PREGNANCY AND MEDICAL RADIATION

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INTRODUCTION

- Thousands of pregnant patients and radiation workers are exposed to ionizing radiation each year

- Lack of knowledge is responsible for great anxiety & probably unnecessary termination of many pregnancies

- For many patients, the exposure is appropriate, while for others the exposure may be inappropriate, placing the unborn child at an unjustified increased risk

- The pregnant patient or worker has a right to know the magnitude and type of potential radiation effects that might result from in utero exposure

FUNDAMENTAL CONCEPTS

- Radiation usage should be ***Justified*** (provide more benefit than harm).
- Medical exposure of a pregnant patient has additional ethical considerations (at least two individuals need to be considered for consent)
- Medical procedure should be optimized (not too high or low dose , optimal dose for both Radiotherapy/ Radio diagnosis)
- Reducing radiation dose after a procedure has been performed is only rarely possible.(***NM***)

GESTATIONAL AGE

Effects of radiation on fetus will depend upon gestational age:

1. **Pre-implantation** : Extends from fertilization to the time at which the embryo attaches to the wall of the uterus.

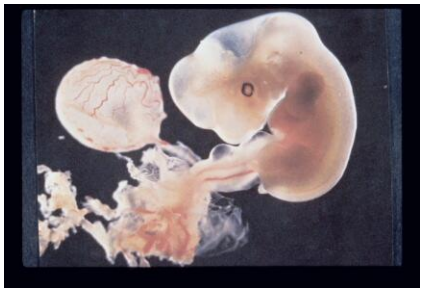
2. **Organogenesis**: The period during which major organs are developed 3^{rd} to 8^{th} week, post conception.

3. **Fetal period**: During which growth of the structures already formed takes place, from 9 weeks until birth. (CNS development 8 to 25 weeks).

EFFECTS OF IN-UTERO IRRADIATION

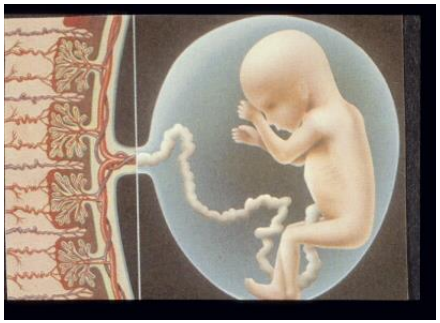
- Prenatal doses from most properly done diagnostic procedures present no measurable increased risk of prenatal death, malformation or impairment of mental development over the background incidence of these entities
- Higher doses, such as those involved in therapeutic procedures, can result in significant fetal harm
- Radiation risks are most significant during organogenesis and the early fetal period, somewhat less in the second trimester, and least in the third trimester

Most risk



Less

Least



EFFECTS OF IN-UTERO IRRADIATION

Clinical radiation effects are due to

(1) **Cell killing** (cell killing have a practical threshold below which the effect is not seen)

(2) **Unrepaired / Misrepaired DNA damage** (Leukaemia, cancer, and potential hereditary effects are due to unrepaired or misrepaired DNA damage, increases with dose & there is no identifiable threshold dose below which the chance is zero)

- Protracted exposures probably have less overall effect than a brief radiation exposure of high intensity

