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Foetal Dose and Pregnancy Policy

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Foetal dose and pregnancy policy

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- Facts about foetal irradiation
- General foetal doses
- Hospital policy to reduce foetal dose
- Estimation of foetal dose
- Radiation safety principles

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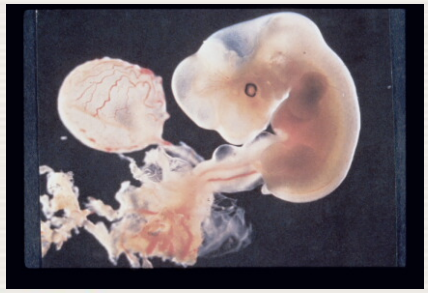
Fetal Radiation Risk

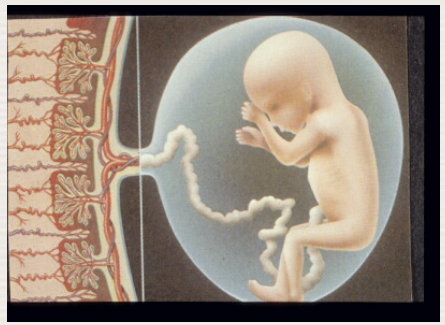
- There are radiation-related risks throughout pregnancy which are related to the stage of pregnancy and absorbed dose
- Radiation risks are most significant during organogenesis and in the early fetal period somewhat less in the 2nd trimester and least in the third trimester

Most risk



Less

Least



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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 cells 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

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Leukemia and Cancer

- Radiation has been shown to increase the risk for leukemia and many types of cancer in adults and children
- Throughout most of pregnancy, the embryo/fetus is assumed to be at about the same risk for carcinogenic effects as children

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Leukemia and Cancer

- The relative risk may be as high as 1.4 (40% increase over normal incidence) due to a fetal dose of 10 mGy
- Individual risk, however, is small with the risk of cancer at ages 0-15 being about 1 excess cancer death per 1,700 children exposed “in utero” to 10 mGy

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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, see text	higher

