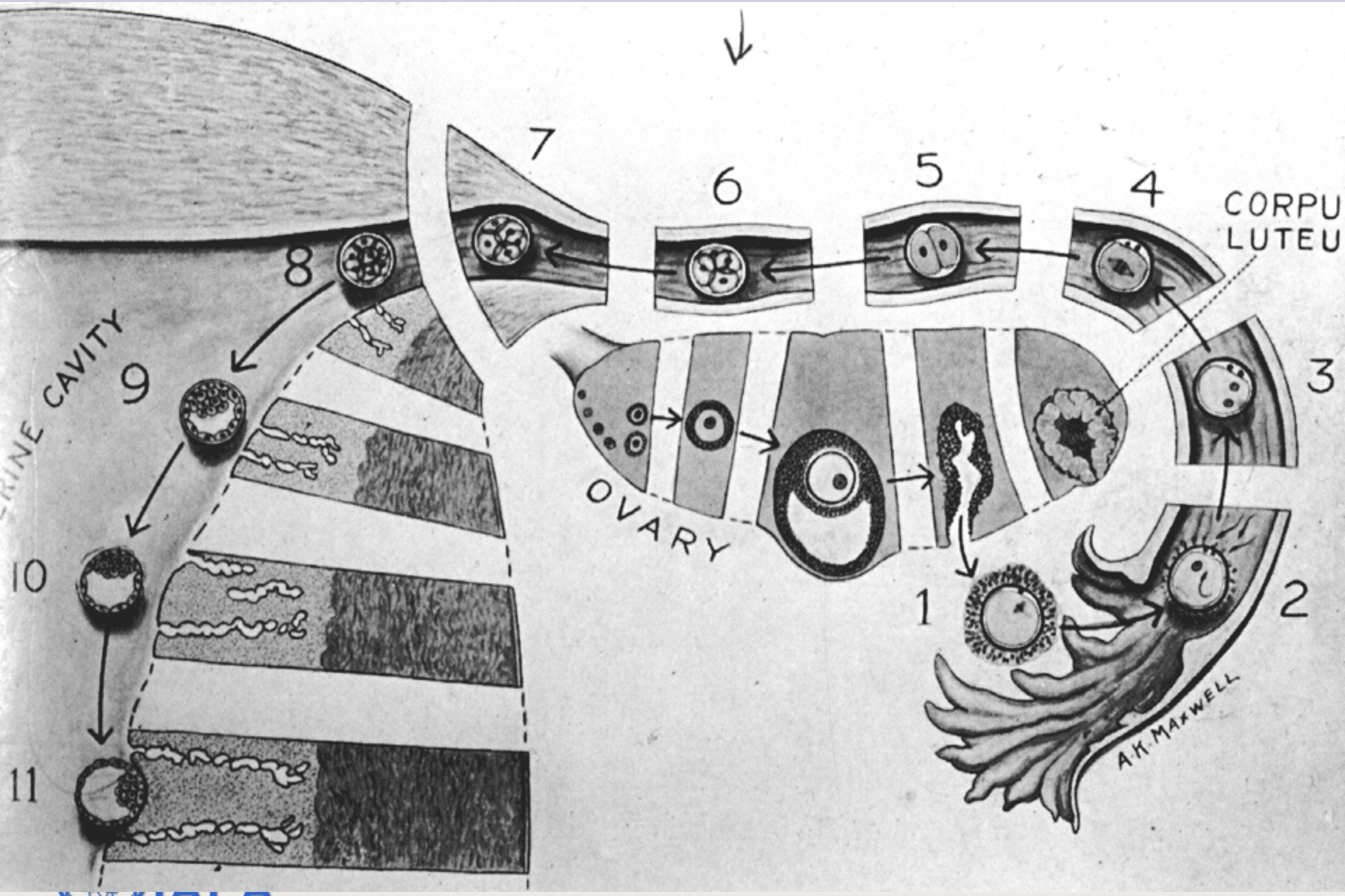


Inadvertent exposure



Psychological issue or uncertainty

Q. How sensitive is early conceptus?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Pre-implant stage (up to 10 days)

- Only lethal effect, all or none
- Embryo contains only few cells which are not specialized
- If too many cell are damaged-embryo is resorbed
- If only few killed-remaining pluripotent cells replace the cells loss within few cell divisions
- Atomic Bomb survivors - high incidence of both - normal birth and spontaneous abortion