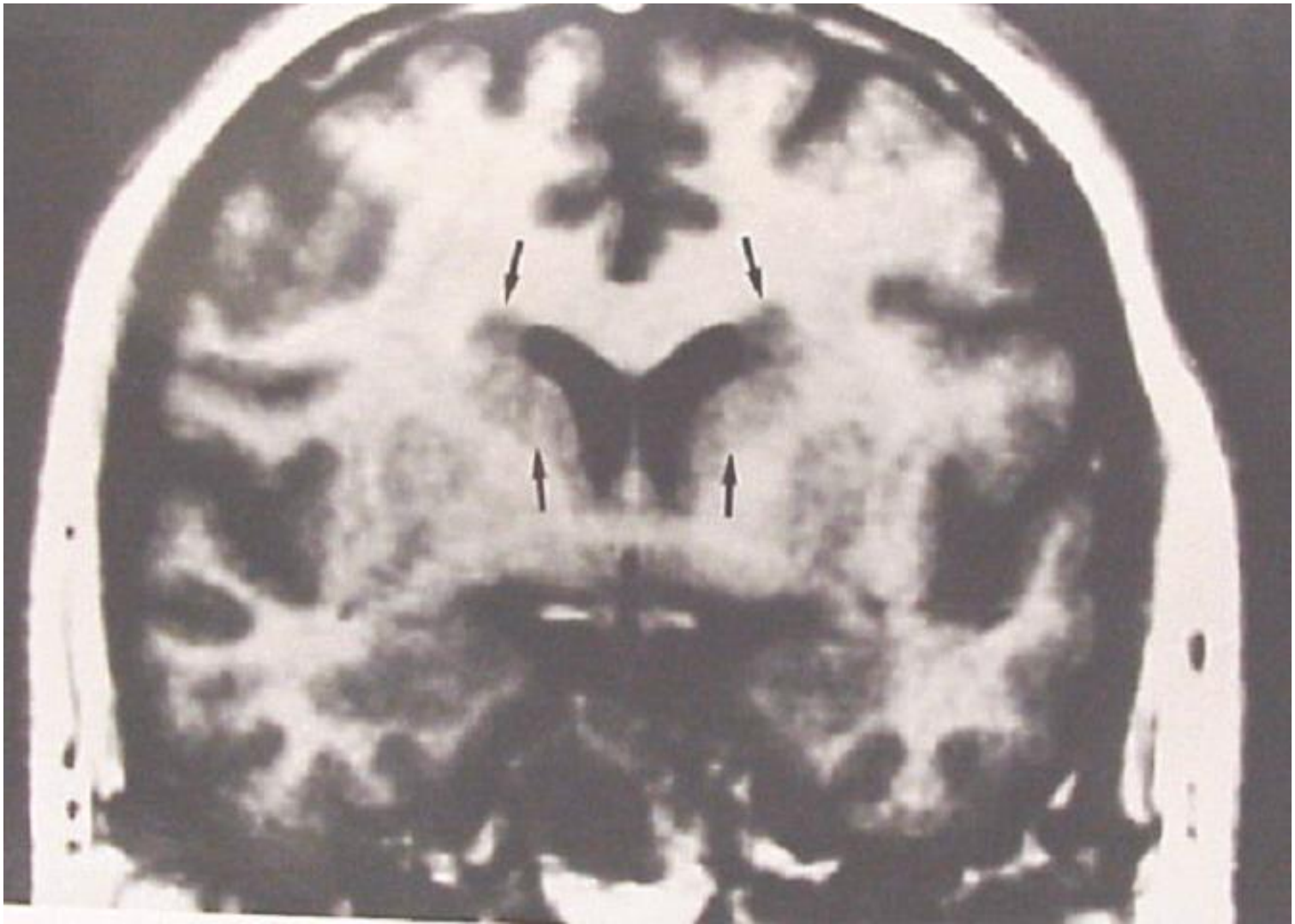
RADIATION-INDUCED MALFORMATIONS

- Malformations have a **threshold of 100-200 mGy or higher** and are typically associated with central nervous system problems
- Fetal doses of 100 mGy are not reached even with 3 pelvic CT scans or 20 conventional diagnostic x-ray examinations
- These levels can be reached with fluoroscopically guided interventional procedures of the pelvis and with radiotherapy