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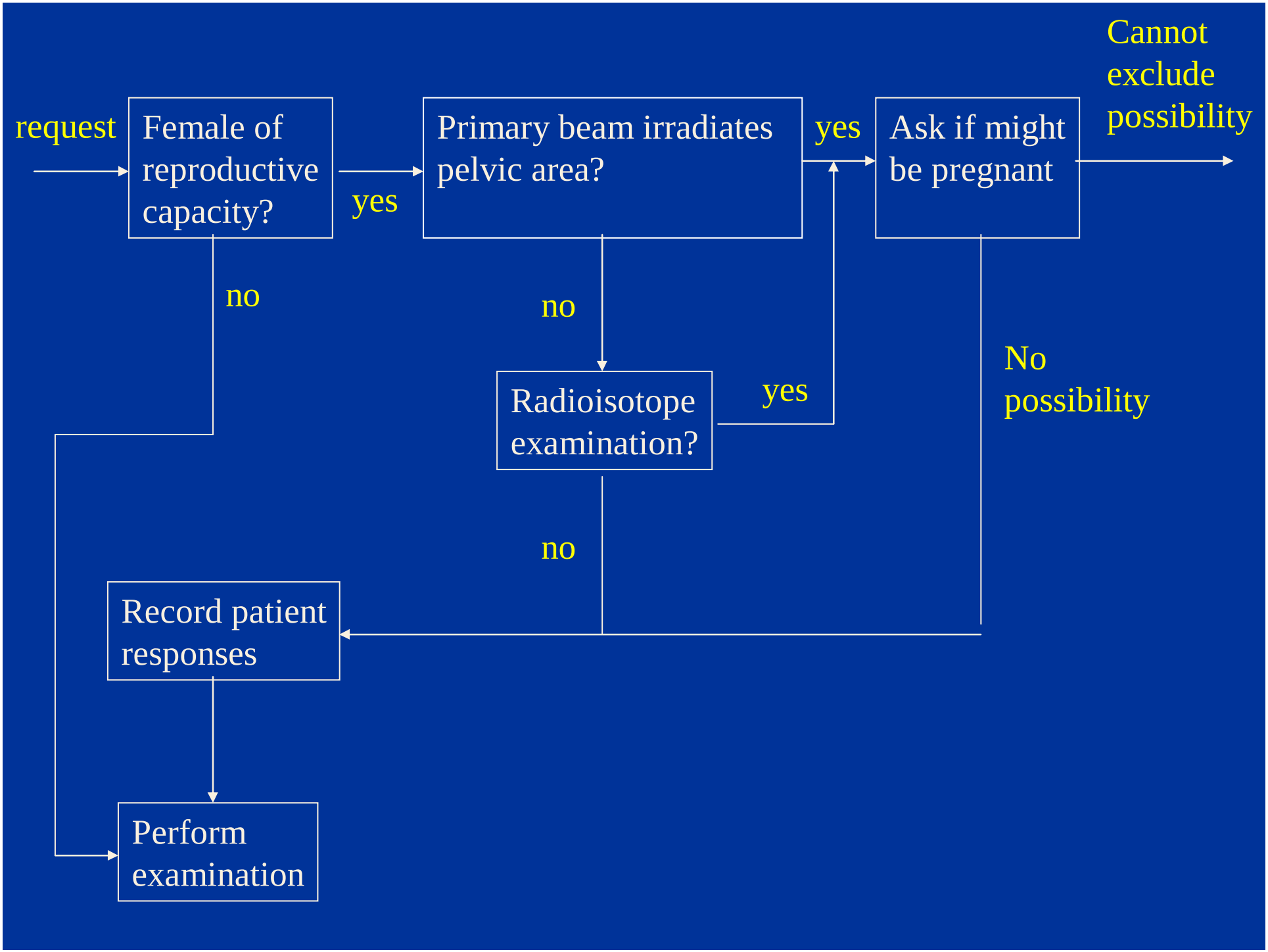
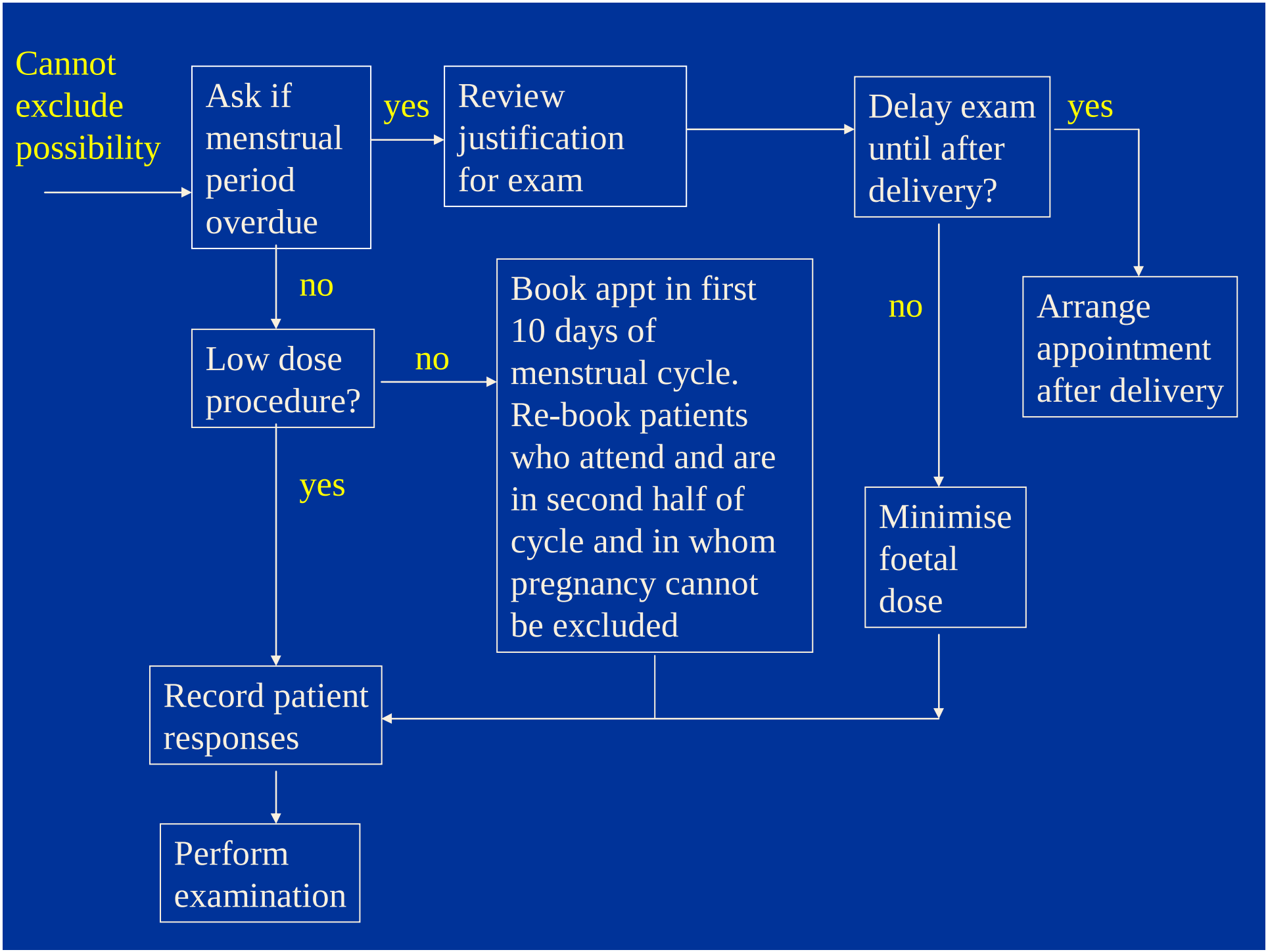
Patient definitely or probably pregnant

