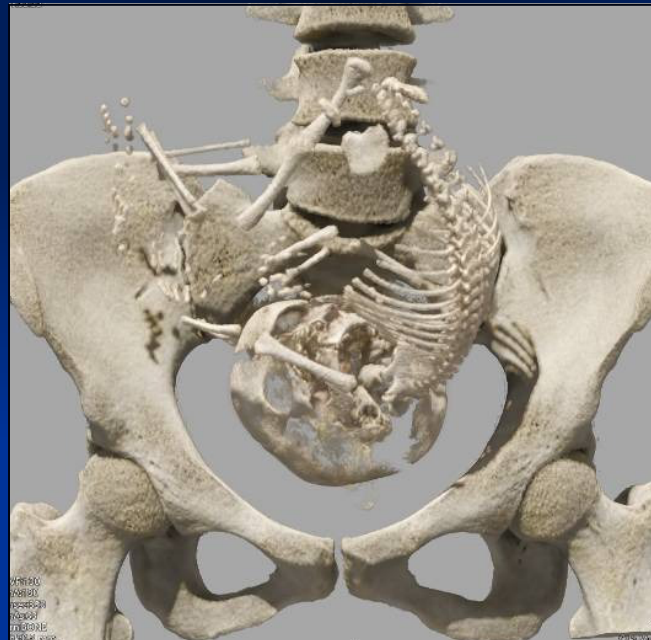




Exploration of the fetal skeleton by ultra low-dose CT

*Guidelines from the Fetal Imaging Task Force
of the European Society of Pediatric Radiology*

Dr P. Bach, Dr M. Cassart, Dr M. Chami, Dr C. Garel, Pr M. Panuel



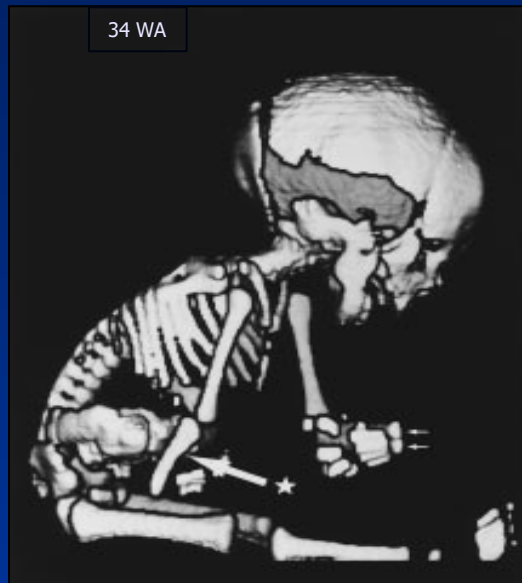
No disclosures



Before 2004: Maternal abdominal Xrays

- ✓ No standard views of the fetal skeleton,
- ✓ Superimposition of the maternal and fetal skeletons
- ✓ Uncontrolled and non-homogeneous irradiation

1993 : Helical CT Scanner



« *This new method promises to become a powerful diagnostic tool for perinatal use* »

Sohda et Hamada, Prenat Diagn 1997

- ✓ High radiation doses delivered : 25-40 mGy
- ✓ Poor quality multiplanar reformations

FETAL CT: A TOOL OF REFERENCE

➤ 2004: MDCT

Multidetector Computed Tomography

- Significantly reduced dose and acquisition time
- High spatial resolution, improved reformations

➤ 2010: MBIR

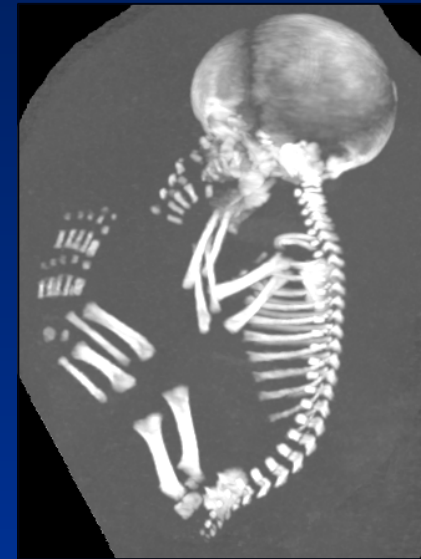
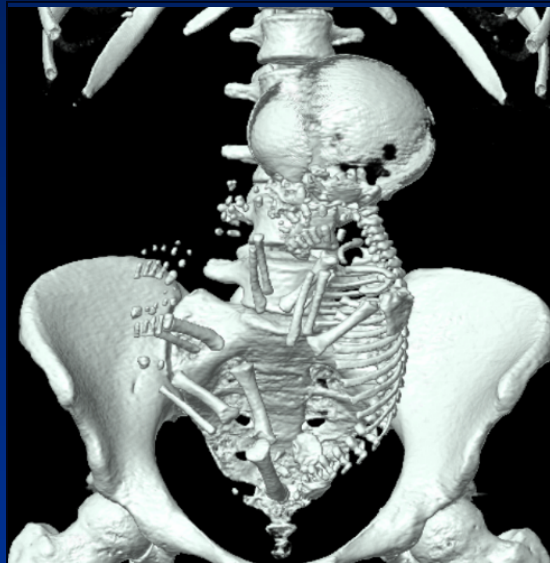
Iterative reconstruction algorithms

