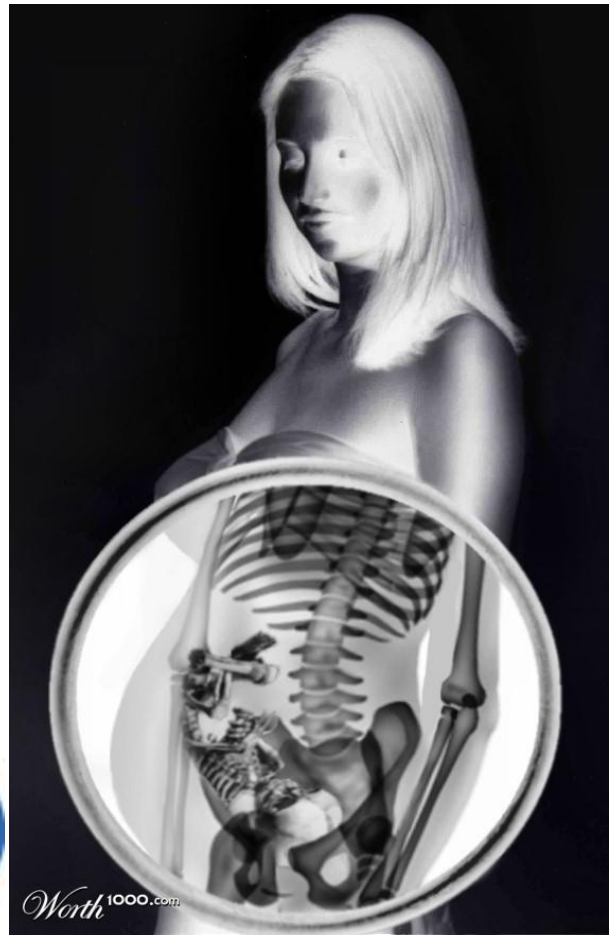
Non-Obstetric Medical Imaging in Pregnancy and Lactation

Dr. Patrik AERTS

OLV-hospital
Department of Radiology
Moorselbaan 164
B 9300 AALST
BELGIUM



- Evidence based guidelines
  - Radioprotection
  - iodinated contrast agents
  - Gadolinium
- Compare with other modalities
- RX, US, CT, MR

- Radiation dose: GRAY (Gy)= 1 Joule/kg: amount of absorbed energy
- Effective dose (E): idea of the biologic effects on tissue
  - Sievert (Sv) of milliSievert (mSv): radiation dose (Gy) X Relative biol eff (rbe)

Radiation exposure in Belgium

- Mean background equivalent radioactivity: 2,4 mSv
- Medical:
  - 2,15 mSv/year in 2005
  - 2,42 mSv/year in 2008
  - 2,3 mSv/year in 2010
  - Today: +/- 1,5 mSv/year (1,1 – 2,3 mSv)

Medical radiation mSv

Extremity radiogr: 0,05
Chest radiogr: 0,1-0,3
Intraoral radiograp: 0,005
Cerv spine radiogr: 0,2 - 0,3
Dorsal spine radiogr: 0,7
Lumbar spine radiogr: 1,5 - 3
Abdominal radiogr: 1
IVP: 2,5

CT extremity < 1
CT chest 4-18
Cardiac CT: 4-40
CT C-spine: 3-4
CT brain: 0,9-4
CT L-spine: 1.5-10
CT abdomen: 4-15

mammogram: 0,4
PET scan: 7 – 10

coronary angiography: 5 – 8
intervent proced: 5-70

Medical radiation mGy for fetus: very low for most exams!!!