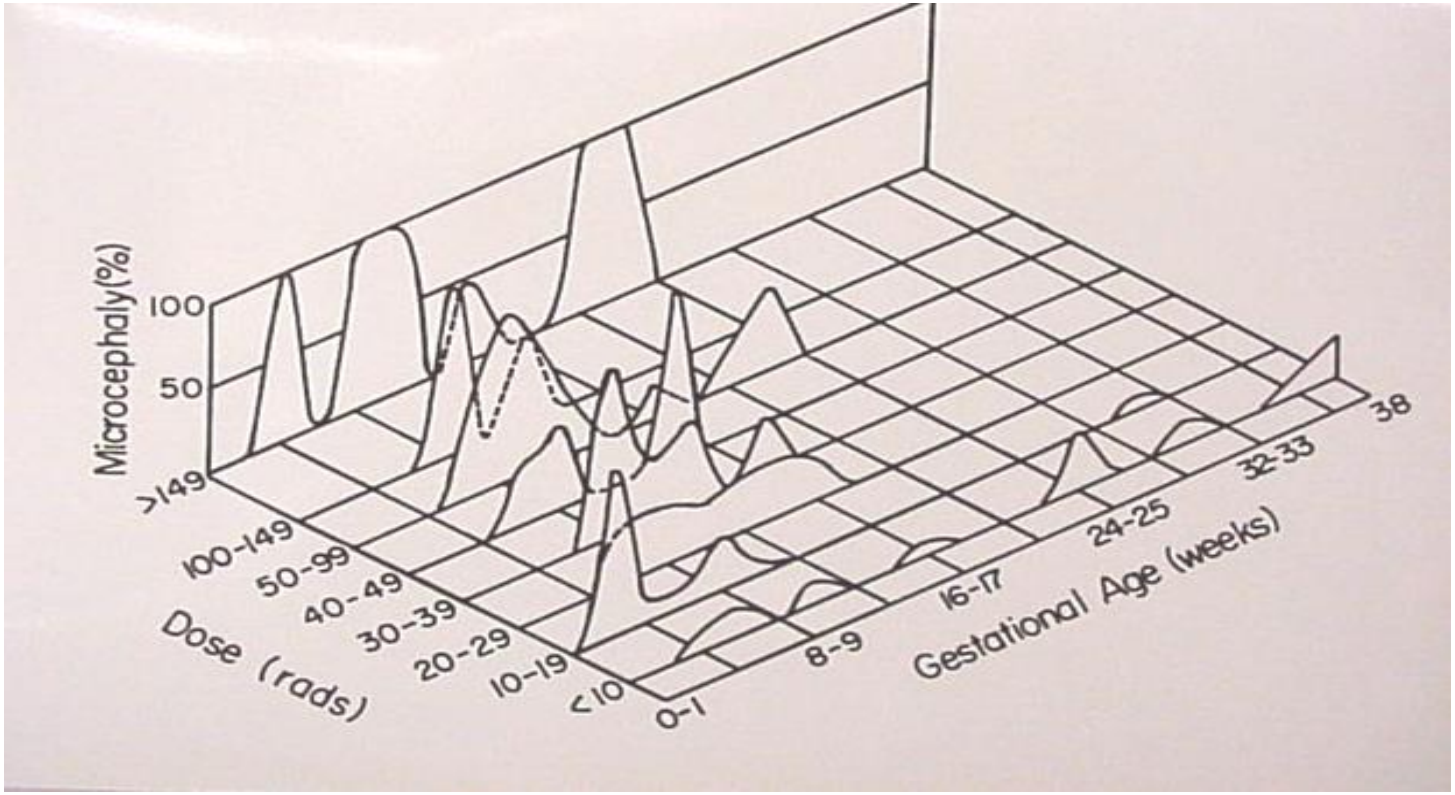
CENTRAL NERVOUS SYSTEM EFFECTS

- 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 and microcephaly, particularly during 8-15 weeks and to a lesser extent at 16-25 weeks

Heterotopic gray matter (arrows) near the ventricles in a mentally retarded individual occurring as a result of high dose in-utero radiation exposure



Frequency of microcephaly as a function of dose and gestational age occurring as a result of in-utero exposure in atomic bomb survivors (Miller 1976)



•Frequency of microcephaly increases with dose at early gestation period

LEUKAEMIA AND CANCER

- Radiation has been shown to increase the risk for leukaemia and many types of cancer in adults and children

- 0-15 yrs age spontaneous incidence 2-3/1000 (without radiation)

- Throughout most of pregnancy, the embryo/fetus is assumed to be at about the same risk for carcinogenic effects as children

LEUKAEMIA AND CANCER

- Raised rate of leukemia is found in atomic bomb survivor (Hiroshima) who were irradiated in-utero for doses >> obstetric X-ray dose

- Relative risk 1.4 (1.0 with back ground) indicating 40% increases over the back ground radiation due to prenatal X-ray, appears to be an outer estimate

- For an individual exposed in utero to 10 mGy, the absolute risk of cancer at ages 0-15 is about 1 excess cancer death per 1,700

Probability of bearing healthy children as a function of radiation dose

Dose to conceptus (mGy) above natural background	Probability of no malformation	Probability of no cancer (0-19 years)
0	**97**	**99.7**
1	**97**	**99.7**
5	**97**	**99.7**
10	**97**	**99.6**
50	**97**	**99.4**
100	**97**	**99.1**
>100	**Possible**	**Higher**

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

PRE-CONCEPTION IRRADIATION

- New studies of survivors of childhood cancer treated with radiotherapy have not shown genetic effects in their offspring