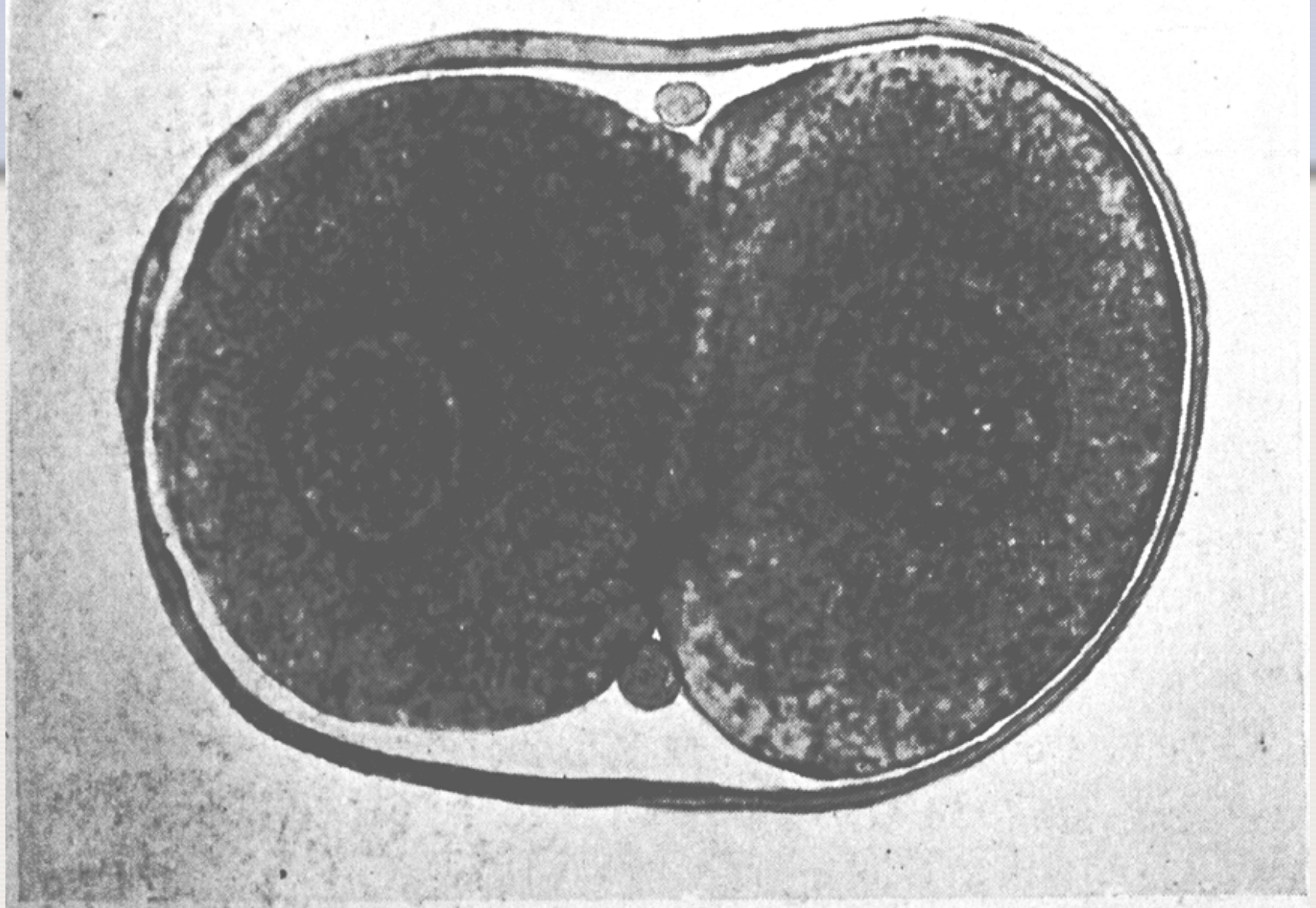
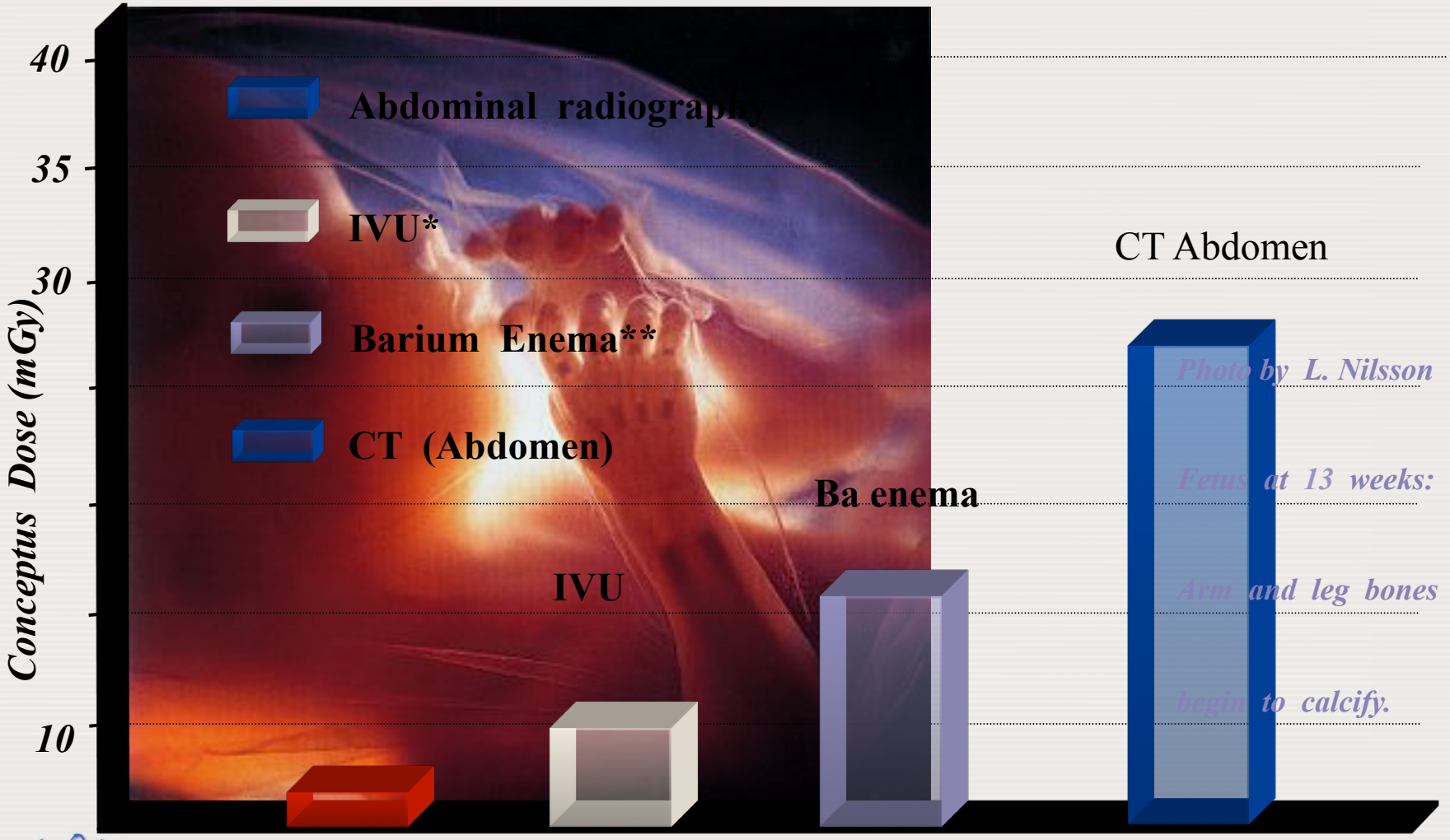


FIG. 29.—Photomicrograph of the 2-celled stage of the human zygote. × 500. (Reproduced by the courtesy of Drs. Hertig and Rock.)