- C-spine radiogr: 0,001
- Extermity radiogr: 0,001
- Chest radiogr: 0,002
- Dorsal spine radiogr: 0,003
- Abd and L-spine rad: 1

Radiographics 2015;35:1751-1765

Table 1: Radiation Doses Associated with Common Radiologic Examinations

Modality	Fetal Dose (mGy)	Maternal Dose (mSv)	Breast Dose (mGy)
CT			
Head or neck	1.0–10	0.9–4.0	…
Pulmonary angiography	0.01–0.66	2.7–40	8–70
Abdominal	1.3–35	3.5–25	…
Pelvic	10–50	3.3–10	…
Abdomen and pelvis	13–25	3–45	…
Aortic angiography of chest, abdomen, and pelvis, with or without contrast agent	6.7–56	4–68	16–130
Coronary artery angiography	0.1–3	7–39	10–90
Nonenhanced CT of abdomen and pelvis to evaluate for nephrolithiasis	10–11	3–10	…
Nuclear medicine			
Low-dose perfusion scintigraphy	0.1–0.5	0.6–1.0	0.1–0.3
V/Q scintigraphy	0.1–0.8	1.2–2.8	0.2–0.7
Technetium 99 (^{99m}Tc) bone scintigraphy	10–50	6.7	…
Fluorine 18 (^{18}F)–FDG PET/CT whole-body scintigraphy	9.4–21.9	13.5–31.9	14
^{18}F-FDG PET myocardial viability	6.8–8.1	7	…
Myocardial perfusion with ^{99m}Tc-sestamibi	17	11.4–14.8	…
Myocardial perfusion with ^{99m}Tc-tetrofosmin	8.45	9.3–11.6	…
Radiography			
Mammography, two views	0.001–0.01	0.1–0.7	3
Chest radiography, two views	0.0005–0.01	0.06–0.29	<0.04
Extremity and cervical spine radiography	<0.001	0.03–0.22	…
Abdominal radiography	0.1–0.3	0.01–1.1	…
Lumbar spine radiography	1.0–10	0.5–1.8	…
Other			
Intravenous pyelography	5–10	0.7–3.7	…
Double-contrast barium enema	1.0–20	2.0–18.0	…
Small bowel examination	7	3.0–7.8	…

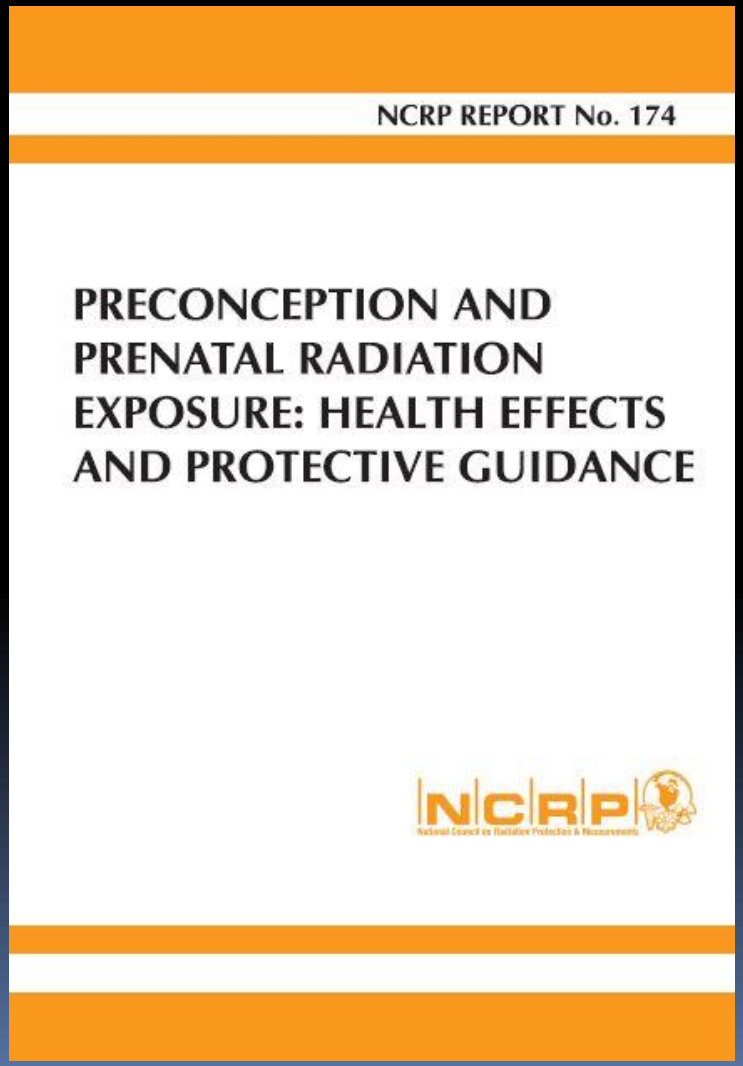
Source.—References 6–8,10,11,16–21.
Note.—Estimated dose varies according to protocol, radiotracer type and dosage, method of dose calculation, and patient-dependent factors (eg, weight or body habitus and percentage of glandular breast tissue). FDG = fluorodeoxyglucose, PET = positron emission tomography, V/Q = ventilation-perfusion.