- In the absence of human data, as a precautionary measure, females receiving ovarian dose in excess of 500mGy, are recommended to delay the pregnancy by at least 2 months

INFORMED CONSENT AND UNDERTAKING

- The pregnant patient or worker has a right to know the magnitude & type of potential radiation effects, might result from in-utero exposure.
- Communication should be related to the level of risk, more detailed explanation is necessary where the exposure likely to exceed 1mGy.
- The consent must be documented & and undertaking is taken from the patient on this behalf

EXPOSURE OF PREGNANT PATIENTS

- In some circumstances, if the exposure is inappropriate, the unborn child may be at increased risk of harm to health
- Prenatal doses from most properly performed diagnostic procedures present no measurably increased risk of prenatal death, malformation, or mental impairment
- Higher doses such as those from therapeutic procedures can result in significant fetal harm

MEDICAL RADIATION PROCEDURES

- All medical practices (occupational and patient-related) should be justified (more benefit than risk)
- Medical exposures should be justified for each patient before they are performed
- After it is decided to do a medical radiation procedure, the fetal radiation dose should be reduced while still obtaining the required diagnostic information

EVALUATION OF POTENTIALLY PREGNANT PATIENTS

In females of child-bearing age, an attempt should be made to determine who is, or could be, pregnant, prior to radiation exposure

NOTICES

- A missed period in a regularly menstruating woman should be considered due to pregnancy, until proven otherwise

- Notices regarding pregnancy should be posted in patient waiting areas, such as
    - If it is possible that you might be pregnant, notify the physician or other staff before your x-ray examination, treatment, or before being injected with a radioactive material

DIAGNOSTIC RADIOLOGY

- If fetus receives indirect dose of <50mGy no ill effect observed
- When the fetus is in direct primary beam, the technique used must be tailored to reduce fetal dose
- Whenever a woman of child bearing age comes for radiological examination, it is prudent to consider her pregnant to start with & further steps to the taken to verify the same (Yes/No)
- For pelvic examination, if the ULTRA SOUND examination can give the designed diagnosis, X-ray examination to be avoided

DIAGNOSTIC RADIOLOGY

- As fetal doses are usually well below **50 mGy** in diagnostic radiology, pregnancy tests are not usually done.

- In cases where a high-dose fluoroscopy procedure of the abdomen or pelvis (e.g embolisation) is contemplated, depending on the patient reliability and history, the physician need to insist for a pregnancy test

MINIMIZING FETAL DOSE IN DIAGNOSTIC RADIOLOGY

To minimize direct fetal dose

- Collimate the beam to area of interest
- Increase kVp
- Remove anti-scatter Grid
- Minimize the number of radiographs

•Double contrast enema's deliver larger doses to fetal approaches 50mGy when time of exposure exceeds 7 min.

COMPUTED TOMOGRAPHY

- For CT scans with uterus in the field of view fetal doses are in the range 10-40mGy.

- The dose can be minimized by limiting the scanning area to area of interest.

  Eg: Upto kidney level rather than to scan the entire abdomen & pelvis.

TERMINATION OF PREGNANCY IS NOT JUSTIFIED IN DIAGNOSIS RADIOLOGY, AS THE FETAL DOSES RARELY EXCEED 100MGY

Fetal Dose Estimation in Diagnostic radiology

- Fetal dose estimation may be necessary only when the fetus is in primary beam
- Fluoroscopy is subject to more uncertainty compared to CT/ Radiograph
- Determination of the absorbed dose to the embryo or fetus from plain film abdominal or pelvic radiography examinations is difficult, but usually the dose can be estimated within a 50 percent error

APPROXIMATE FETAL DOSES FROM CONVENTIONAL X-RAY EXAMINATIONS

Data from the UK, 1998		
Examination	Dose Mean (mGy)	Dose Maximum (mGy)
Abdomen	1.4	4.2
Chest	<0.01	<0.01
Intravenous uro-gram; lumbar spine	1.7	10
Pelvis	1.1	4
Skull; thoracic spine	<0.01	<0.01

APPROXIMATE FETAL DOSES FROM FLUOROSCOPIC AND COMPUTED TOMOGRAPHY PROCEDURES

Data from the UK, 1998		
Examination	Dose Mean (mGy)	Dose 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