- Ultra low dose protocols CTDI vol = 1.4 -3.5 mGy
- Reduction in acquisition time to about 3 sec

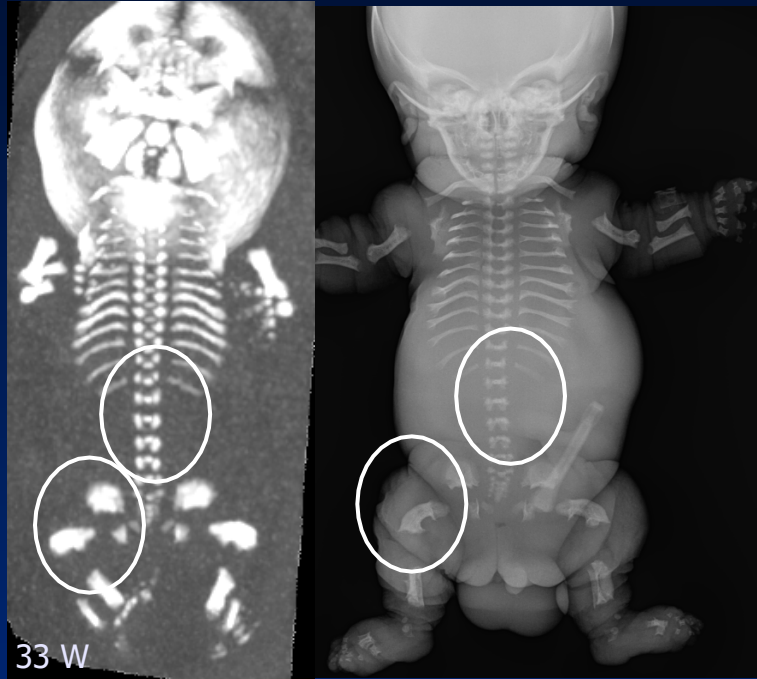
* Standards radiographs: 4-8 mGy

FETAL CT : MAIN ADVANTAGES

- Visibility of the entire fetal skeleton
- No maternal bones superimposition
- Views like post natal radiographs



EXCELLENT PRE AND POST NATAL CONCORDANCE

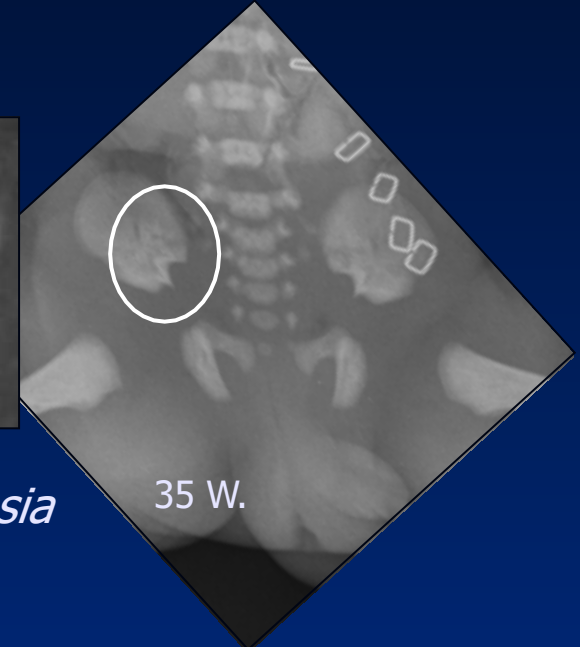


Thanatophoric dysplasia

- Severe platyspondyly and Short ribs
- Severe micromelia with curved femur



Anauxetic dysplasia RMRP gene mutation



- Hypoplastic squared pelvic bones
- Medial spur more visible on post mortem radiographs, one month later.