… relativity… fetal radiation

- Mean background radiation in Belgium is 2,4 mSv per year.
- Fetal radiation 0.5-1 mSv per 9 months

Potential risks of radiation

- Genetic
- Teratogeneous
- oncogenic



Genetic risk: preconception radiation risks

- "radiation of spermcells and eggs"

- No evidence of germline mutations manifesting as heritable disease known humans (atomic bomb-survivors, children treated for cancer, occupationally exposed workers)

- (radiation induces mutations in microbes and human cells)

Deterministic effects (teratogeneous)

- Dose dependant:
  - Risk certainly possible from 150-200 mGy
  - Fetal damage 500 mGy and up

- Time dependant:
  - First two weeks postconceptus (pregnancy usually not known):
    - 0,1 5 - 0,2 Gy abortion possible (if no abortion, then no malformation!) "all-or-none-period"
  - Week 3-5 postconceptus:
    - 0,25-0,5 Gy: abortion;
    - End of week 5: IU growth retardation possible from 0,5 Gy
  - Week 6-13 postconceptus:
    - Irreversible growth retardation from 0,25 -0,5 Gy
    - (abortus from 1 Gy)
  - Week 14-23 postconceptus:
    - Growth retardation less likely
    - (abortion from2 Gy)
  - Mental retardation, low IQ?
    - week 8 -25 from 0,5 Gy

Teratogeneous effects

- Dose less than 15 mGy: no risk
- Dose more than100 mGy: consider medical abortion
- Dose more than 150 mGy: risks are very high!!!

- spontaneous abortion 15% (without radiation)

Teratogeneous risk

- Chance of birth without malformation without radiation: 96%
- Chance of birth without cancer during childhood (mostly leukemia) without radiation: 99,93 %
- together: 95,93%

Teratogeneous risks

- Radiation of 100 mSv:
  - Chance of birth without malformation: from 96% to 95,80%
  - Chance of birth without childhood cancer from 99,93% to 99,07%
  - together: from 95,93% to 94,91%
- We can NEVER reach such dose in diagnostic examinations!!!

Carcinogesis arises from stochastic or nondeterministic effects

- Hard to predict oncogenic risks in radiation less than 100 mSv.
- ICRP: 1 cancer per 500 fetus exposed to 30 mGy (0.2%)
- ACR: 20 mGy = additionial projected risk of 40 cancers per 5000 baby's : 0.8%
- Risk bigger in exposures in 1st trimester
- Is not alarming:
  - Baseline risk for dying from childhood cancer is extremely low (1-2,5 pts per 1000)
  - Absolute risk for childhood cancer from diagnostic radiation in any individual is very low

oncogenic risk in postnatal exposure (child)

- BEIR (Biological Effects of Ionizing Radiation) liftetime risk model: 1 adult pt in 100 will develop cancer after 100 mSv (versus 42 % cancer risk) RELATIVITY!!!
- child 5 years 100 mSv exposure: chance for cancer
  - 3,4% (girls), 1,8% (boys)
- Pt 30 year 100 mSv exposure: chance for cancer
  - 1,1% (women), 0,7% (men)

