RADIATION EXPOSURE IN PREGNANCY

Project ECHO 7/26/19

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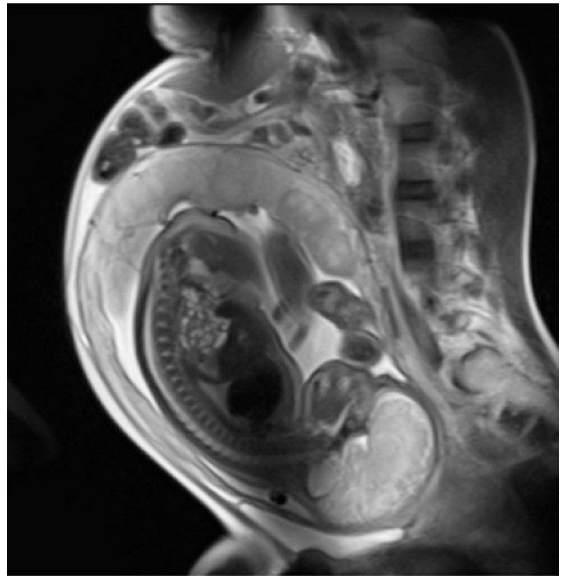
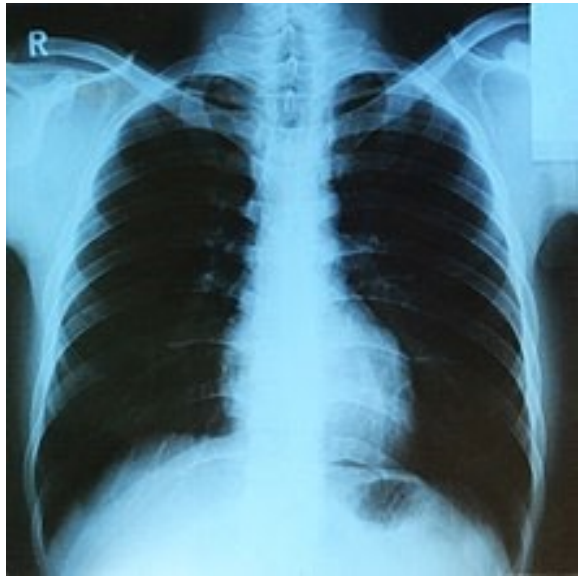
LEARNING OBJECTIVES

- Describe the different types of radiation used in common diagnostic tests
- Describe the fetal radiation exposure associated with common diagnostic tests
- Learn the risks of radiation exposure at different gestational ages
- Think about how to incorporate these principles into patient care and counseling





CASE: 22 YO G1 AT 26 WKS

- Sunday 1am
  - 24 hours of abdominal pain, anorexia, nausea.
  - Presents to ED with non-localizing exam, WBC 15,000
  - US abdomen/pelvis no etiology found, appendix not visualized
  - No one available to read pelvic MRI
- Sunday 6 am
  - CT w/ PO contrast ordered > patient goes to CT 4 hours later

CASE: 22 YO G1 AT 26 WKS

- Sunday 10 am
  - Patient arrives in CT, told "your baby will have higher risk of childhood leukemia," patient declines imaging
  - OB and radiology go back and forth about imaging
  - Patient's exam worsens; team convinced she has appendicitis, urge General Surgery to take her to OR; they are not convinced and 'require CT evidence' before operating
  - Contrast given again because earlier contrast ill-timed
- Sunday 5pm
  - Gets CT but before results are back becomes septic and unstable
  - Taken to OR and found to have ruptured appendix and abdominal abscess
  - Subsequently goes into preterm labor and delivers very preterm fetus