- If pregnancy is established or likely:
  Review justification
  - Can examination be deferred until after delivery
  - Does delaying examination involve greater risk
  - If procedure is to undertaken, the fetal dose should be kept to the minimum consistent with the diagnostic purpose(s)


request
Female of reproductive capacity?
yes
Primary beam irradiates pelvic area?
yes
Ask if might be pregnant
Cannot exclude possibility
no
no
Radioisotope examination?
yes
No possibility
no
Record patient responses
Perform examination


Cannot exclude possibility
Ask if menstrual period overdue
yes
Review justification for exam
Delay exam until after delivery?
yes
Arrange appointment after delivery
no
Low dose procedure?
no
Book appt in first 10 days of menstrual cycle. Re-book patients who attend and are in second half of cycle and in whom pregnancy cannot be excluded
no
Minimise foetal dose
yes
Record patient responses
Perform examination

Foetal doses following common diagnostic x-ray examinations (1)

Examination	Mean foetal dose (mGy)	Max foetal dose (mGy)
Conventional x-ray		
Abdomen	1.4	4.2
Ba enema	6.8	24
Ba meal	1.1	5.8
Chest	<0.01	< 0.01
IVU	1.7	10
Lumber spine	1.7	10
Pelvis	1.1	4
Skull	< 0.01	< 0.01
Thoracic spine	< 0.01	< 0.01

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from"Advice on exposure to ionising radiation during pregnancy, NRPB, CoR, RCR. 1998

Foetal doses following common diagnostic x-ray examinations (2)

Examination	Mean foetal dose (mGy)	Max foetal dose (mGy)
CT		
Abdomen	8	49
Chest	0.06	0.96
Head	< 0.005	< 0.005
Lumbar spine	2.4	8.6
Pelvis	25	79
Pelvimetry	0.2	0.4