Sensitivity of the early conceptus

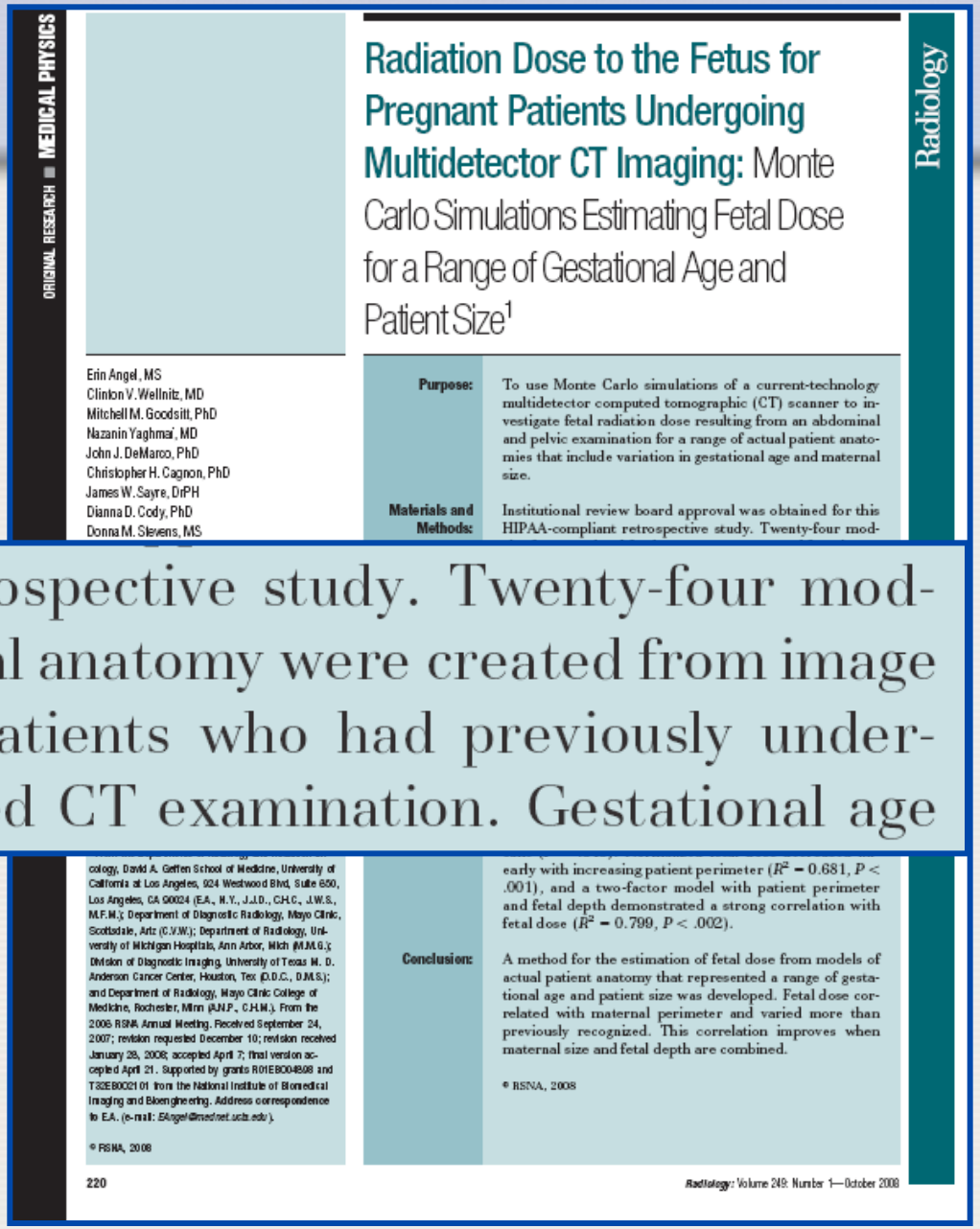
- **Till early 1980's, early conceptus was considered to be very sensitive to radiation - although no one knew how sensitive?**
- **Realisation that**
  - **organogenesis starts 3-5 weeks after conception**
  - **In the period before organogenesis high radiation exposure may lead to failure to implant. Low dose may not have any observable effect.**

Conceptus dose from abdominal X-ray examinations



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

Radiology: Volume 249: Number 1—October 2008



ORIGINAL RESEARCH ■ MEDICAL PHYSICS

Radiation Dose to the Fetus for Pregnant Patients Undergoing Multidetector CT Imaging: Monte Carlo Simulations Estimating Fetal Dose for a Range of Gestational Age and Patient Size[1]

Erin Angel, MS
Clinton V. Wellnitz, MD
Mitchell M. Goodsitt, PhD
Nazanin Yaghmai, MD
John J. DeMarco, PhD
Christopher H. Cagnon, PhD
James W. Sayre, DrPH
Dianna D. Cody, PhD
Donna M. Stevens, MS

Purpose: To use Monte Carlo simulations of a current-technology multidetector computed tomographic (CT) scanner to investigate fetal radiation dose resulting from an abdominal and pelvic examination for a range of actual patient anatomies that include variation in gestational age and maternal size.

Materials and Methods: Institutional review board approval was obtained for this HIPAA-compliant retrospective study. Twenty-four models of maternal and fetal anatomy were created from image data from pregnant patients who had previously undergone clinically indicated CT examination. Gestational age