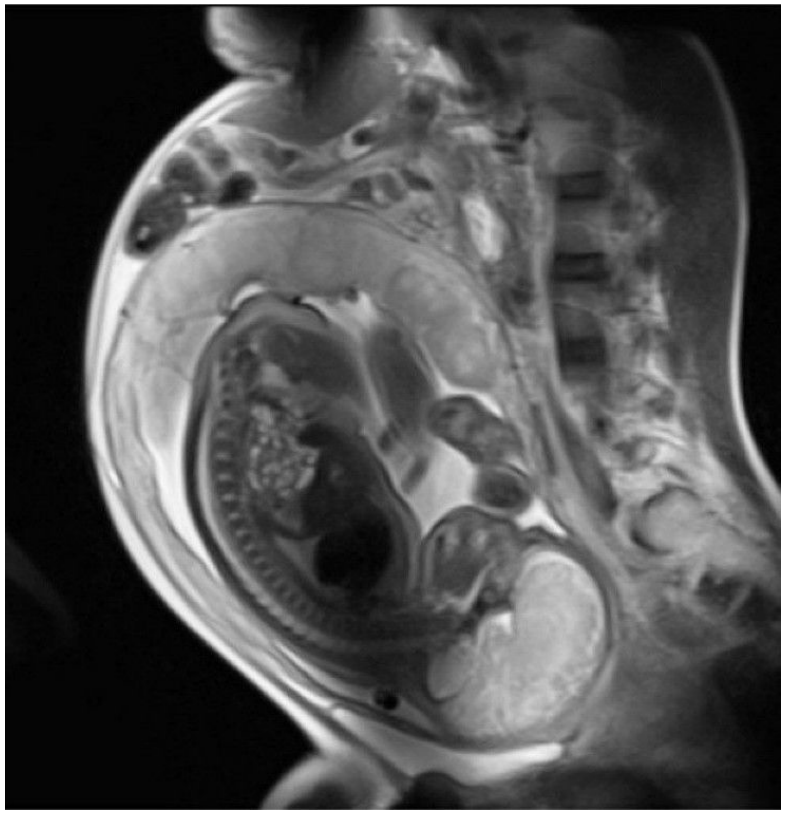
BACKGROUND

- Pregnant women need imaging too
- Reluctance to image pregnant women even when indicated
- Use of ionizing radiation has substantially increased in past two decades in U.S. and Canada
- Accidental exposure before pregnancy is diagnosed…How do you counsel these patients?
- Most of what we know is from radiation disasters

Hiroshima Atomic Bomb, 1945

TYPES OF RADIATION

- Radiation is energy that comes from a source and travels through some material or through space*
- Non-ionizing radiation
  - Ultrasound (sound waves)
  - MRI
- Ionizing Radiation
  - X-rays
  - CT scans
- Nuclear medicine studies
  - Pulmonary ventilation perfusion, thyroid, bone, CV, and renal scans



* Groen et al. ”Fear of the unknown: Ionizing radiation and pregnancy.” Am J Obstet Gynecol (June 2012).

MEASURES OF IONIZING RADIATION

TABLE 1
Commonly used measurements for ionizing radiation and their units[7,8]

Variable	Commonly used units	SI units	Conversion
Radio activity[a]	Curie (Ci)	Becquerel (Bq)	1 Ci relates to 37 gigabecquerel (GBq)
	1 Ci = 1g of radium	1 Bq = 1 decay/s	1 GBq relates to 27 mCi
Exposure[b]	Roentgen (R)	Coulomb (C)/kg	1 R relates to 258 μC/kg
			1 C/kg relates to 3876 R
Absorbed dose[c]	Radiation absorbed dose (rad)	Gray (Gy)	1 Gy = 100 rad
		1 Gy = 1 J/kg	1 rad = 0.1 Gy
Equivalent dose[d]	Roentgen equivalents man (rem)	Sievert (Sv)	1 Sv = 100 rem
		1 Sv = 1 Gy × radiation weighting factor (Wr)	1 rem = 0.1 Sv

SI, international system of units.

[a] Radio activity is measurement for source of radiation and depends on type and amount of material and distance from where measurement is taken. Conversion from curie to becquerel is not the same for every material, but this equation is commonly cited; [b] Exposure is only used for gamma and x-ray. Alpha, beta, and neutrons cannot be calculated in roentgen. Measurement of exposure can be done by Geiger counters (or other survey meters) that will give information on radiation per time period in a certain location. Dosimeters will calculate accumulative dose of exposure over time; [c] Absorbed dose is energy deposited by radiation (J)/kg. Since tissue differs in density, same amount of radiation will give a different absorbed dose to different tissue, calculated using tissue-weighting factor; [d] Equivalent dose is dose calculated as if a body is homogeneously exposed to radiation, taking into account that tissues have different density and taking into account the impact factor of different radiation types. Impact factor is sometimes called radiation weighting factor (Wr). For x-ray, the gamma and beta radiation impact factor is 1 and therefore 1 Gy = 1 Sv. For alpha radiation, the impact factor is 20. Alpha radiation is more harmful for the human body. In medical practice, radiation exposure is mostly related to x-ray. Therefore, equation of 1 R = 1 rad = 1 rem is often accepted, although not totally reflecting reality.