Oncogenic risk in postnatal exposure

- Published Online: 07 June 2012 The Lancet
- **Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study**
- Dr Mark S Pearce PhD , Jane A Salotti PhD , Mark P Little PhD , Kieran McHugh FRCR , Choonsik Lee PhD , Kwang Pyo Kim PhD , Nigel J Howe MSc , Cecile M Ronckers PhD , Preetha Rajaraman PhD , Alan W Craft MD , Louise Parker PhD, Amy Berrington de González DPhil

Funding
US National Cancer Institute and UK Department of Health

Oncogenic risk in postnatal exposure (child)

- Pearce et al: Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study (The Lancet, June, 7 2012)
  - Dose of 50 mGy: 3 x more chance of leukemia
  - Dose of 60 mGy: 3 x more chance of brain tumor
  - reality: risk remains low: if first CT in child younger than dan 10 y, chance of leukemie and brain tumor after 10 years elevated with 1 in 10.000

BMJ

BMJ 2013;346:f2360 doi: 10.1136/bmj.f2360 (Published 22 May 2013)

RESEARCH

Cancer risk in 680 000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians

John D Mathews *epidemiologist*[1], Anna V Forsythe *research officer*[1], Zoe Brady *medical physicist*[1 2], Martin W Butler *data analyst*[3], Stacy K Goergen *radiologist*[4], Graham B Byrnes *statistician*[5], Graham G Giles *epidemiologist*[6], Anthony B Wallace *medical physicist*[7], Philip R Anderson *epidemiologist*[8 9], Tenniel A Guiver *data analyst*[8], Paul McGale *statistician*[10], Timothy M Cain *radiologist*[11], James G Dowty *research fellow*[1], Adrian C Bickerstaffe *computer scientist*[1], Sarah C Darby *statistician*[10]

24%????

- 1985-2005 (mean dose/scan 4,5 mSv)
- 0-19 years old
- Follow-up: 10 years
- "Incidence rate ratio" for cancer was 24% greater for exposed than for unexposed people
- Solid tumors, leukaemia, myelodysplasia, other lymphoid cancers

Oncogenic Risk in utero

- NCRP 2014: oncogenic risk of radiation in utero lower than radiation in childhood!
- "In Utero" Study Hiroshima:
  - Radiation (in utero) induced cancers : 94
  - the excess relative risk increased with dose (distance from hypocenter) in both groups (in utero and early childhood)
  - The excess absolute rates exhibited little change in the "in utero group"

lifetime risks following "in utero" exposure is considerable lower than in early childhood

pregnancy

- IV contrast: I en Gd
- CT
- MR
- US
- Acute trauma
- Cardiovascular pathology
  - Pulm embolism
- Neurologic Conditions
- Acute appendicitis
- Acute cholecystitis
- Acute urolithiasis
- Breast feeding

IV contrast (I and Gd) during pregnancy and lactation

IODINATED CONTRAST AGENTS

- Less than 1% of IV contrast will arrive in breast milk and less than 1% will be absorbed by the child
- ACR: safe to continue breast feeding (cessation of breast feeding for 24 hours can be considered)
- No teratogeneous effects known (theoretically hypothyroidy, probably not relevant)
- conclusion: ACR guidelines: no IV contrast if not necessary

IV contrast (I and Gd) during pregnancy and lactation

GADOLINIUM

- No damaging effects known to fetus
- Half life of Gd in children is higher than in adults (glom filtr); not known for fetus
- ACR guidelines: use only Gd if medical benefits for mother are higher than potential risk for fetus

CT in pregnancy

- Higher dose than X-ray
- CT abdomen: only after risk-benefit analysis+ radioprotection
- other CT's: much less radiation on fetus

MR in pregnancy

- No known adverse effects on fetus
- Potential risk of heating?(radiofreqency pulses), especially with higher SAR?
- Adverse effects of noise?