GUIDELINES for the INDICATIONS ULTRASONOGRAPHIC CRITERIA



Musée de l'homme Paris « L'homme exposé » 2007-2009

Shortness of long bones: the most frequent indication

*After Placental vascular insufficiency and
chromosomal anomalies have been excluded +++*

ULTRASONOGRAPHIC CRITERIA

✓ Severe isolated brachymelia:

= FL more than 5 weeks delay compared to median growth value for GA

The restriction growth affects

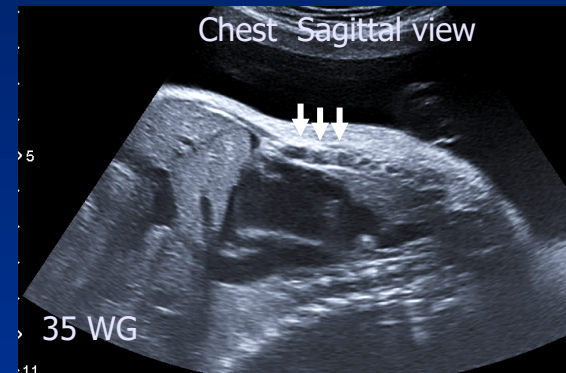
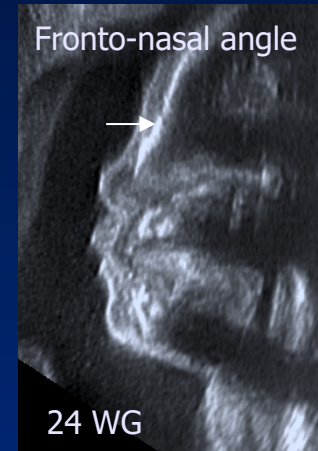
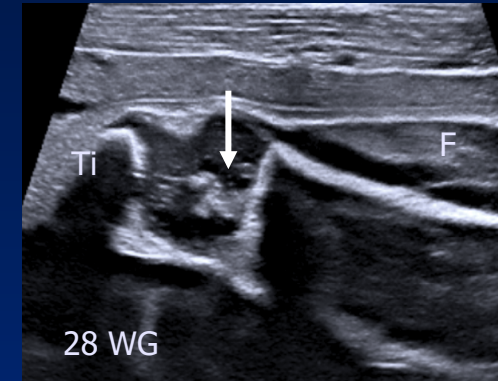
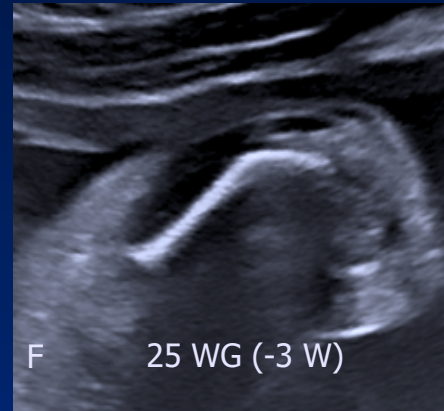
- All the limbs: Micromelia
- The proximal segment: rhizomelic brachymelia
- The middle segment: mesomelic brachymelia

GUIDELINES for the INDICATIONS

ULTRASONOGRAPHIC CRITERIA

✓ Severe or mild brachymelia associated with one or more anomalies:

- Abnormal long bones shape
bowled, angulated, fractured
- Cartilage stippling
- Narrow chest
- Binder phenotype
- Vertebral anomalies
- Joint disruption: *clubfeet*
- Pelvic bone abnormalities: *unossified pubic bones*



GUIDELINES for the PROCEDURE

RADIATION RISK:

Parental information and consent

- ✓ Currently, the fetal skeletal survey protocol delivers a radiation dose below 5 mGy*
- ✓ No increased malformation, mental retardation or cancer risk has been observed in the general population before the age of 19, for fetuses exposed to radiation below 5 mSv**

*Fetaldose.org

Saltybaeva N et al. "Radiation Dose to the Fetus From Computed Tomography of Pregnant Patients —Development and Validation of a Web-Based Tool" Investigative Radiology, 2020

**International Commission on Radiological Protection (ICRP)

STANDARD PROTOCOL ACQUISITION After 26 WG



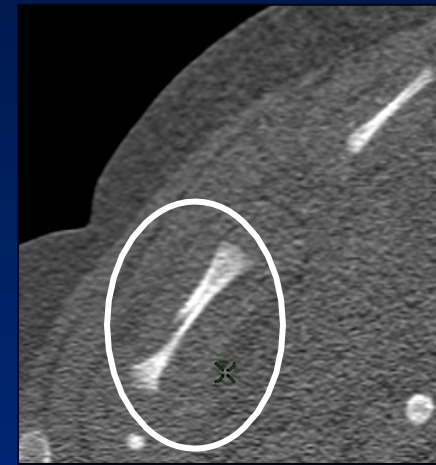
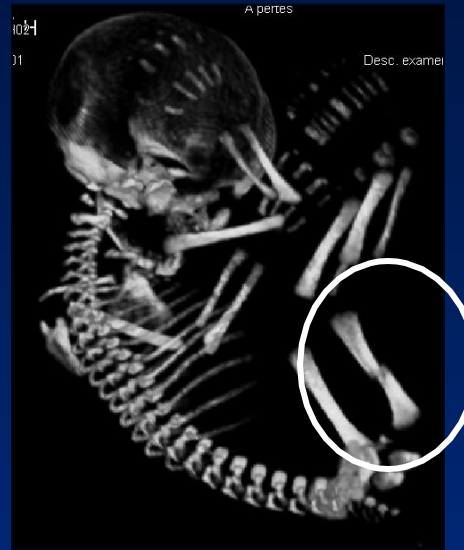
- supine position +/- hyperventilation
- Mother breath holding
- No scout view