Groen. Ionizing radiation and pregnancy. Am J Obstet Gynecol 2012.

Groen. Ionizing radiation and pregnancy. Am J Obstet Gynecol 2012

Fetal Radiation Doses Associated with Common Radiologic Examinations

Procedure	Fetal Dose (mGy)
2 view Chest X-ray	< 0.01 mGy
CT Head	0.001-0.01 mGy
X-ray extremity	<0.001 mGy
Abdominal X-ray	0.1-3.0 mGy
CT Chest/CT Pulm Angiogram	0.01-0.66 mGy
VQ scan	0.1-0.37 mGy
CT Abdomen	1.3-35 mGy
CT Pelvis	10-50 mGy
US	Non-Ionizing
MRI	Non-Ionizing
Background Radiation	1 mSv
Commercial Flight	0.1 mSv

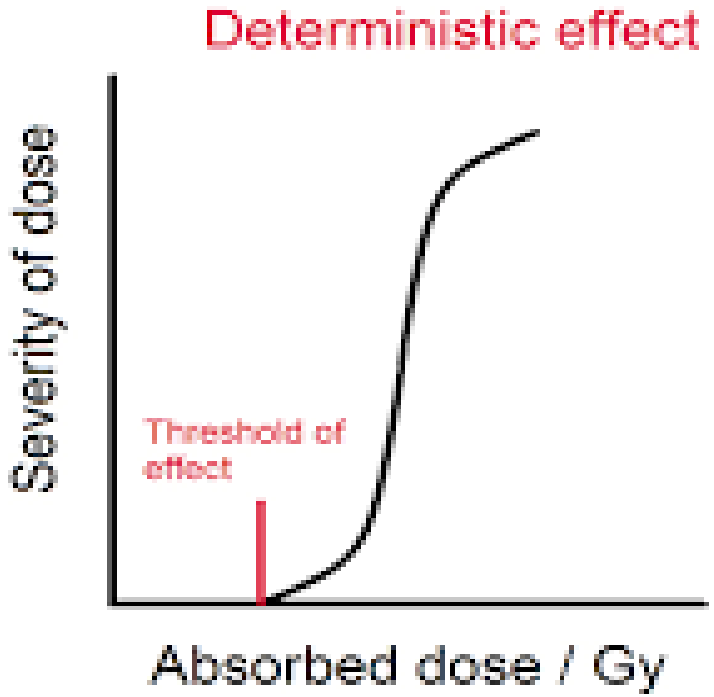
Adapted from Groen. Ionizing radiation and pregnancy. Am J Obstet Gynecol 2012 and ACOG Committee Opinion 723: Guidelines for Diagnostic Imaging During Pregnancy and Lactation (October 2017)