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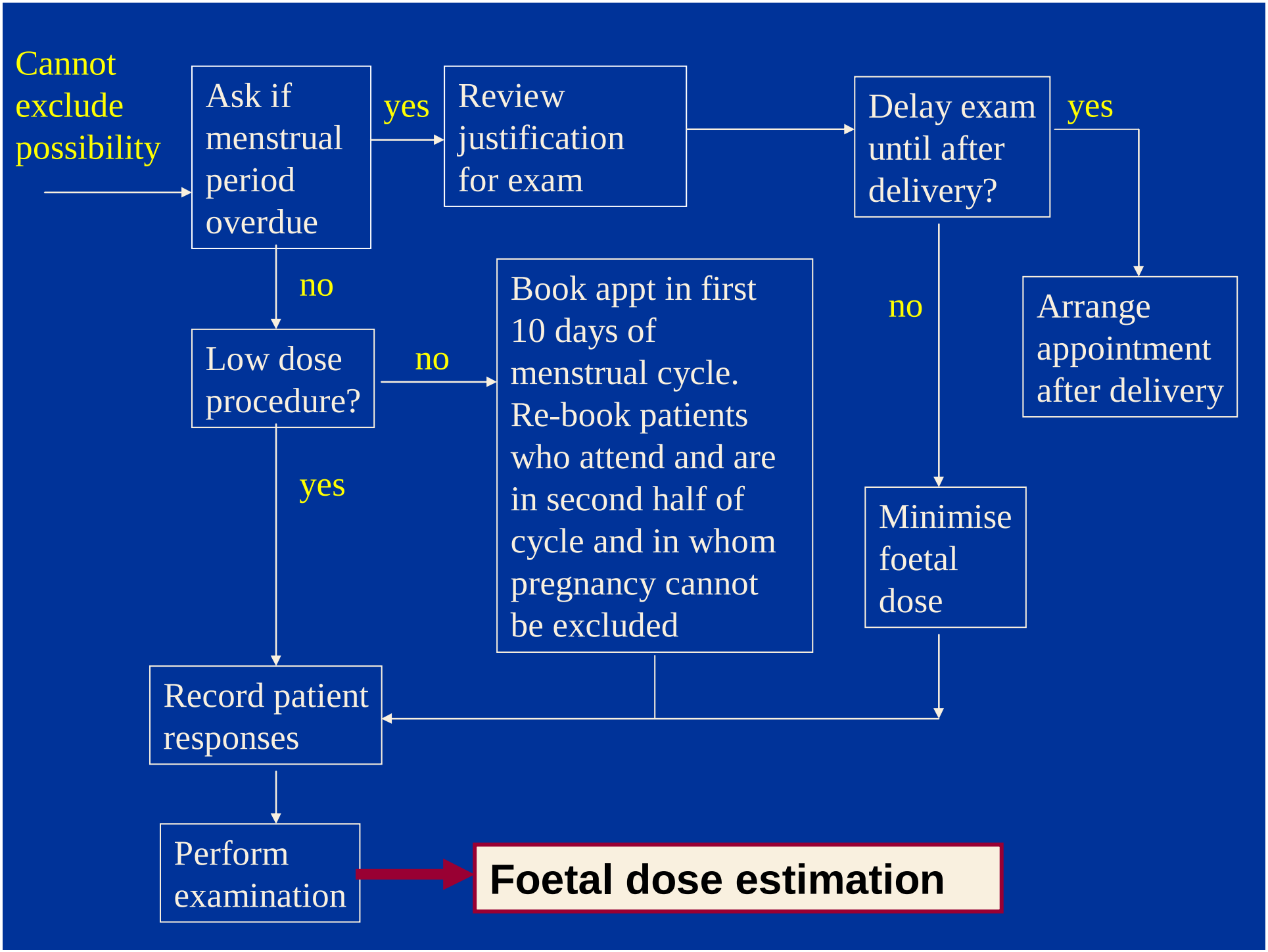
from"Advice on exposure to ionising radiation during pregnancy, NRPB, CoR, RCR. 1998


Cannot exclude possibility
Ask if menstrual period overdue
yes
Review justification for exam
Delay exam until after delivery?
yes
Arrange appointment after delivery
no
Low dose procedure?
no
Book appt in first 10 days of menstrual cycle. Re-book patients who attend and are in second half of cycle and in whom pregnancy cannot be excluded
no
Minimise foetal dose
yes
Record patient responses
Perform examination
Foetal dose estimation

Foetal dose determination

- **Patient monitoring**
  - TLD are commonly used to monitor the patient during an examination without affecting the resultant image**.**
- **Simulation of the examination** using a suitable anthropomorphic phantom loaded with TLD at a position corresponding to the uterus. This approach requires a knowledge of the technique factors and procedures used. It is particularly useful for estimating the total doses for fluoroscopy examinations where it is difficult to accurately evaluate the total dose.

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Critical steps if there is advanced warning of the foetal exposure

- Ensure that the procedure is justified
- Consider monitoring the mother using a TLD positioned to measure the entrance dose if foetus is in the primary beam
- Ensure all details of the procedure are recorded
  - Radiographic: number of exposures, for each – kVp, mAs, filtration, distance to patient surface, field size at detector, position of field centre on the patient
  - Fluoroscopy: total exposure time, as above
  - Patient: size, weight, pregnancy stage
- Try to view any films to determine if the foetus was actually in the primary beam
- Determine the surface dose from TLD or from use of the collected data. Use tube output information from QA records or take measurements from the unit used after the procedure.
- Determine the distance from the surface to the foetus. Use depth dose curves to determine the maximum dose to the foetus. It may be possible to use software to assist.
- Check the calculation by another method to ensure the estimated dose is reasonable.
- Write a report of the incident and inform the head of department and radiation protection officer.