FETAL DOSE FROM SKIN DOSE

Approximate fetal doses from common diagnostic procedures in UK		
Conventional X-ray examinations		
Examination	Mean skin dose (mGy)	Maximum (mGY)
Abdomen	1.4	4.2
Chest	<0.01	<0.01
Intravenous Urogram	1.7	10
Lumbar spine	1.7	10
Pelvis	1.1	4
Skull	<0.01	<0.01
Thoracic spine	<0.01	<0.01
Fluroscopic examinations		
Barium mean (UGI)	1.1	5.8
Barium enema	6.8	24
Computed Tomography		
Abdomen	8.0	49
Chest	0.06	0.96
Head	<0.05	<0.05
Lumbar spine	2.4	8.6
Pelvis	25	79

- Fetal dose can be estimated from skin if the technical factors concerning the beam energy and PDD are known

NUCLEAR MEDICINE AND PREGNANT PATIENTS

- Most diagnostic procedures are done with short-lived radionuclides (such as technetium-99^{m}) that do not cause large fetal doses
- Often, fetal dose can be reduced through maternal hydration and encouraging voiding of urine
- Some radionuclides do cross the placenta and can pose fetal risks (such as iodine-131)

NUCLEAR MEDICINE AND PREGNANT PATIENT

- The fetal thyroid accumulates iodine after about 10 weeks gestational age
- High fetal thyroid doses from radioiodine can result in permanent hypothyroidism
- If pregnancy is discovered within 12 h of radio-iodine administration, prompt oral administration of stable potassium iodine (60-130 mg) to the mother can reduce fetal thyroid dose. This may need to be repeated several times

APPROXIMATE WHOLE BODY FETAL DOSE (mGy) FROM COMMON NUCLEAR MEDICINE PROCEDURES

Procedure	Activity (MBq)	Early pregnancy	9 months
^{99m}Tc			
Bone scan	750	4.7	1.8
Lung scan	240	0.9	0.9
Liver colloid scan	300	0.6	1.1
Thyroid scan	400	4.4	3.7
Renal DTPA	300	9.0	3.5
Red blood cell	930	6.0	2.5
I-123 thyroid uptake	30	0.6	0.3
I-131 thyroid uptake	0.55	0.04	0.15

NUCLEAR MEDICINE AND BREAST FEEDING

A number of radionuclides are excreted in breast milk. It is recommended that breast feeding is suspended as follows:

- Completely after ^{131}I therapy
- 3 weeks after ^{131}I, ^{125}I, ^{67}Ga, ^{22}Na, and ^{201}Tl
- 12 h after ^{131}I hippurate and all ^{99m}Tc compounds
- 4 h after ^{99m}Tc red cells, DTPA, and phosphonates

FETAL DOSE OF NUCLEAR MEDICINE PATIENT

- Careful estimation of fetal doses is not usually necessary after diagnostic studies involving 99mTc
- If the pregnancy is discovered within several hours of the radioiodine administration and the fetus is old enough to have a functional thyroid, one should consider giving a thyroid-blocking agent potassium iodide
- If the pregnancy is discovered later, the placental transfer of radioiodine can result in very high absorbed doses to the fetal thyroid that may cause significant fetal thyroid damage
- Since the fetal whole body dose is usually below 100 mGy, there is no reason to terminate the pregnancy

RISK ASSOCIATED WITH THE CONCENTRATION OF RADIOACTIVE IODINE IN FETUS

- The radioiodine easily concentrates in the thyroid of the fetus & produce Hypothyroidism

- To avoid radioactive iodine therapy to the pregnant thyroid patient, where-ever feasible & postpone till the child birth

- If I^{131} therapy is essential for saving the life of the pregnant patients, risk to the fetus is estimated & conveyed to the patient relatives & the options include termination of pregnancy

- The absorbed dose to the fetus (whole body) from I^{131} therapy is in the range of 50-100μGy/MBq of administered activity

DOSE TO PREGNANT FAMILY MEMBERS OF NUCLEAR MEDICINE PATIENT

- Some nuclear medicine patients have pregnant family members at home and enquire about the dose they might give to such a person.

- Usually the total dose to complete decay from the radionuclide in the patient is calculated at 0.5 or 1.0 meters.

- For most diagnostic nuclear medicine procedures, the total decay dose at 0.5 meter from the patient ranges from 0.02-0.25 mGy and at 1 meter from the patient the dose is 0.05-0.10 mGy

- No significant risk to pregnant family members

RADIOTHERAPY

- In pregnant patients, cancers that are remote from the pelvis usually can be treated with radiotherapy.