• COLLIMATION	80 X 0.5 MM
• ROTATION TIME	0.35 sec
• VOLTAGE	100 kV if standard BMI (20-25) *
	80 mAs effective*
	with no automatic dose modulation
• CTDI VOL	1.4 to 3.5 mGy BMI standard
• DLP RANGE	95. mGy.cm +/- 10

**if BMI > 25,
Voltage should be increased up to 120 kV
or mA can be increased by 30 %*

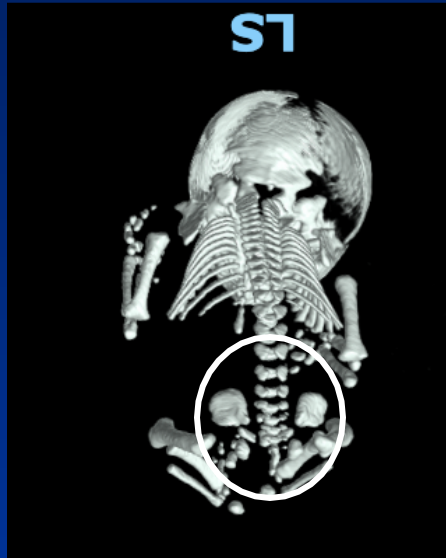
GUIDELINES for the PROCEDURE

- Movement artefacts can simulate hemivertebrae ,ribs or long bone fractures



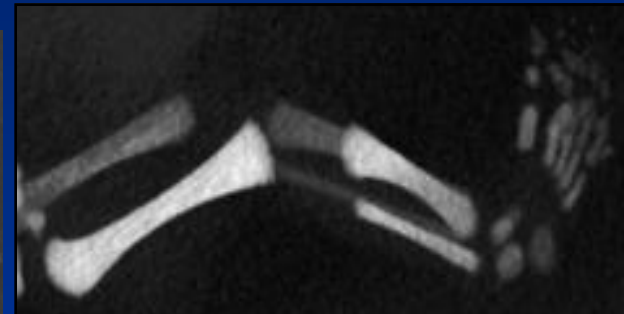
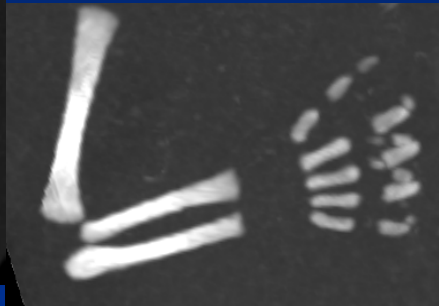
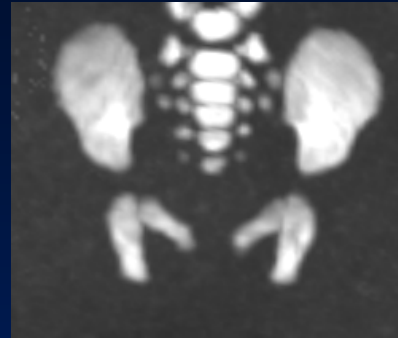
- Absence of movement artifacts must be checked on the native sections, thus ending the exploration +++

Post processing: 3D Volume Rendering reformations



- Post-processing starts with 3D Volume Rendering for a global view of the fetal skeleton
- 3D VR is not enough for a specific analysis of the bone appearance

Post processing : MIP reformations



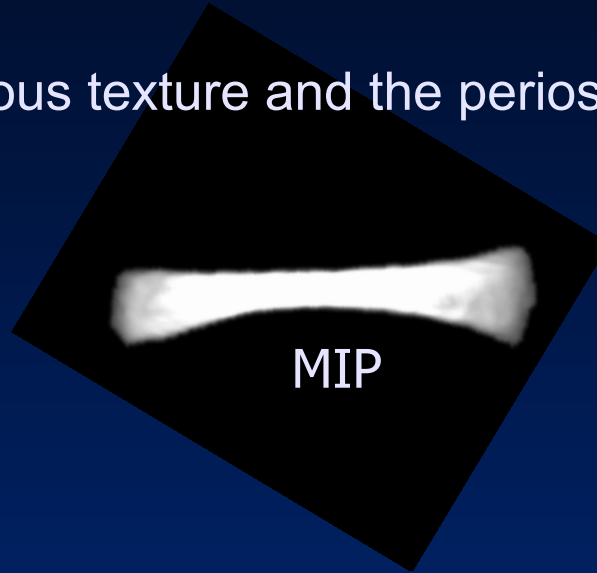
To analyze the skeleton as well as the postnatal radiographs