MR in pregnacy

- RF fields of the RF transmitter coil
- In time varying magnetic field gradients
- Static magnetic field (max 4T for clinical use)

MR in pregnancy

- International Commission on Non-Ionizing Radiation Protection:
  - postpone elective examinations after 1st trimester
- American Congress of Obstetricians and Gynecologists:
  - MR better than X-ray

MR in pregnancy

- ACR expert panel (2007):
  - MR can be used (always) after risk-benefit analysis
  - Questions (ICNIRP and NCRP 2014):
    - Can we obtain the same information with US?
    - Will the results of the MR chance therapy?
    - Can the MR be postponed untill after delivery?

US in pregnancy

- NCRP 2014: use of color doppler in first trimester less appropiate (higher energy levels) "risk-benefit"
- No contrast agents

Acute Trauma in pregnacy

- 6-7% of all pregnant women have a trauma!
- In 11% doctors don't know if the patient is pregnant
- In 7% the patient doesn't know that she is pregnant.
- Most obstetric complications of trauma occur in third trimester.

Acute abdominal trauma in pregnacy

- etiology: (USA)
  - Traffic accident (49%)
  - fall (25%)
  - Violence (18%) (partner violence)
  - Gun shots (4%)

- Dead of the mother results almost always in fetal dead

Acute abdominal trauma in pregnancy

- First choice: ultrasound
- In case of pathology: immediately CT with IV contrast
  - Preferrable only portal venous phase
  - Dose not too low, cfr diagnostic quality!
- Fetal dose is max 2,5-3,0 mSv for CT abdomen: no problem
- MR is NO option

Acute abdominal trauma in pregnant patients

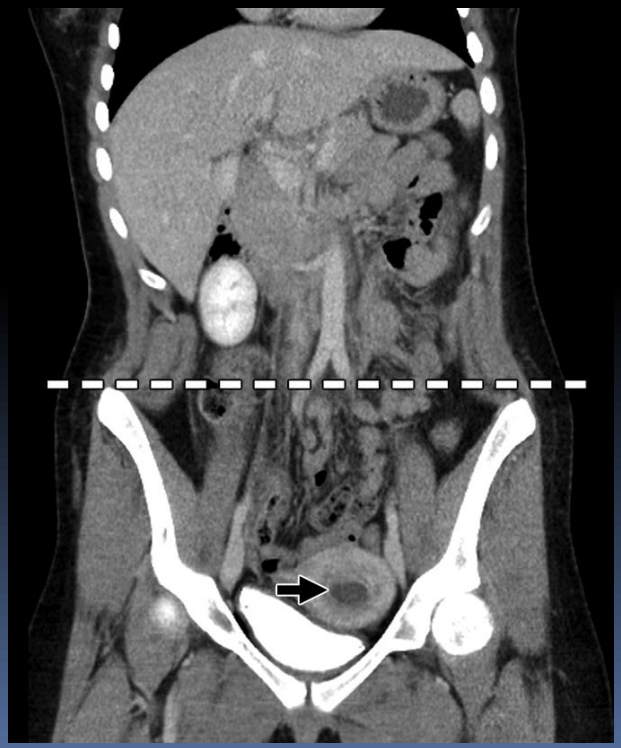
- Fetal Dose reduction in Pregnant patients with Trauma (M.T. Corwin et al.)
  - AJR 2016; 206:705-712

When no patholgy is suspected lower than iliac crest: CT scan can be limited, ending at the top of the iliac crests

Acute abdominal trauma in pregnant patients

- Reduction of fetal radiation depends on age

5 weeks



38 weeks

Acute abdominal trauma in pregnant patients

- Fetus of 5 weeks: would receive 4,3% of the total dose for a full scanning study
- 20 weeks: 26,2%
- 40 weeks: 59,9%

Acute trauma in pregnant patients

- Extremity X-ray: no problem (extra lead apron protection can be considerd)
- Head-neck trauma: CT brain and C-spine no problem
- Suspicion of lumbar spine trauma or pelvic trauma: X-ray, low dose CT, if possible pt stable consider MR

Cardiovascular pathology

- 1% of all pregnancies
- PS, AS, MS, aortic coarctation and dissection, cong cyanotic conditions, pulm embolism, pulm hypertension

Cardiovasc imaging: estimated fetal dose (mGy)