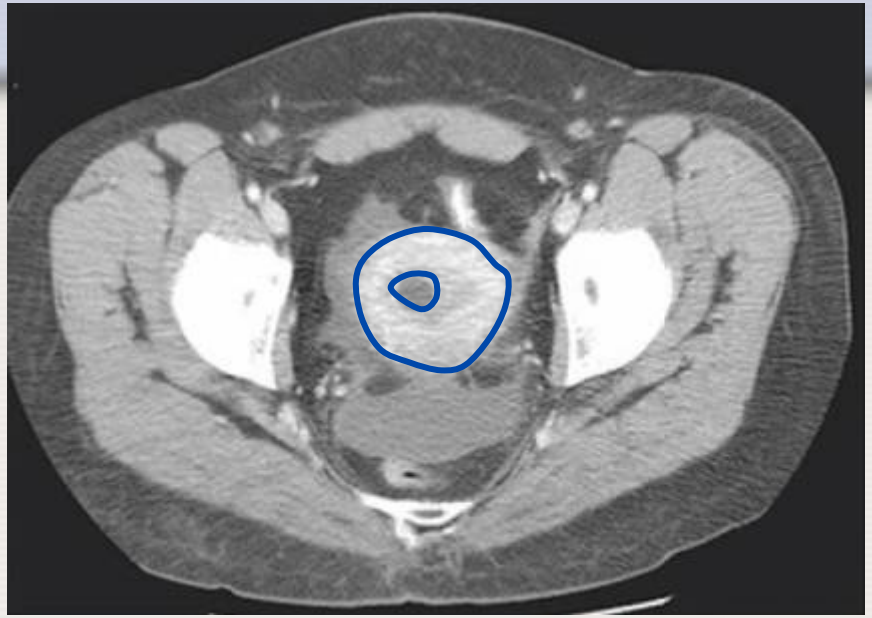
early with increasing patient perimeter ($R^2 = 0.681$, $P < .001$), and a two-factor model with patient perimeter and fetal depth demonstrated a strong correlation with fetal dose ($R^2 = 0.799$, $P < .002$).

Conclusion: A method for the estimation of fetal dose from models of actual patient anatomy that represented a range of gestational age and patient size was developed. Fetal dose correlated with maternal perimeter and varied more than previously recognized. This correlation improves when maternal size and fetal depth are combined.

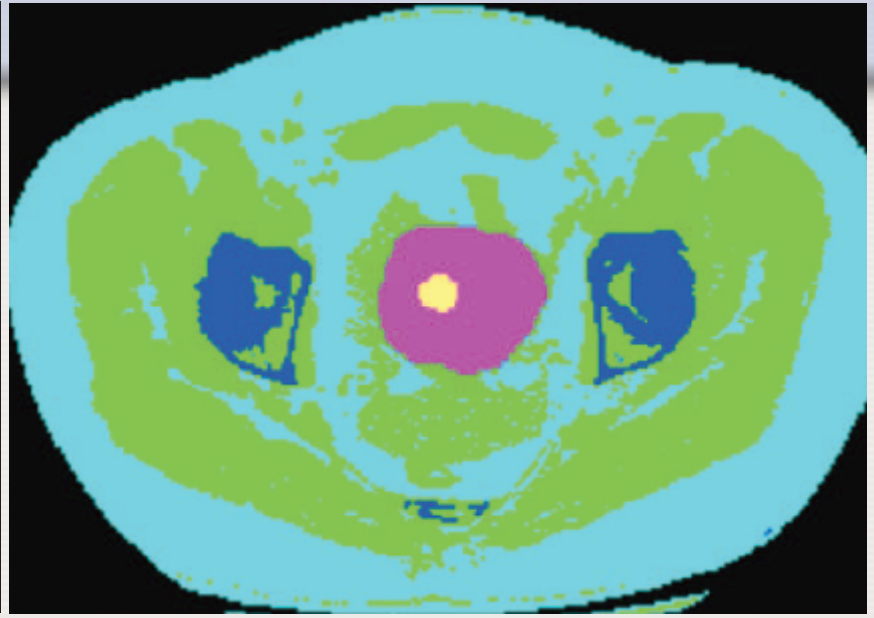
cology, David A. Geffen School of Medicine, University of California at Los Angeles, 924 Westwood Blvd, Suite 650, Los Angeles, CA 90024 (E.A., N.Y., J.J.D., C.H.C., J.W.S., M.F.M.); Department of Diagnostic Radiology, Mayo Clinic, Scottsdale, Ariz (C.V.W.); Department of Radiology, University of Michigan Hospitals, Ann Arbor, Mich (M.M.G.); Division of Diagnostic Imaging, University of Texas M. D. Anderson Cancer Center, Houston, Tex (D.D.C., D.M.S.); and Department of Radiology, Mayo Clinic College of Medicine, Rochester, Minn (N.N.P., C.H.M.). From the 2006 RSNA Annual Meeting. Received September 24, 2007; revision requested December 10; revision received January 28, 2008; accepted April 7; final version accepted April 21. Supported by grants R01EB004808 and T32EB002101 from the National Institute of Biomedical Imaging and Bioengineering. Address correspondence to E.A. (e-mail: *EAngel@mednet.ucla.edu*).

HIPAA-compliant retrospective study. Twenty-four models of maternal and fetal anatomy were created from image data from pregnant patients who had previously undergone clinically indicated CT examination. Gestational age