- Cancers in the pelvis cannot be adequately treated by radiotherapy without severe or lethal consequences for the fetus.

NON-PELVIC RADIOTHERAPY FIELDS

- Can be treated with careful estimation of fetal dose shielding of pelvic area must be considered (shielding can reduce the dose to fetus by 50%).

- Treatment with other modalities (surgery & chemotherapy) are considered & RT can be delayed till child birth wherever feasible.

FETAL DOSE DURING RADIOTHERAPY

- Peripheral doses from teletherapy machine (Co-60), due to Head leakage contributes to fetal dose, so that machine specific measurements should be made.
- In-vivo measurements are recommended for better accurately than calculated estimation of doses.
- Avoid localization exposures (Film/EPID) through the fetus
- The field size, gantry angle, radiation quality, field trimmers on edge nearer to fetus are optimized to minimize fetal dose.
- Fetal dose when brain is treated with RT ~ 30mGy, AP/PA mantle fields, for the chest of Hodgkin's disease ~ 400-500mGy.

BRACHYTHERAPY

Permanent implant prostate patients & pregnant family members

- The isotopes used for permanent implants (I-125, Au-198 & pd-103) have short range emission of a few ten's of keV
- They pose no danger to pregnant family members

When a woman treated with radiotherapy can become pregnant

- Probably after a few years, to make sure that, she is disease free & doesn't require radiotherapy.

DOCUMENTATION REQUIRED

- Complete details of Nuclear medicine procedures & RT treatment procedures must be documented & maintained.

- Till the woman is delivered & also the born-child grows into a healthy adult.

- All radiation administering departments (RD/NM/RT) must display prominently at the entrance, the following notice

- **“IF IT IS POSSIBLE THAT YOU MIGHT BE PREGNANT, NOTIFY THE PHYSICIAN OR TECHNICIAN BEFORE RECEIVING ANY RADIOACTIVE MATERIAL “**

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

TERMINATION OF PREGNANCY

- High fetal doses (100-1000 mGy) during late pregnancy are not likely to result in malformations or birth defects since all the organs have been formed
- A fetal dose of 100 mGy has a small individual risk of radiation-induced cancer. There is over a 99% chance that the exposed fetus will NOT develop childhood cancer or leukaemia

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 500 mGy, there can be significant fetal damage, the magnitude and type of which is a function of dose and stage of pregnancy
- At fetal doses between 100 and 500 mGy, decisions should be based upon individual circumstances

RISKS IN A PREGNANT POPULATION *NOT* EXPOSED TO RADIATION

Risks:

- Spontaneous abortion	> 15%
- Incidence of genetic abnormalities	4-10%
- Intrauterine growth retardation	4%
- Incidence of major malformation	2-4%

SUMMARY

- Medical professionals using radiation should be familiar with the effects of radiation on the embryo and fetus.

- At doses in excess of 100-200 mGy, risks related to nervous system abnormalities, malformations, growth retardation, and fetal death should be considered.

- The magnitude of risks differs quite considerably between the various stages of pregnancy

SUMMARY

- All medical practices (both occupational and patient-related) involving radiation exposure should be justified (result in more benefit than risk)

- Prior to radiation exposure, female patients in the childbearing age group should be evaluated and an attempt made to determine who is or could be pregnant

SUMMARY

- Medical radiation applications should be optimized, If possible, for pregnant patients, the medical procedures should be tailored to reduce fetal dose

- After medical procedures involving high doses of radiation have been performed on pregnant patients, fetal dose and potential fetal risk should be estimated

- 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 course of pregnancy

SUMMARY

- Radiation research involving pregnant patients should be discouraged

- **Termination of pregnancy *at fetal doses of less than 100 mGy is not justified based upon radiation risk***.

- At higher fetal doses, informed decisions should be made based upon individual circumstances

WEB SITES FOR ADDITIONAL INFORMATION ON RADIATION SOURCES AND EFFECTS

European Commission (radiological protection pages):
europa.eu.int/comm/environment/radprot

International Atomic Energy Agency:
www.iaea.org

International Commission on Radiological Protection:
www.icrp.org

United Nations Scientific Committee on the Effects of Atomic Radiation: **www.unscear.org**

World Health Organization:
www.who.int

Thank You