Critical steps if there is no advanced warning of the foetal exposure

- Determine all details of the procedure by interviewing the radiographer and or radiologist involved. Try to view any films to determine if the foetus was actually in the primary beam
  - Radiographic: number of exposures, for each – kVp, mAs, filtration, distance to patient surface, field size at detector, position of field centre on the patient
  - Fluoroscopy: total exposure time, as above
  - Patient: size, weight, pregnancy stage
- Determine the surface dose from use of the collected data. Use tube output information from QA records or take measurements from the unit used after the procedure.
- Determine the distance from the surface to the foetus. Use depth dose curves to determine the maximum dose to the foetus. It may be possible to use software to assist.
- Check the calculation by another method to ensure the estimated dose is reasonable.
- Write a report of the incident and inform the head of department and radiation protection officer.

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Documentation

- Data collection forms are very useful to ensure that all data is collected.
- Separate forms may be needed for plain X ray and CT
- The result form should be carefully written
- Ideally the form should include information comparing the estimated dose to background radiation levels. An estimate of risk is also useful as well as a comparison of the radiation risk to risks from other sources.

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Software that will calculate foetal dose

Calculate

2. Scan Range

1. Age Group: Adult — Patient Sex: ○ male ● female — Get Values

Scan Range Data and Conversion Factors				
Scan Range z from z-	to z+	L [cm]	Σ f(z) [mSv/mGy*cm]	Σ f(uterus,z) [mSv/mGy*cm]
75	84	9	0.022	0.000

3. Scanner Model — Manufacturer: Toshiba — Scanner: Aquilion-Series

Scanner Data: Head / Neck				
$_nCTDI_w$ [mGy/mAs]	$P_{B,H}$	k_{CT}	k_{OB}	U_{ref} [kV]
0.189	0.67	0.8	2.29	120

4. Change mode — ☐ Body mode for head/neck region

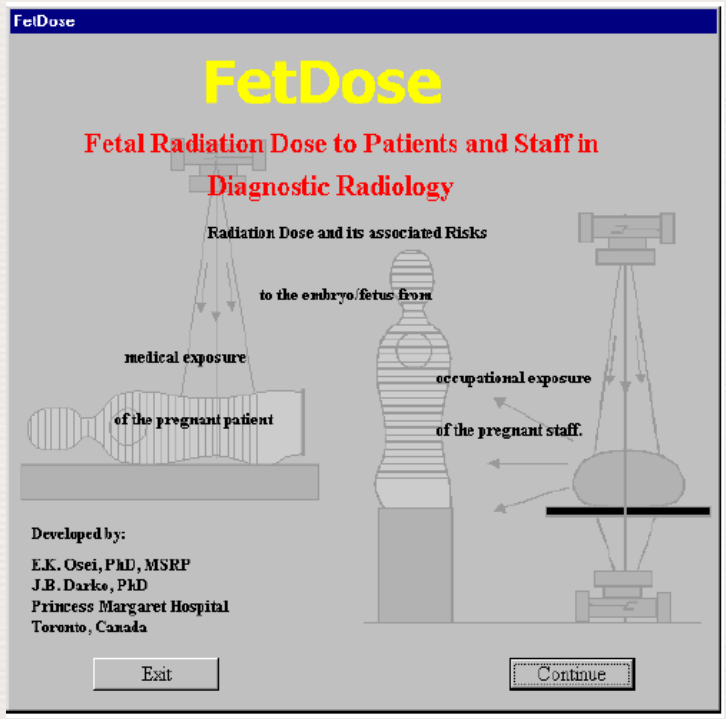
5. Scan Parameters

Please Enter Actual Settings:								
U [kV]	I [mA]	t [s]	I * t [mAs]	Q [mAs]	N * h [mm]	TF [mm]	p	Ser.
135	250	1.00	250	0	2.0	1.5	0.8	1.5

6. Results

Dose Values per Scan or per Series*				
$CTDI_{w,eff}$ [mGy]	$CTDI_w$ [mGy]	DLP_w* [mGy*cm]	E* [mSv]	D_{uterus}* [mSv]
193.3	145.0	1740	5.1	0.0

Dose Values per Examination		
DLP_w [mGy*cm]	E [mSv]	D_{Uterus} [mSv]
2610	7.6	0.0



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Selected text in a document on foetal dose

Opinion

The maximal dose, thought to be most relevant for this case, appears to be at maximum 1.2 mGy and more likely to be about 0.6 mGy.