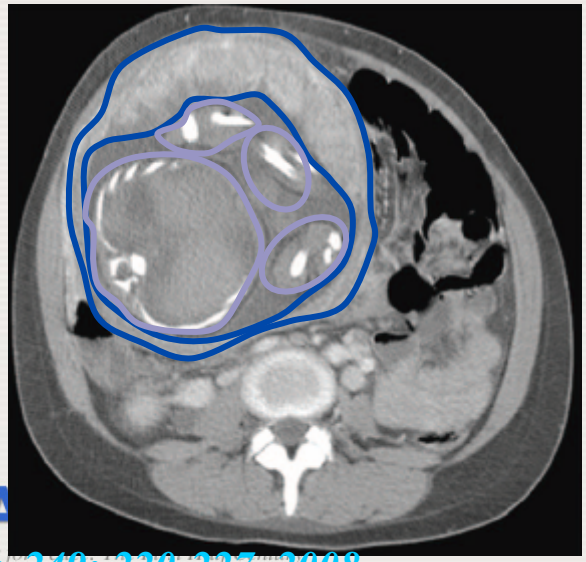
Early Gestation

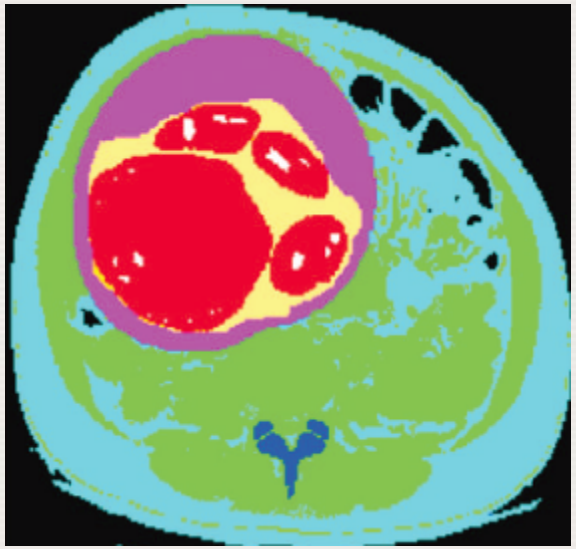


Voxelized Phantoms



Late Gestation





Radiology, 249: 220-227, 2008

Figure 5

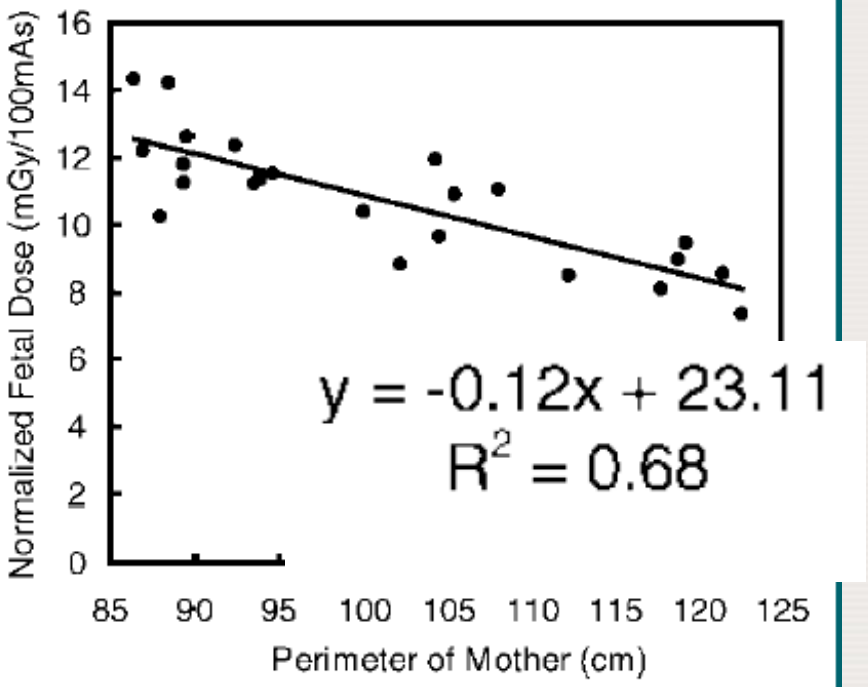


Figure 5: Graph of radiation dose to fetus versus perimeter of mother. Perimeter of mother correlates linearly with normalized fetal dose ($R^2 = 0.681$; $P < .001$; standard error of the estimate = 1.053).

ORIGINAL RESEARCH ■ OBSTETRIC IMAGING

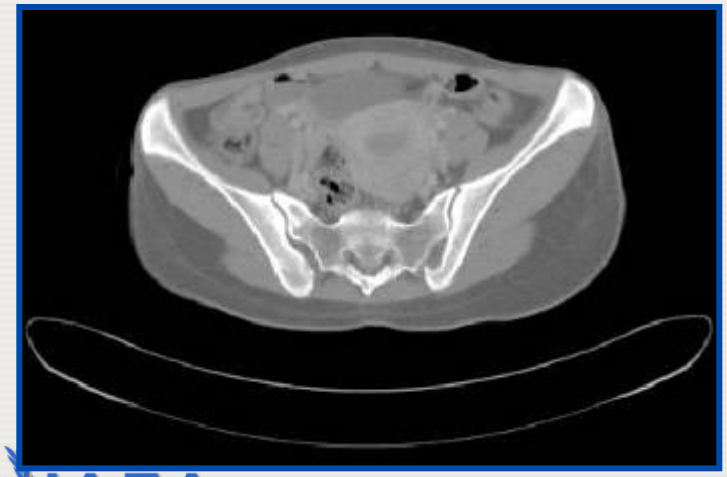
Radiation Dose to the Conceptus from Multidetector CT during Early Gestation: A Method That Allows for Variations in Maternal Body Size and Conceptus Position[1]

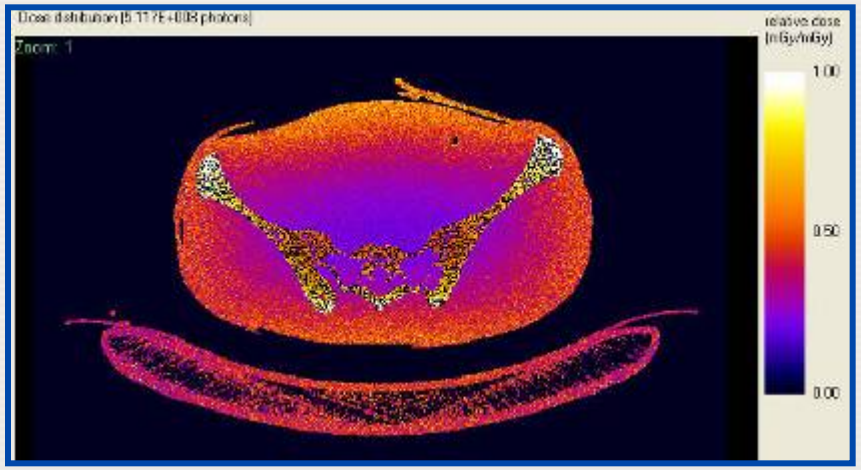
J. Damilakis et al. Radiology (In press)

2010 Nov;257(2):483-9

Patient-based modeling

MC simulations were based on 117 patient models created using image data of young female patients who underwent abdominal CT studies.