Post processing: MPR reformations

More specifically used to explore the osseous texture and the periosteum of the long bones



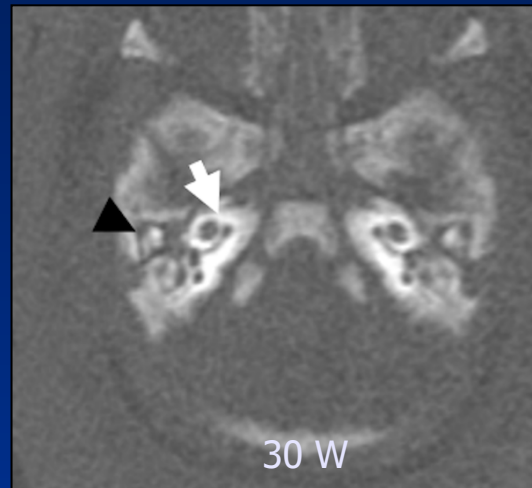
MPR
cortical medullary differentiation



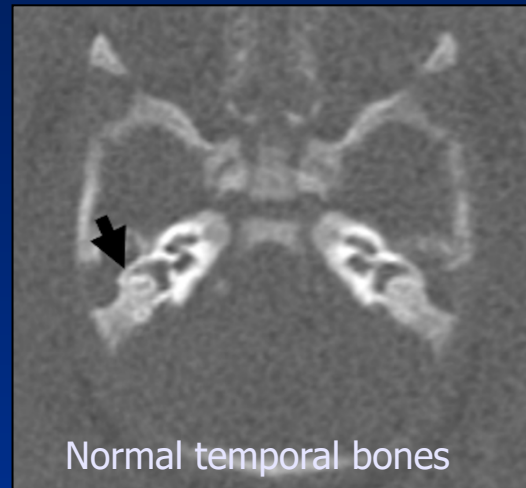
MIP



3D VR



30 W



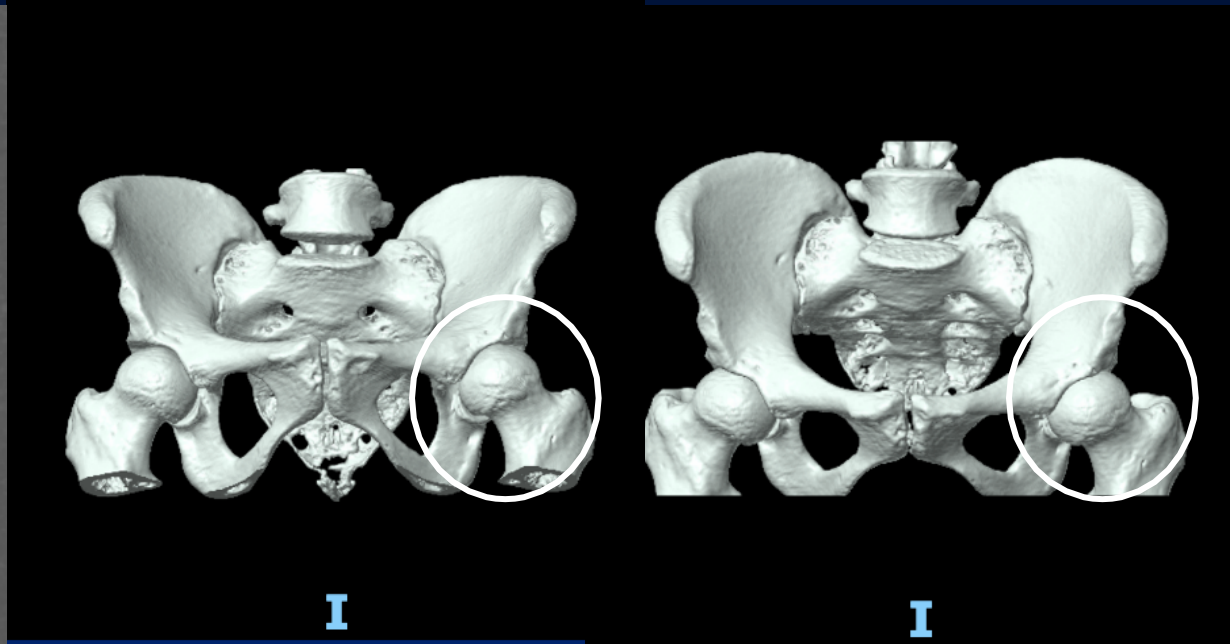
Normal temporal bones

MPR in the axial plane of the temporal bones
the middle and inner ears are well visualized