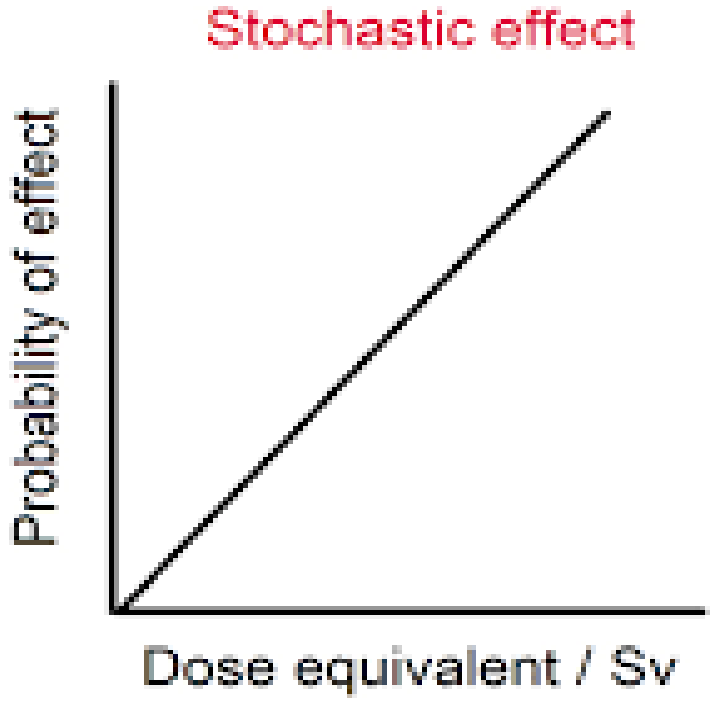
EFFECTS OF IONIZING RADIATION IN PREGNANCY

- **Deterministic:** threshold exists
  - Depends on radiation dose and trimester of pregnancy
  - Examples: pregnancy loss, malformations, neurobehavioral abnormalities, fetal growth retardation
  - ***Is there a dose below which no deleterious effects on fetus may occur?***
    - ***ICRP suggests <100 mGy (10 rad)***
    - ***ACOG suggests <50 mGy (5 rad)***

EFFECTS OF IONIZING RADIATION IN PREGNANCY

- **Stochastic:** the more radiation given, the greater the chance of disease
  - No defined threshold and amount of radiation does not predict severity of disease
  - Examples: cancer





https://iopscience.iop.org/book/978-0-7503-1058-1/chapter/bk978-0-7503-1058-1ch4

Table 1: Summary of Suspected In-Utero Induced Deterministic Radiation Effects* [3,4]

Menstrual or Gestational age	Conception age	<50 mGy (<5 rad)	50-100 mGy (5 - 10 rad)	>100 mGy (>10 rad)
0 - 2 weeks (0 - 14 days)	Prior to conception	None	None	None
3rd and 4th weeks (15 - 28 days)	1st - 2nd weeks (1 - 14 days)	None	Probably none	Possible spontaneous abortion.
5th - 10th weeks (29 - 70 days)	3rd - 8th weeks (15 - 56 days)	None	Potential effects are scientifically uncertain and probably too subtle to be clinically detectable.	Possible malformations increasing in likelihood as dose increases.
11th - 17th weeks (71-119 days)	9th - 15th weeks (57 - 105 days)	None	Potential effects are scientifically uncertain and probably too subtle to be clinically detectable.	Increased risk of deficits in IQ or mental retardation that increase in frequency and severity with increasing dose.
18th - 27th weeks (120 - 189 days)	16th - 25th weeks (106 - 175 days)	None	None	IQ deficits not detectable at diagnostic doses.
>27 weeks (>189 days)	>25 weeks (>175 days)	None	None	None applicable to diagnostic medicine.

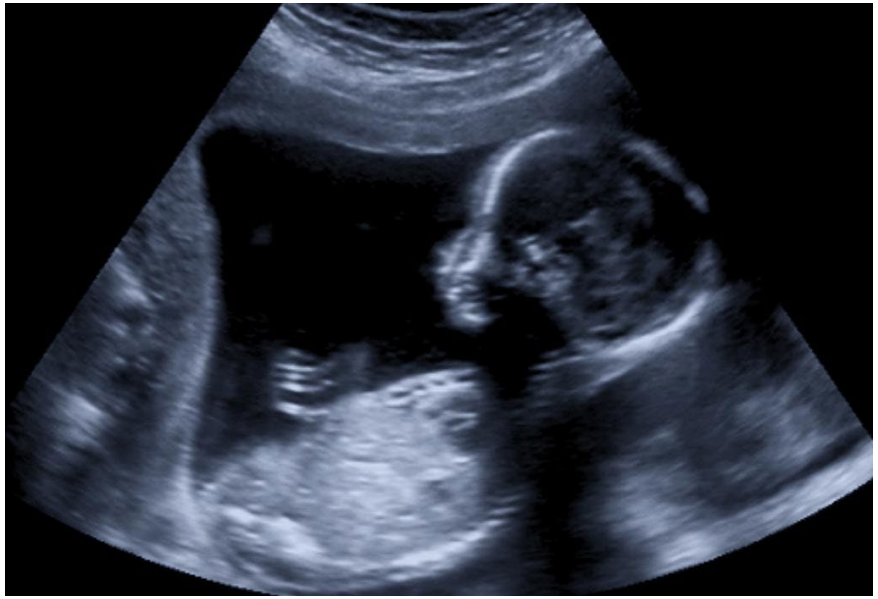
American College or Radiology Practice Guidelines for Imaging Potentially Pregnant Patients, 2008

STOCHASTIC EFFECTS

- No defined threshold and amount of radiation does not predict severity of disease
- Multiple studies showed high dose radiation did not lead to increased risk of childhood cancer
- But in multiple studies have showed that for obstetrical radiography, fetal exposure > 10 mGy = RR 1.5-2.0 for childhood leukemia
  - Baseline risk 1 in 3000 so risk still quite low!