Fetal dose & implications

- Uterus dose from a diagnostic scan of pelvis typically ≈ **30-40 mGy but can be higher**
- CT without contrast followed by PET/CT **≈ 50 mGy**
- At this level careful fetal dosimetry assessment is recommended
- At level >100 mGy, issue of termination comes up
- Radiation dose becomes important if pelvis is covered in CT
- For brain, chest, cardiac: mainly PET contributes

Approximate fetal doses from conventional x-ray examinations

data from the UK 1998

	Mean (mGy)	Maximum (mGy)
Abdomen	1.4	4.2
Chest	<0.01	<0.01
Intravenous urogram or lumbar spine	1.7	10
Pelvis	1.1	4
Skull or thoracic spine	<0.01	<0.01

Approximate fetal doses from fluoroscopic and computed tomography procedures

data from the U.K. 1998

	Mean (mGy)	Maximum (mGy)
Barium meal (UGI)	1.1	5.8
Barium enema	6.8	24
Head CT	<0.005	<0.005
Chest CT	0.06	1.0
Abdomen CT	8.0	49
Pelvis CT	25	80

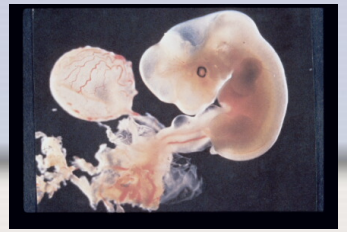
Dosimetry- PET

- Early stage of pregnancy: dose to embryo/fetus is considered same as dose to uterus
- After about 12 weeks, trophoblastic nutrition is replaced by placental nutition
- Dose will depend if compound's transfer through placenta and accumulation in placenta & distribution in mother
- Earlier there was No documented evidence of placental transfer of FDG

Dosimetry

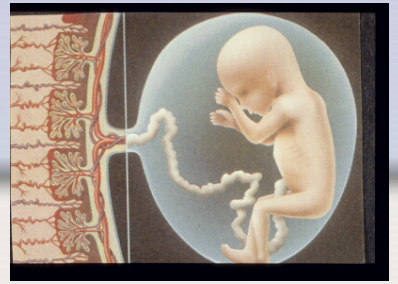
- Now fetal accumulation of FDG has been shown in images in human
- FDG dose coefficients are now available for early pregnancy and 3, 6 and 9 months.

FETAL RADIATION RISK



Most risk

Less



Least

- Lethal effects - threshold 100 mGy to the fetus
- Malformations - threshold 100-200 mGy or higher
- Mental retardation – more than 100 mGy

  -3 IQ units/100 mGy

  ~ 1000 mGy: severe mental retardation
  8-15 weeks (40% per Gy)
  16-25 weeks: (10% per Gy)

- Cancer (leukemia and others) - Absolute risk ~ 0.06% for 10 mGy to fetus

Keep the perspective…!

Dose to fetus of a patient

Lung scintigraphy (240 MBq)	0,9 mGy (early pregnancy)
Kidney scintigraphy (300 MBq)	9,0 mGy (early pregnancy)

Pelvis CT:	mean: 25 mGy	max: 80 mGy
Abdomen CT:	mean: 8 mGy	max: 49 mGy
Fluoroscopy:	mean: ~ 10 mGy	max: ~ 50 mGy or more

Radiotherapy: Tangential breast irradiation. Tumour dose 50 Gy

4.5x11 cm²: 22-168 mGy (late pregnancy)

11.5x18.0 cm²: 65-586 mGy (late pregnancy)

Int J Rad Oncology, Biol Physics 55, 2003

Higher Exposure Rate Constants

Radionuclide	ERC (R/hr/mCi at 1 cm from point source)
Fluorine-18	6.0
Indium-111	3.4
Gallium-67	1.1
Technetium-99m	0.6
Thallium-201	0.4

Embryo/fetal dose from ^{18}F-FDG

Absorbed dose per unit activity administered to mother mGy/MBq

	Early	3m	6m	9m
^{18}F-FDG 2 hr void	0.018	0.018	0.016	0.015
^{18}F-FDG 4 hr void	0.022	0.022	0.017	0.017

Typical value= 20 microGy/MBq
For whole body with 350 MBq= 350x 20=7 mGy
For brain= 250 MBqx 20= 5 mGy

REVIEW OF STANDARDS Conclusions

There is general agreement in the radiation protection community that the embryo/fetus should be afforded the same level of protection as members of the general public and protected at approximately a 1 mSv dose restriction.

Women should be encouraged to declare their pregnancies as early as possible after discovery of pregnancy, to permit the employer to provide this level of protection to the embryo/fetus

6. Can a child accompany a patient to the PET/CT centre?

It is advisable not to bring children along to the PET/CT centre. Following injection of radioactive material and before the scan starts, it is important that the patient is relaxed, so that the staff can get the best scan possible. The radiation exposure to accompanying child from the patient, although small, is better avoided as far as possible.

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7. Can a pregnant woman accompany a friend, partner or child who is having a scan?

It is not desirable. Although the radiation dose from the person undergoing a scan is fairly low, it is desirable to keep the radiation exposure to the foetus as low as reasonably achievable. Should a pregnant woman's presence be necessary to comfort a small child, specific advice to keep their distance from the child and from other patients who have undergone PET scans or other diagnostic and therapeutic radionuclide procedures should be provided. In such a case, the contact time should be as short as possible.

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8. Can a patient breastfeed after a scan?

Some of the administered ^{18}F-FDG might be excreted in small amounts in breast milk. Normally, the scan should be delayed until breast feeding has stopped. But if the scan is needed urgently, then it is advisable to collect milk before the scan, so that this can be used to provide a feed after the scan. Furthermore, milk should be collected and discarded for 2 hours after the scan. Normal breast feeding can resume after that.

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9. What if an ancillary staff member is in the early stage of pregnancy and is exposed to a patient who has undergone PET/CT?

There is no significant risk involved in such an exposure. For details »

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10. After a PET scan, how long does a patient need to wait before using public transportation without setting off radiation detectors?

There is no danger to other travellers on public transportation following a PET scan with due attention to pregnant women and children as in Qn. 7. However, in some countries, radiation detectors in public areas and specific locations such as airports can be inadvertently activated by even small amounts of radiation. Radiation detectors are now more sensitive than ever before. Nonetheless, the isotopes used for PET imaging decay so rapidly that after only 24 hours there is no danger of activating a radiation detector. However, it may be a good idea for the patient to obtain a document from the PET Centre stating that they have undergone a PET/CT scan, in case they are questioned.

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11. Does a patient need to restrict his or her activities after a PET/CT scan?