Post processing: Maternal skeleton reformations



Lethal fetal
Ciliopathy:
Severe short ribs



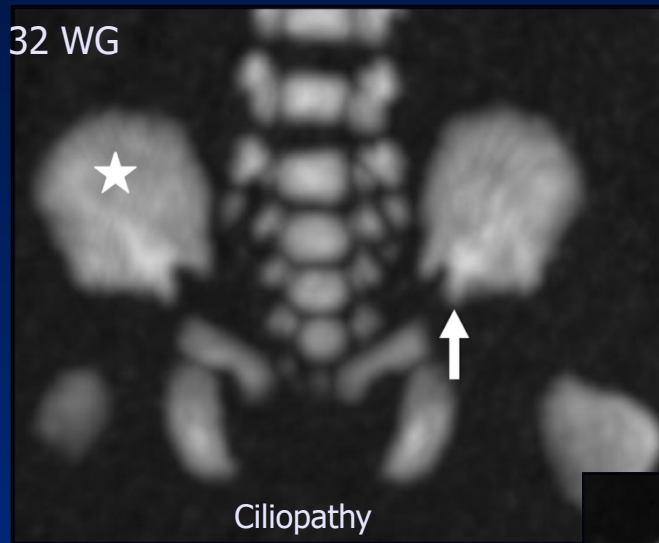
The mother is known for a mild Jeune dysplasia.
Skeletal reformations show