- Chest radiography < 0,0001
- Pulm CTA 0,01-0,66
- Cor CTA prosp gating +/- 1
- Cor CTA retrosp gating +/- 3
- Abdominopelv CTA 6,7-56
- Cor angio 0,074
- Dir fluoro (hip-heart) 0,094-0,244/min
- Electrophys intervention 0,0023-0,012/min

Cardiovasc imaging: estimated fetal dose (mGy)

- Lungperfusion 0,56
- Lungventilation 0,0054-0,9
- Myocardial perfusion 5,3-17
- PET viability 6-8,3
- PET perfusion +/-2

Ac pulmonary embolism in pregnant patients

- Incidence equal over all 3 trimesters (1/1000 pregn)
- highest incidence postpartal (15 x more frequent than during pregnancy)
- Pregnacy associated pulmonary embolism = 7-10 x more frequent than other population
- Pregnancy associated VTE = 3 x more frequent than pregnancy associated pulmonary embolism
- 75-96% more chance of VTE left!! Compression phenomenon of left iliac vein?

Ac pulmonary embolism in pregnant patients

- 3 x more chance for isolated VTE of iliac veins
- 15-24% of non-detected VTE: ac pulmonary embolism (with 15% mortality)
- D-dimer not usable (usually elevated during pregnancy)
- Missed diagnosis PE: mortality 30%

Ac pulmonary embolism in pregnant patients

- D-Dimer negative: STOP
- if D-Dimer positive:
  - MRV abdomen? Not always good results…
  - first color doppler LL (because 1/3 of the proven PE have DVT)
    - if color doppler positive
      - In last trimester: STOP and start therapy
    - If color doppler negative:
      - Angio CT of V/Q perfusion?

Acute pulmonary embolism angio CT or V/Q scinti

- Discussion who has the lowest dose…
- Fetal radiation dose is always very low: 0,1-0,4 mSv
- Angio CT gives more radiation on breast tissue (10-70 mGy) than V/Q (0,22-0,28)
  - Breasts during 1ste trim: more carcin risk!
  - Due too higher cardiac output angio CT less good during pregnancy, but same problem withV/Q… meta-analysis: angio CT better

Acute pulmonary embolism angio CT or V/Q scinti

- Fleischner Society: angio CT, also because of the advantage of CT for detecting other pathology
- Radioprotection:
  - Leadprotection abdomen???
  - Bismuth breasts protection reduces dose, but more artfecats
- V/Q:
  - No ventilation scinti, lowers the dose (only perfusion)
  - Good hydration and empty the bladder as soon as possible after the exam!

Acute pulmonary embolism angio CT or V/Q scinti

- Fetal dose CT (performing CT the same way as for non-pregnant patients):

  0.003-0.13 mSv
- Fetal dose scinti:

  0.1-0.2 mSv

9 questions regarding cardiovasc imaging

1. Is the pt pregnant, gestational age?
2. Is echocardiography satisfactory for diagnosis?
3. Is additional imaging appropriate for the diagnosis?
4. can imaging be delayed until second or third trimester or after delivery?
5. Is obstetric intervention before imaging possible? Termination of pregnancy? Early delivery?

9 questions regarding cardiovasc imaging

6. can MRI address the clinical situation?

7. Is imaging with radiography, fluoroscopy, CT, radiofarmaceutical agents required?

8. Is imaging with a contrast agent required for the diagnosis or treatment?

9. Are interventions appropriate to reduce fetal dose exposure (reduced tube current, reduced voltage, reduced radiophamaceutical dose, increased hydration and voiding)

Cardiov imaging: relative risk consideration

- Echocardiography: any time
- Cardiac MR, MRA, echocardio with microbubble contrast or dobutamine, chest radiography, iodinated contrast agents, performed as indicated (cat B)
- Gd, echocardiography with adenosine and regadenoson, radiopharmaceuticals: cat C
- Cor angio and electrophysiologic interventions: no problem (reduce fluoroscopy time, fetal shielding with lead apron)