No. Although the scan involves injection of a radioactive substance, which will lead to radiation exposure of persons in his/her vicinity, the amount of radiation coming from the patient following the scan is low. The patient can carry out all routine activities without any risk to others, with the consideration of limiting contact with pregnant women and children as in Qn. 7.

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12. Are any additional restrictions required for a patient's behaviour for positron emitting tracers other than ^{18}F-FDG?

^{18}F-FDG is by far the most commonly used radiotracer. Other tracers with shorter half lives (e.g. ^{82}Rubidium, ^{13}N-ammonia, ^{11}C and ^{15}O water) decay much faster than FDG, and therefore require no additional restrictions. Radiation dose rates from non-fluorine tracers with longer half lives have not been established in clinical use and are used very rarely in research studies. Individualized instructions would be required if these tracers are used.

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13. Are members of the nursing and ancillary staff at risk when taking care of patients after PET/CT examination?

No, there is no significant risk to the staff taking care of these patients. However, radiation from patients undergoing other diagnostic and therapeutic radionuclide procedures such as bone scans or radioiodine therapy may pose a risk of radiation exposure to medical staff and does require attention. Patients

Comment……!!!

Central Nervous System Effects

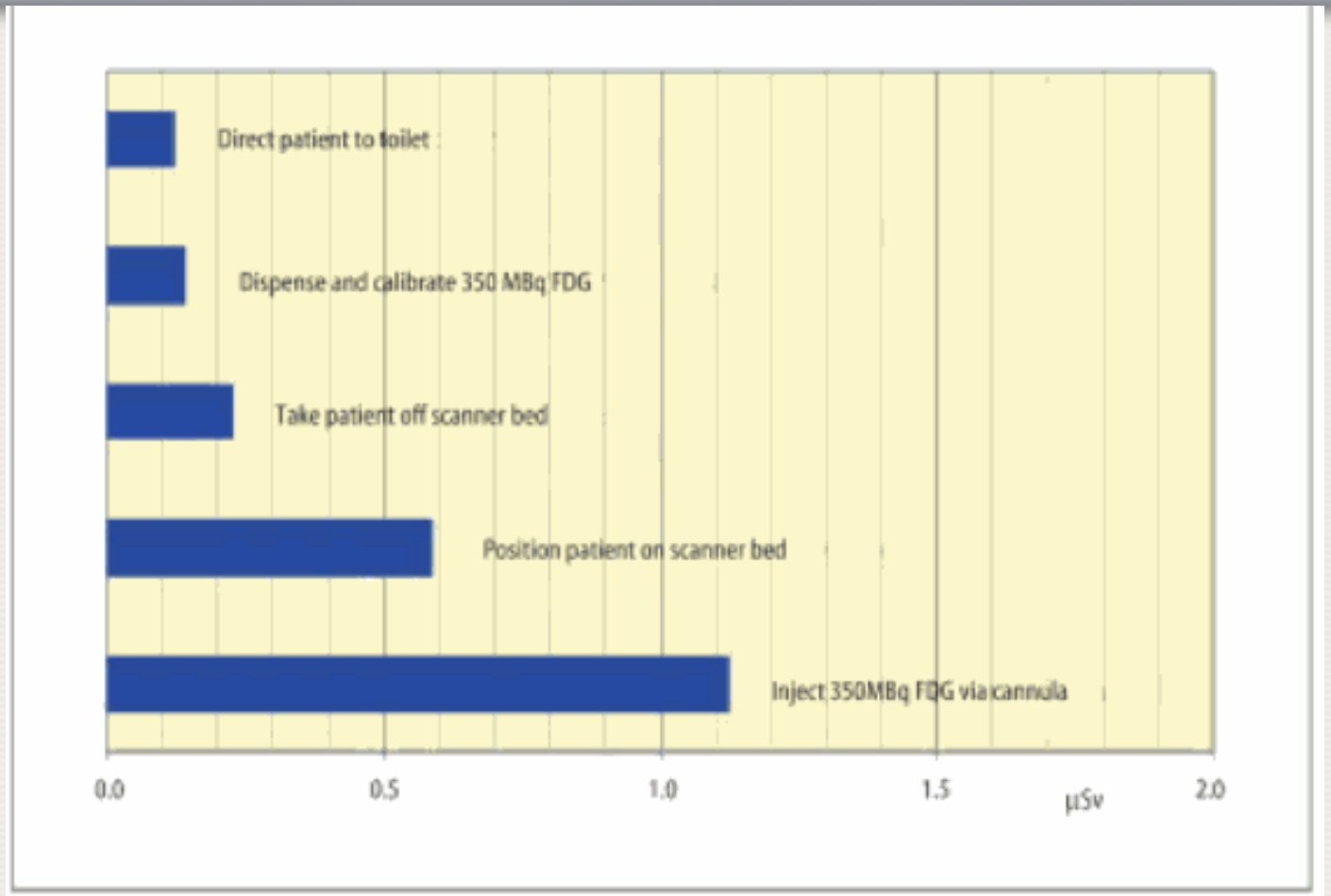
- During 8-25 weeks post-conception the CNS is particularly sensitive to radiation
- Fetal doses in excess of 100 mGy can result in some reduction of IQ (intelligence quotient)
- Fetal doses in the range of 1000 mGy can result in severe mental retardation particularly during 8-15 weeks and to a lesser extent at 16-25 weeks

Pre-conception Irradiation

- Pre-conception irradiation of either parent's gonads has **NOT** been shown to result in increased risk of cancer or malformations in children
- This statement is from comprehensive studies of atomic bomb survivors as well as studies of patients who had been treated with radiotherapy when they were children