- Shortened femoral neck
- Defect of femoral head covering

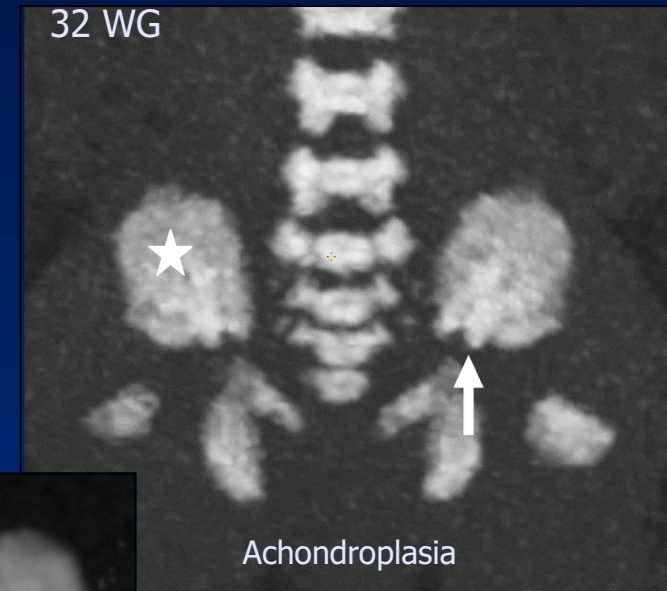
GUIDELINES for the IMAGE INTERPRETATION

DIAGNOSIS: ANATOMICAL KEY POINTS

Pelvic bones: sacrosciatic notch, iliac bone shape

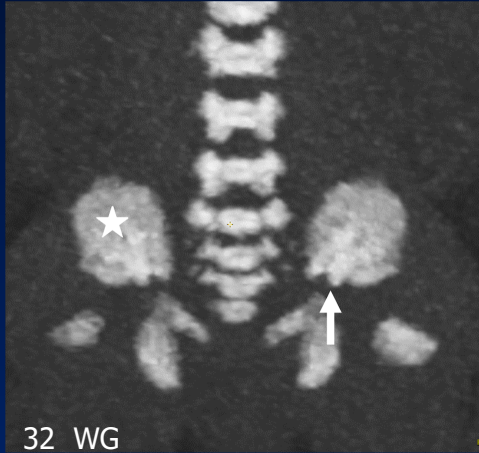


Mild brachymelia
Narrow chest

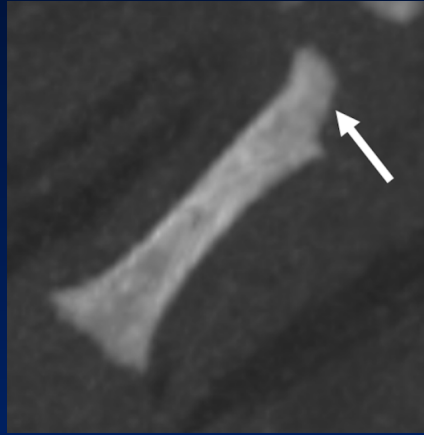


DIAGNOSIS AND PROGNOSIS

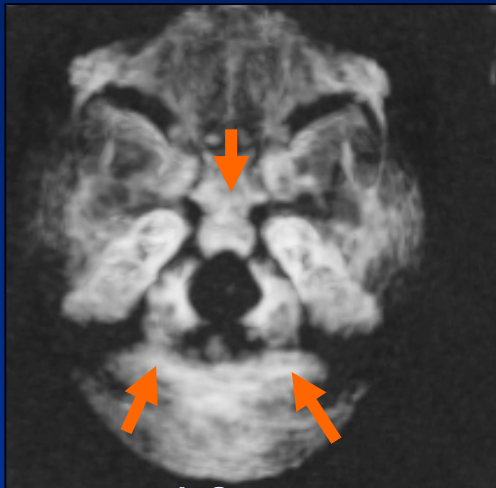
Interpedicular distance and foramen magnum



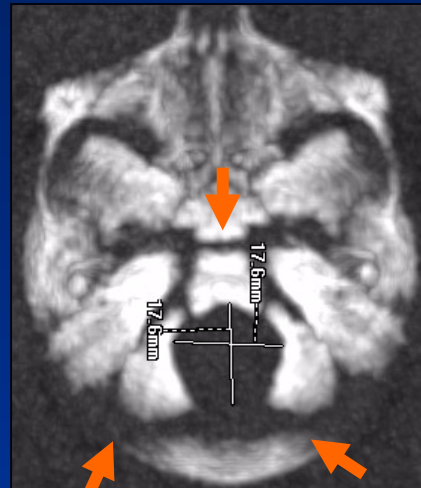
CT scan confirm Achondroplasia



Narrowed lumbar canal



Narrowed foramen magnum

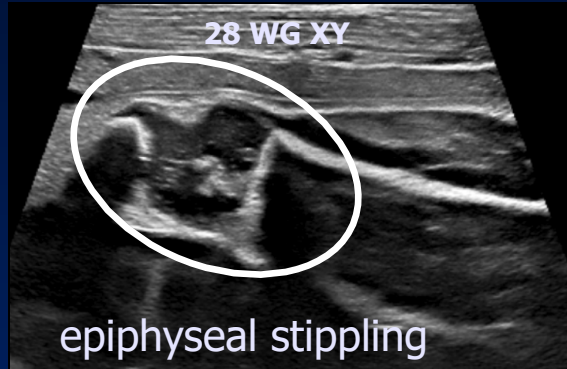


Normal 31 WG

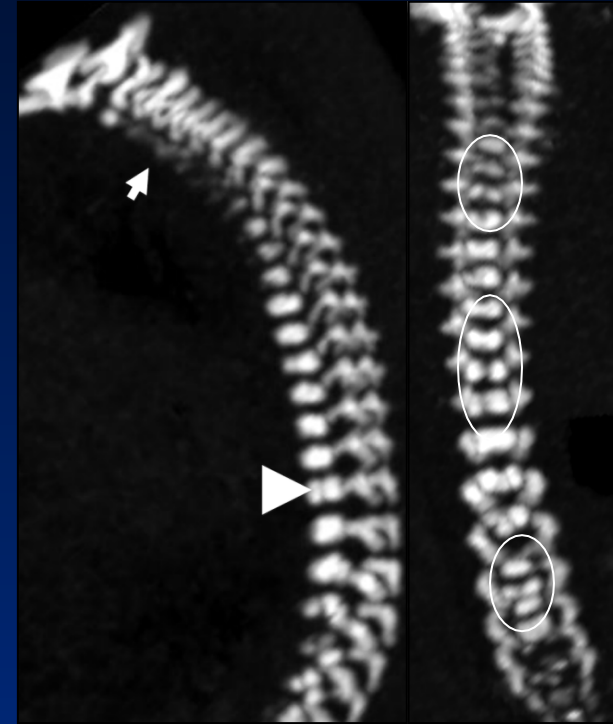
CT help in the neurologic
prognostic evaluation