NON-IONIZING RADIATION

- **US**
  - No documented adverse fetal effects
  - Theoretical risk of tissue temperature elevation
  - "ALARA" principle
- **MRI**
  - Deep soft tissue structures
  - Theoretical concerns but **no e/o actual harm**
  - Gadolinium contrast
    - Avoid except when would change treatment
    - Do not stop breastfeeding

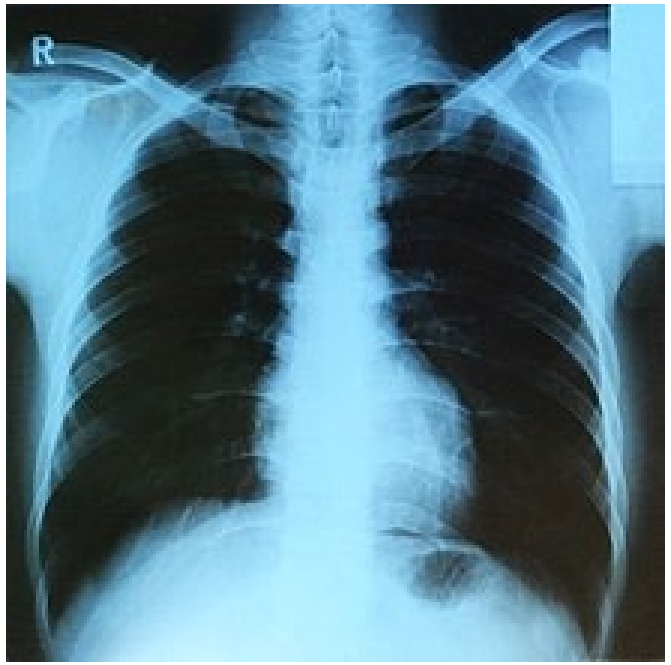


Bottom line:

- US and MRI are acceptable/safe
- Avoid Gad but use if important
- If Gad used, breastfeeding okay

IONIZING RADIATION

- **X-rays**
  - Remember exposures from common diagnostic tests:
    - 2 view CXR = 0.0005-0.01 mGy
    - X-ray c-spine: < 0.001 mGy
    - X-ray any extremity: < 0.001 mGy
    - X –ray abdomen: 0.1-3.0 mGy
  - Remember: Total threshold 50mGy (ACOG) or 100 mGy (ICRP)
  - No risk to lactation



<u>Bottom line:</u>

- Won't exceed thresholds at any GA with any one x-ray imaging test
- Should counsel on very small increased risk of leukemia if fetal exposure > 10 mGy

IONIZING RADIATION

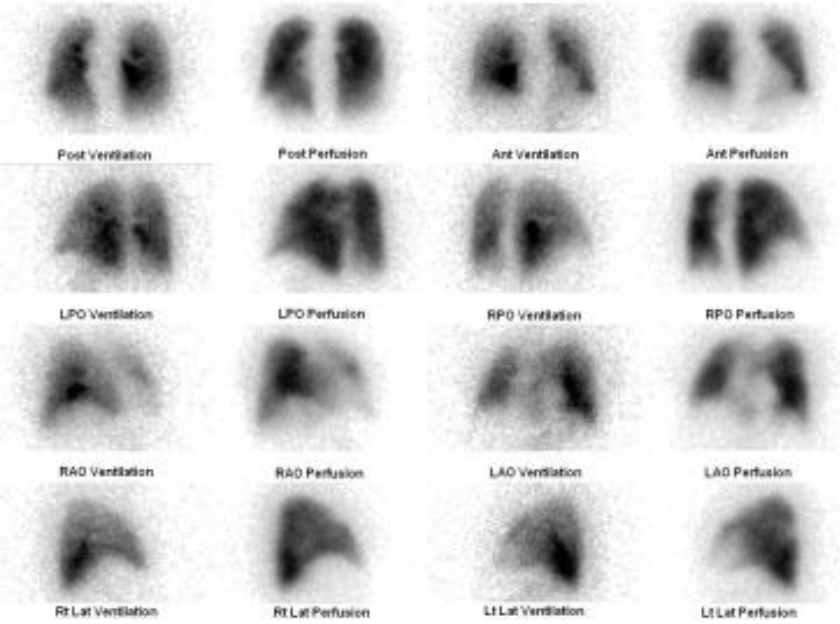
- **Computed Tomography (CT) Scans**
  - Remember exposures from common diagnostic tests:
    - CT chest = 0.01-0.66 mGy
    - CT Abd 1.3-35 mGy
    - CT Pelvis 10-50 mGy – but can decrease to 2.5 mGy by using low-exposure techniques
  - Remember: Total threshold 50mGy (ACOG) or 100 mGy (ICRP)
  - Oral contrast: no real or theoretical harm
  - IV contrast: can cross placenta; theoretical harm, avoid if possible