Neurologic Conditions in Pregnant Patients

- CT of head and neck is considered safe because the fetus is out of the scanning field
- Risk of the fetus from MR imaging appears to be negligible and is outweighted by the potential benefit
- Iodinated contrast is category B (no risks found)
  - Check thyroid function after birth
- Gadolinium is category C (adverse effects on the fetus at supraclinical doses)

Neurologic Conditions in Pregnant Patients

- Headache
- Epilepsy
- Preeclampsy
- Eclampsy
- PRES
- Infarct or hemorrhage related stroke
- SAH
- Venous thrombosis
- Pituitary disorders

Ac appendicitis in pregnant patients

- Incidence: 1 in 1700 pregnancies
- Often atypical clinical signs especially in third trimester appendix moves upwards!
- First choice: ultrasound
  - Sensitivity: 85-100 %
  - Specificity: 92-96%
- ACR: second choice MR (also for diff diagn!!)
  - Sensitivity: 90-100%
  - Specificity: 93,6-98,1%

Ac appendicitis in pregnant patients

- MR:
  - T2 3 planes
  - STIR, T2 FS FSE in best plane for app
  - Ax T1 GRE in and opposed phase
- CT:
  - Controversial, not as second examination!

Ac urolithiasis in pregnant patients

- Inc: 1 in 3300 pregnancies
- 70-80% disappear spontaneously!

- First choice: ultrasound (sens 34-95,2%)
  - DD: physiologic hydronephrosis (60-94% inc)
    - Resistance Index!
    - consider transvag US: distal lithiasis
- Second choice: abdominal CT(reduc radiation dose!)
- Second choice: MRU (if available)

Ac cholecystitis in pregnant patients

- Higher incidence in pregnancy:
  - Diminished gallbladder contractility
  - elevated cholesterolsynthesis
  - elevated gall stasis

- First choice: US
- Second choice: MRCP

Diagnostic Breast Imaging in Pregnant & Lactating Patients

- New palpable mass that persists for more than two weeks and spontaneous unilateral masses with bloody discharge: work-up
  - US
  - Mammography: insignificant fetal dose, so pregnancy status is not important!
  - Lactating patients: use breast pump first to reduce density
  - Biopsy should be considered
  - CE-MR imaging should be delayed until postpartum period, unless very essential

Legislation: Medical Exposure to Ionising Radiation (2018)

Special attention to pregnancy and lactation

- Art 21:
  - Check possible pregnancy-lactation
  - If yes: Justification! Consider extra precautions!
- Art 23:
  - Protection of the fetus: same as any other person, meaning: < 1 mSv during pregnancy
  - Pregnant woman can not accompany a patient in X-ray room or nuclear medecine

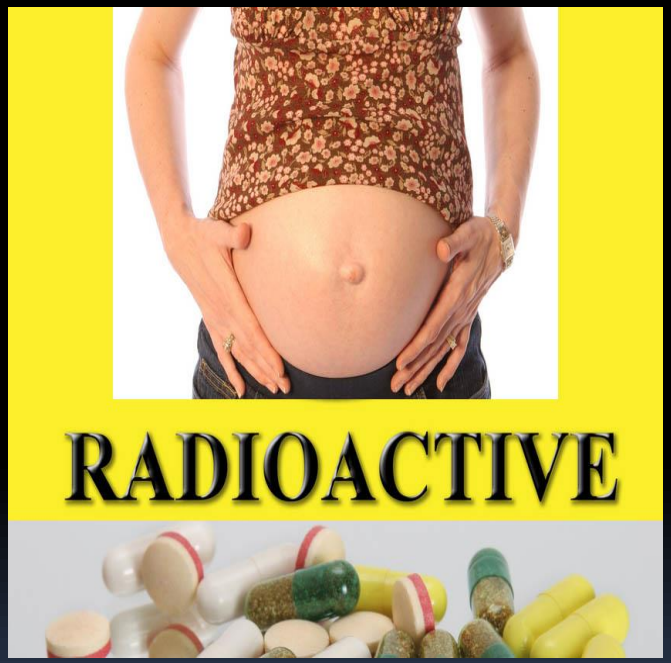
- Art 28:
  - Warnings in waiting areas, cabins, etc… in understandable words!
- Art 49:
  - Accidental exposure: calculation of the dose
- Art 61:
  - Education: special attention to pregnancy and children