The stochastic risk to the unborn child to develop a fatal cancer in childhood should be considered. Using the rate of about 15%/Sv[3,4], the calculated excess risk is less than 0.01%. This should be compared to the risks in a pregnant population *not* exposed to radiation[5] of more than 10% excluding the risk of spontaneous abortion.

References

[1]E. K. Osie, J. B. Darko, F. K *et al.*, "Software for the estimation of foetal radiation dose to patients and staff in diagnostic radiology," J. Radiol. Prot. 23, 183-194 (2003).

[2]H. T. Winer-Muram, J. M. Boone, H. L. Brown *et al.*, "Pulmonary Embolism in Pregnant Patients: Fetal Radiation Dose with Helical CT," Radiol. 148 (2), 487-492 (2002).

[3]EC, "Radiation Protection 100: Guidance for protection of unborn children and infants irradiated due to parental medical exposures," 1998.

[4]ICRP, Report ICRP Publication 60, "1990 Recommendations of the International Commission on Radiological Protection," 1991.

[5]ICRP, Report 87, "Pregnancy and Medical Radiation," 2000.

High dose procedures

- Defined as procedures resulting in fetal doses of tens of mGy
  - Abdominal and pelvic CT, Ba studies
- Dose estimations, typical doses in each department
- Apply 10 day rule
- If inadvertent exposure - the risk from radiation may be smaller than risks with invasive fetal diagnostic procedures. Further, termination may not be justified.

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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

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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 natural background radiation.

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Research on Pregnant Patients

- Radiation research involving pregnant patients should be discouraged

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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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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

Risks in a pregnant population not exposed to medical radiation

Risks:

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

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Summary

- Thousands of pregnant women are exposed to ionizing radiation each year
- An appropriate risk evaluation should be made in order to avoid probably unnecessary termination of pregnancies
- The justification principle of radiation protection should always be based upon individual circumstances.

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Thank you for your attention

In *utero* doses following common diagnostic procedures (below 1 mSv); taken from NRPB surveys of diagnostic radiology and nuclear medicine (NRP98)

Examination	Fetal equivalent dose (mSv)	
	Mean	Maximum
Conventional X-rays		
Chest	**< 0.01**	**< 0.01**
Skull	**< 0.01**	**< 0.01**
Thoracic spine	**< 0.01**	**< 0.01**
Computed tomography		
Chest	**0.06**	**0.96**
Head	**< 0.005**	**< 0.005**
Pelvimetry	**0.2**	**0.4**
Nuclear medicine		
^{99m}Tc lung perfusion (MAA)	**0.2**	**0.4**
^{99m}Tc lung ventilation (aerosol)	**0.3**	**1.2**
^{51}Cr glomerular filtration (EDTA)	**<0.01**	**0.01**

In *utero* doses following common diagnostic procedures (greater than 1 mSv); taken from NRPB surveys of diagnostic radiology and nuclear medicine (NRP98)

Examination	Fetal equivalent dose (mSv)	
	Mean	Maximum
Conventional X-rays		
Barium enema	6.8	24
Intravenous urography	1.7	10
Lumbar spine	1.7	10
Computed tomography		
Abdomen	8	49
Pelvis	25	79
Nuclear medicine		
^{75} Seleno-cholesterol	---	14
^{67} Ga tumorous and abscesses	---	12
^{131}I thyroid metastases	---	22

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*Gestational Sac Location, and Fetal Absorbed Dose**

	Bladder Partially Filled	Bladder Full
***Gestational sac location:**		
Distance from anterior surface (cm)	3.8	6.7
Distance from posterior surface (cm)	16.2	13.3
***Normalized fetal absorbed dose (rad):**		
AP projection	0.77	0.45
PA projection	0.048	0.087

* *Ragozzino et al 1981*

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***Fetal location at maximum and minimum bladder volume determined by sonography.*

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