PROGNOSIS

Vertebral segmentation



Chondrodysplasia punctata

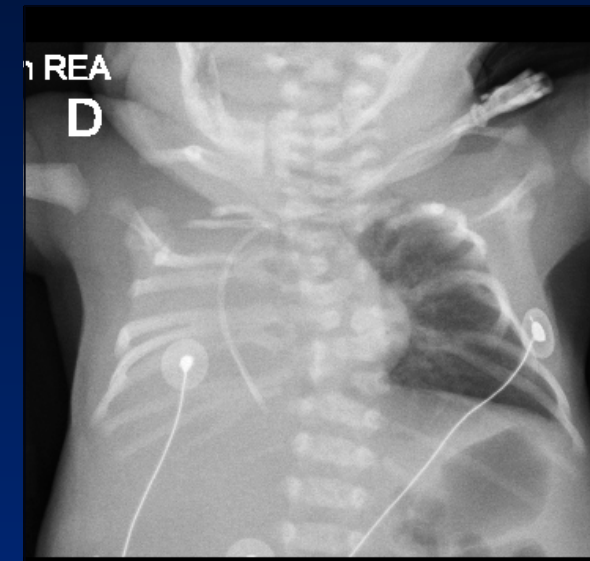
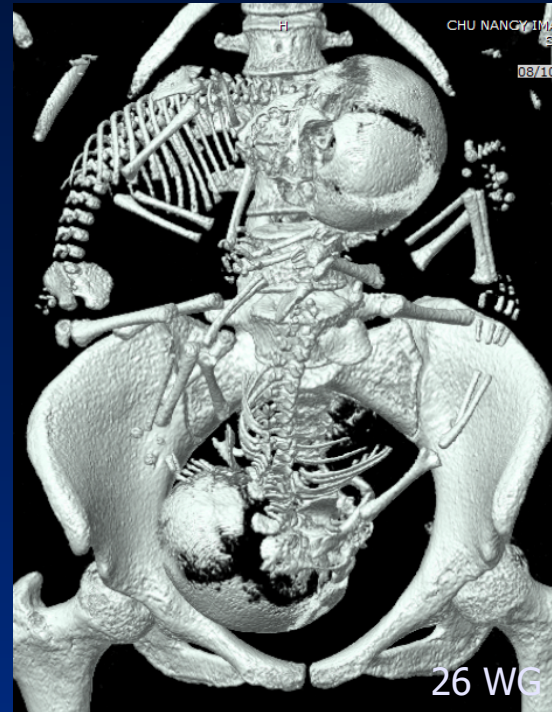


Hypoplasia of the cervical vertebrae confirmed at CT

It may be responsible for further spinal instability

PROGNOSIS

Chest malformations



Day 1

The prognosis related to neonatal respiratory distress risks can be anticipated with the CT

GUIDELINES for the IMAGE REPORTING

Standardized CT Report

- **US findings, indications**
Gestational age (based on 1st trimester datation)
US biometry (percentiles, % of the median, Z score)
US anomalies
- **CT scan protocol and dosimetry** report (vol CTDI and DLP)
- **Skeletal mineralization** compared to the maternal skeleton
- **Bone maturation** compared to gestational age

GUIDELINES for the IMAGE REPORTING

CHECK LIST

Axial skeleton

Skull

- Calvaria: shape / sutures
- Face: frontonasal angle, Mandibular / Maxillary
- Base of the skull:
spheno-occipital and intra-occipital sutures
- Temporal bones:
cochlea, lateral semicircular canals Identification

Spine

- Vertebral bodies: shape, number
- Interpedicular distance

Thorax: length, shape, count of ribs

Appendicular skeleton


Scapular and pelvic girdles

- Clavicles and scapula: size and shape
- Iliac wings: hypoplastic, squared, sacroiliac notch, horizontal acetabular
- pubic bones: ossified or not

Long bones

- Diaphysis: symmetry, bowing, fractured,
Metaphysis: flare, irregular
Extremities: stippling, number of digits,
phalanges

- Skeletal maturation lasts until puberty +++
- Bone features may become more prominent after birth only+++

 **No evidence of skeletal dysplasia currently identifiable
does not completely rule out this hypothesis**

TECHNICAL LIMITATIONS

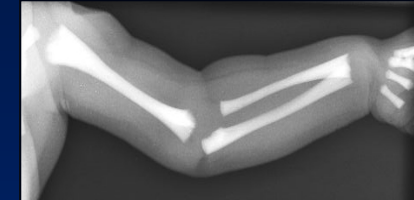
- ✓ Quantification of bone density is not possible



Osteogenesis
Imperfecta



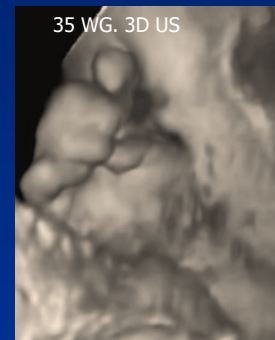
Congenital
osteopetrosis



- ✓ Analysis of the extremities is unreliable



Syndromic craniostenosis:
Lack of visibility of bifidity of the thumb



Syndromic dysostosis:
Membranous Syndactyly
impossible to visualize with CT

MESSAGES TO TAKE HOME



- Fetal ultra low dose CT scan: A reliable and safe tool
- Indications based on strict US criteria
- Diagnostic contribution: Key anatomical points
Pelvis, metaphysis, cervical spine
- Neurologic and respiratory prognosis: Perinatal management
- Genetic orientation: Multidisciplinary consensus