Conclusion

- Ask the patient about possible pregnancy before an examination!
- Consider human chorionic gonadotropin in case of doubt (if possible in acute situations)

Radiologists

- ALARA: radiation dose as low as reasoanble achievable
- ASARA: medical procedures as safe as reasonable achievable
- AHARA: medical benefits as high as reasonable achievable



Clinicians

- dialogue!!! Often not black-white: consider all risks versus benefit!!! JUSTIFICATION
- Guidelines available!!! Medicolegal importance!!!
- final responsability for imaging choice: radiologist

Pregnancy was not known??

- Cfr supra.

- Medical abortion can be considered 100 mSv or more
- Less than 20 mSv: no risk
- 20-100 mSv: no abortion, but medical surveillance

Pregnancy was not known??

- Medical physicist can accurately determine fetal dose from DAP or DLP
- Dialogue obstetrician, clinician, radiologist
- Psychologic importance!!!
  - Incidence spontaneous abortion
  - Incidence abnormalities

TALK WITH THE PATIENT

literature

Corwin M.T. Quantification of Fetal Dose Reduction if Abdominal CT Is Limited to the Top of the Iliac Crests in Pregnant Patient With Trauma. AJR 2016;206:705-712

Kanekar S. Imaging of Neurologic Conditions in Pregnant Patients. Radiographics 2016;36:2102-2122

Tirada N. Imaging Pregnant and Lactating Patients. Radiographics 2015; 35:1751-1765

Linton O. The national Council on Radiation Protection and Measurements: A Growing Structure. Radiology 2014; 271:1-4

NCRP Report No 174: Preconception and Prenatal Radiation Exposure: Health Effects and Protective Guidance (2013-2014)

Rao V. The Choosing Wisely Initiative of the American Board of Internal Medecine Foundation: What Will Its Impact Be on Radiology Practice? AJR 2014;202:358-361

Browne AM. Evaluation of Image Qualily of Pulmonary 64-MDCT Angiography in Pregnancy and Puerperium. AJR 2014; 202:60-64

Costello J. CT Radiation Dose: Current Contrversies and Dose Reduction Strategies. AJR 2013; 201:1283-1290

Matthews D. Cancer Risk in 680.000 People Exposed to Computed Tomography Scan in Childhood or Adolescence: Data Linkage Study of 11 million Australians. BMJ 2013; 346: f2360 doi:10.1136

literature

Tremblay E. Quality Initiatives: Guidelines for Use of Medical Imaging during Pregnancy and Lactation. RadioGraphics 2012; 32:3 897-911

Wang P.I. Imaging of Pregnant and Lactating Patients. Part 1: Evidence-based Review and recommendations. AJR 2012; 198: 778-784

Wang P.I. Imaging of Pregnant and Lactating Patients. Part 2: Evidence-based Review and recommendations. AJR 2012; 198: 785-792

Sadro C. Imaging of Trauma: Part 2, Abdominal Trauma and Pregnancy – A Radiologist's Guide to Doing what is Best for the Mother and Baby. AJR 2012; 199:1207-1219

Patel S.J. Imaging the Pregnant Patient for Nonobstetric Conditions: Algorithms and Radiation Dose Considerations. RadioGraphics 2007; 27:1705-1722

Buls N. Dealing with Pregnacy in Radiology: a Thin Line Between Science, Social and Regulatory Aspects. JBR-BTR, 2009; 92:271-279

Wieseler K.M. Imaging in Pregnant Patients: Examination Appropiateness. RadioGraphics 2010; 30: 1215-1233

Huda W. Embryo Dose Estimates in Body CT. AJR 2010; 194:874-880

Colletti P.P. Cardiovascular Imaging of the Pregnant Patient. AJR 2013; 200:515-521