Bottom line:

- May reach threshold dose with some tests; thorough discussion of risks, benefits
- Maternal benefit from early and accurate diagnosis may outweigh theoretical fetal risks
- If MRI accessible, should consider as safer alternative to CT during pregnancy in cases where they are equivalent for diagnosis in question.

NUCLEAR MEDICINE IMAGING

- Performed by ”tagging” a chemical agent with a radioisotope
- Examples include pulmonary ventilation perfusion, thyroid, bone, CV, renal scans
- Fetal exposure depends on properties of radioisotope
  - **Technetium 99m**: Exposure < 5 mGy, considered safe dose in pregnancy
  - **Radioactive Idodine 131**: crosses placenta, can adversely effect fetal thyroid
    - Detrimental effects can include SAB, hypo/hyperthyroidism, cretinism, theoretic risk thyroid cancer
- **Breastfeeding:** Radionuclide compounds may have harmful effects. Consult specialists.



Bottom line:

- Should not use iodine 131 in pregnancy or during breastfeeding
- If nuclear imaging needed in pregnancy, use technetium 99m

BACK TO OUR CASE: 22 YO G1 AT 26 WKS

- **Appendicitis**
  - Most common general surgery problem in pregnancy
  - Lower threshold for imaging with non-classical presentation – most common!
  - If rupture, fetal mortality increases from 1.5% to 36%
- **Learning Points**
  - Big delay in getting to OR > increased morbidity from rupture, preterm labor
  - Risk of imaging often lower than risk of morbidity and mortality with undiagnosed condition
  - If you need it, get the imaging test that you to need to answer the question quickly
  - Do not delay diagnosis and prompt surgical intervention!

CONCLUSIONS

- Don't order imaging unless you need it to make management decisions
- If you need it, order the imaging that will give you the answer you need
- Most tests result in much lower fetal exposure than dose associated with fetal harm
- Weigh risks of imaging with risks of significant morbidity and mortality to mom and fetus for undiagnosed dangerous conditions
  - Potential fetal risks don’t apply if mother doesn’t survive her disease!
  - Counseling should emphasize often lower risk with imaging than without imaging

THANKS!

- Erin Clark, MD, Maternal Fetal Medicine
- Nathan Blue, MD, Maternal Fetal Medicine

RESOURCES

- ACOG Committee Opinion 723: Guidelines for Diagnostic Imaging During Pregnancy and Lactation (October 2017)
- American College or Radiology Practice Guidelines for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radation, 2008 (Res. 26).
- Groen et al. "Fear of the unknown: Ionizing radiation and pregnancy." Am J Obstet Gynecol (June 2012).
- HPS Specialists in Radiation Protection. "Pregnancy and Radiation."

http://hps.org/publicinformation/ate/cat4.html

- Kruskal et al. "Diagnostic Imaging in Pregnant and Nursing Women." Up to Date. Last updated July 2, 2019.
- https://www.uptodate.com/contents/diagnostic-imaging-in-pregnant-and-nursing-women?search=radiation%20exposure%20in%20pregnancy&source=search_result&selectedTitle=1~150&usage_type=default&display_rank=1
- Kwan et al. "Trends in Medical Imaging During Pregnancy in the United States and Ontario, Canada, 1996-2016." JAMA Network Open. 2019; 2(7).

QUESTIONS?