Radiation Exposure of Pregnant Workers

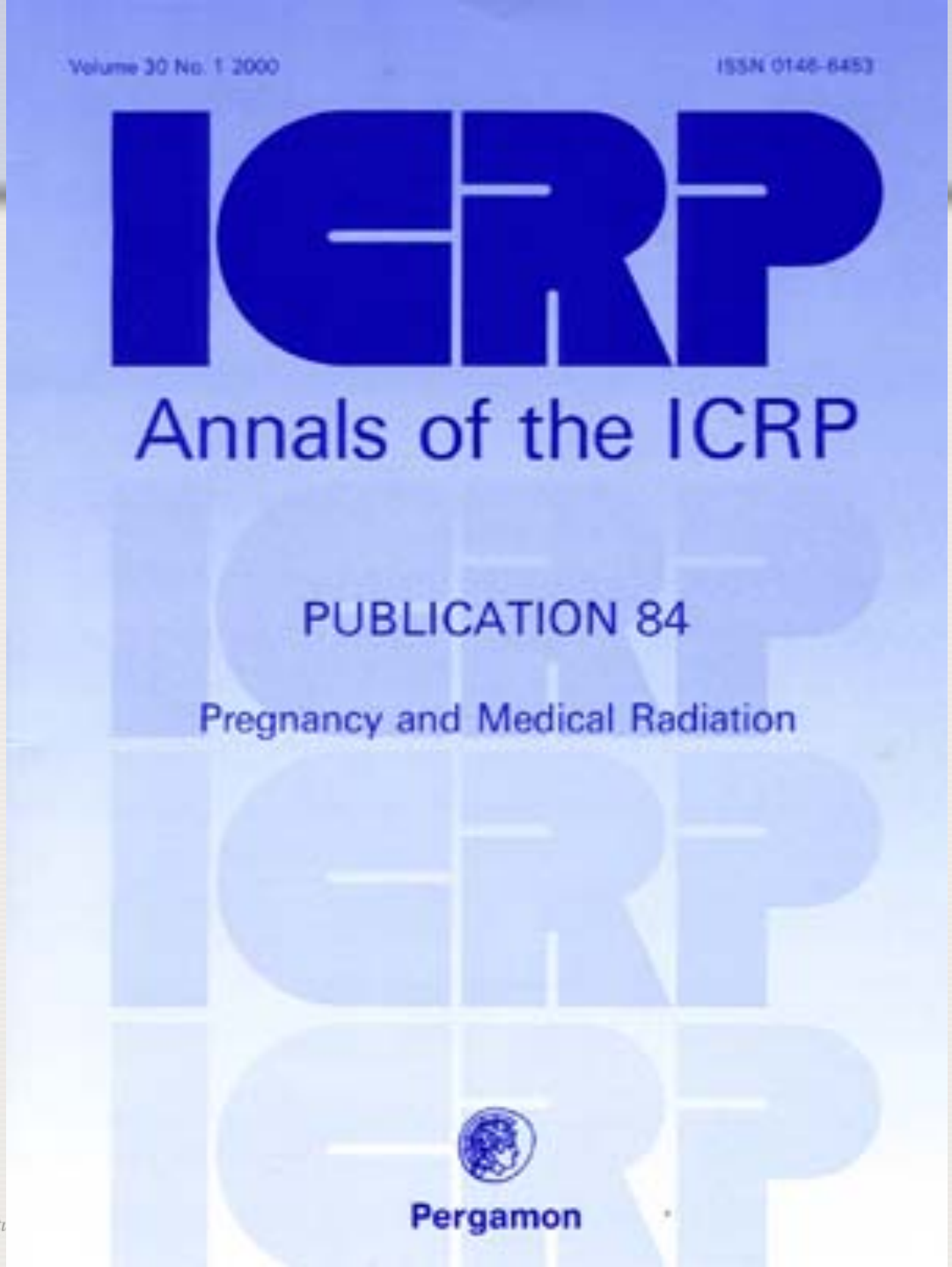
- Pregnant medical radiation workers may work in a radiation environment as long as there is reasonable assurance that the fetal dose can be kept below 1 mGy during the pregnancy.
- 1 mGy is approximately the dose that all persons receive annually from penetrating natural background radiation.



Dose to PET technologist in different tasks

Termination of pregnancy

- Termination of pregnancy at fetal doses of less than 100 mGy is **NOT** justified based upon radiation risk
- At fetal doses in excess of 100 mGy, there can be fetal damage, the magnitude and type of which is a function of dose and stage of pregnancy
- In these cases decisions should be based upon individual circumstances



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Pregnancy and Radiation Protection in Diagnostic Radiology

1. Is there a 'safe' level of radiation exposure for a patient during pregnancy?

Dose limits do not apply for radiation exposure of patients, since the decision to use radiation is justified depending upon the individual patient situation. When it has been decided that a medical procedure is justified, the procedure should be optimized. This means that the conditions should achieve the clinical purpose with the appropriate dose. Safe limits are determined only for the staff and not for patients.

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2. What is the ten-day rule and what is its status?

'Ten day rule' was postulated by ICRP for woman of reproductive age. It states that "whenever possible, one should confine the radiological examination of the lower abdomen and pelvis to the 10-day interval following the onset of menstruation." The original proposal was for 14

Pregnancy and Radiation Protection in Nuclear Medicine

Patient protection

1. What considerations are necessary for accepting a woman of childbearing age for a nuclear medicine examination?
2. In what way do nuclear medicine examinations differ from diagnostic radiology procedures for pregnant patients?
3. Should nuclear medicine examination in pregnancy be permitted? If so, what actions and precautions can reduce radiation exposure to the foetus?
4. What are the typical foetal doses from nuclear medicine examinations?

Radionuclide therapy

5. Should a pregnant patient be treated with radionuclides?

Radioiodine therapy and pregnancy

6. What should be done if radioiodine therapy is given to a patient who is later found to be pregnant?
7. Is there a risk to a pregnant woman if a family member is treated with radioiodine?
8. Should a woman avoid becoming pregnant after radionuclide therapy?

Staff protection

9. A nuclear medicine worker is concerned about radiation exposure during pregnancy. Can she continue performing her routine work?

1. What considerations are necessary for accepting a woman of childbearing age for a nuclear medicine examination?

In women of childbearing age, the possibility of pregnancy and the justification for the examination should be considered. The recommen precautions to prevent or minimise irradiation of the fetus include the following [ICRP 84]:

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The Alliance for Radiation Safety in Pediatric Imaging

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Pledge in Spanish

New! Resource for Radiologists:
***Image Gently* Web-based Practice Quality Improvement Program**

The Alliance for Radiation Safety in Pediatric Imaging
encourages increased awareness of opportunities to lower radiation dose in pediatric interventional radiology procedures with the introduction of its new campaign message:

Step Lightly

Working towards making medical exposure a *Safer practice*

Thank You

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1957–2007