Orthopedic measurements in conventional radiology - a literature review

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Learning objectives

The main purpose is to improve the knowledge about the different kinds of measure in conventional radiology, making possible to identify the pathologic status.

Background

In Portugal, the conventional radiology represents 80% of all imaging exams performed, that make it the first access exam (gold standard) in several diseases, especially in muscle-skeletal issues.

Findings and procedure details

In this poster, we will refer to normal and abnormal measures related with both axial and appendicular skeletons, and how to perform those measures. The sella turcica dimensions, vertebral column scoliosis (Cobb's Method), acromio-clavicular joint, gleno-humeral joint, elbow, wrist, hand, hip, knee (patellar instability) and foot will be studied. For example, in the gleno-humeral joint, the normal distance between the glenoid fossa and the head of humerus should be at maximum of 6mm, otherwise it's suggestive of head's luxation.

In order to perform the poster, we will use several tools, such as specialized books, specialists opinions and daily cases from our service.

Skull

Sella Turcica:

Great variation on its dimensions

Normal dimensions:

- Antero-Posterior distance (5-16mm)
- Height (4-12mm)

Causes of increased sella:
• Intra-sellar adenomas (e.g. prolectinoma)
• Empty sella syndrome
• Rathke cysts and aneurism

Causes of decreased sella:

• Primary hypopituitarism
• Growth hormone default
• Williams syndrome

Fig. 1 on page 12

**Atlanto-Occipital Joint (AOJ):**

Most common anomaly of AOJ and is't it's characterized by anormal projection of odontoid process above foramen magnum’s plan.

The foramen magnum's stenosis may cause medulla olongata's compression and lead to neurological symptoms, hydrocephalia, syringomyelia or even death.

It may become from congenit origin or acquired and it's frequently associated with Platybasia.

Congenit causes:

• *Osteogenesis imperfecta*
• Klippel-Feil syndrome
• Achondroplasia
• I/II Chiari malformation

Acquired causes:

• Rheumatoid Arthritis
• Paget Disease
• Hiperparatiroidism
• Osteomalacia/Rachitis

Fig. 2 on page 13

**Basilar intussusception:**

*McRae line:* it defines the foramen magnum’s plan and it allows a quick primary evaluation. Odontoid process's apex should appear always below this line Fig. 3 on page 14.
**Chamberlain line:** in this line odontoid process shouldn't appear more than 3mm above. In 50% of normal individuals, odontoid process appears below or at line's level Fig. 4 on page 14.

**McGregor line:** Chamberlain's line modification developed for situations of difficult evaluation of foramen magnum's posterior margin - this line continues to the posterior contour of the occipital bone. Easier to use and preferable to Chamberlain's. Odontoid process apex should appear no more than 5mm above this line Fig. 5 on page 14.

**Wackenheim clivus line** Fig. 6 on page 14:

The line drawn along the superior edge of clivus (a).

The odontoid process's detachment above this line indicates atlas anterior subluxation and possible basilar intussusception (b).

Inferior detachment indicates atlas posterior subluxation (c).

**Ranwat Method:** developed by Ranwat due to the frequent difficult to identify hard palate in conventional x-ray. The method consists in two lines:

- Line the unites the centres of C1 anterior and posterior arches
- Line with origin in C2 pedicle and drawn along the odontoid process axis
- 2nd line distance: Basilar intussusception < 15 mm (M) < 13 mm (F) Fig. 7 on page 15

**Occipito-Cervical Dissociation:**

Usually is a fatal lesion caused by cervical hiperflexion in car crashes, sport and falls.

Two types: complete (dislocation) or incomplete (subluxation).

Obvious dislocation is easy to identify, although there are more subtle situations in which the diagnostic may not be correct.

**Harris Method (Basion-Axis Distance):**

- Distance between basion and a line drawn along the posterior edge of axis.
- Dissociation when > 12mm
- More useful, sensitive and specific method to detect a dissociation Fig. 8 on page 15.
**Wackenheim clivus line:** used to verify if there's an anterior or posterior occipital-cervical subluxation. If the line is:

- Anterior to odontoid process - anterior subluxation
- Posterior to odontoid process - posterior subluxation Fig. 9 on page 16

**Atlanto-Axial Instability:**

Instability loss in Atlanto-Axial Joint, leading to a bigger mobility between the vertebrae.

Causes:

- Trauma
- Rheumatoid Arthritis
- Down syndrome
- Congenit diseases (Grissel, Kippel-Feil or Mosquito Syndromes; Achondroplasia)

**Anterior Atlanto-Odontoid distance:** <3mm (children) <5mm (adults)

- Should be measured on inferior extremity of C1 anterior arch Fig. 10 on page 16

**Posterior Atlanto-Odontoid distance:**

- Best method to evaluate instability since this distance measures directly the spinal canal (normal distance: 17-29mm)
- <14 mm à medullar compression Fig. 11 on page 17

**Vertebral Column**

**Thoracic Kyphosis**

*Cobb’s method* is in use.

The measurement is made by drawing a perpendicular to a line drawn across the superior endplate of the upper-end (most tilted) vertebra and the inferior endplate of the lower-end vertebra; the angle formed by the intersection of the two perpendicular lines is the Cobb angle, which is the measure of the magnitude of the curve.

Normal values: 20-40° Fig. 12 on page 18

**Lumbar Lordosis**

*Cobb’s Method* also in use
Scoliosis

Non-structural scoliosis:

- Reversible curve non-associated with bone changes
- It disappears with flexion towards the convexity side
- Non-rotational deformity associated
- Causes: incorrect positioning, lower limb shortening

Structural scoliosis:

- Fixed deformity associated with bone changes
- Do not disappear with positioning changes
- Rotational deformity associated
- Cobb's method in use to evaluate (normal value - 10°)
  - Disadvantages:
    - Do not evaluate correctly the curve as it just measure one bi-dimensional plan
    - Great variability "intra-evaluator"
    - Value can change according to more or less patient's standing position
    - The relation between the easy application and the degree of confidence makes it the best preferable method

- **Reisser-Ferguson Method**: Fig. 14 on page 20
  - **1st** identify the limit vertebrae: they're located on the curve endings and less tilted
  - **2nd** identify the apical vertebra: the more tilted vertebra and located on curve's apex
  - **3rd**: set points on these 3 vertebrae and two lines are drawn from the apical vertebral to which one of the limit vertebrae

- **Greenspan Scoliotic Index**: Fig. 15 on page 22
  - Developed to a more comprehensive evaluation of the scoliotic curve (evaluate the deviation degree of each vertebra)
  - A line is drawn between the centre of the vertebra above the upper vertebra and centre of the vertebra below the lower vertebra
  - Perpendicular lines are drawn from the centre of each vertebra in between to the primary lines. The individual values are added and divided by the vertical line’s length.
  - Vantages:
    - Superior method related to Cobb's as it allows to measure the individual deviation of each vertebra.
• Short segments and little curves normally difficult to measure, are easily measured by this technique.

**Shoulder**

**Acromio-Clavicular Joint:** Fig. 16 on page 24

- Normal value: 2-4mm
- >7mm à confirms lesion
- The difference between left and right side should not be bigger than 3mm

**Sub-Acromial Space:** Fig. 17 on page 24

- Normal value: 1cm
- # 6mm - rupture of rotators cuff
- Acute rupture does not cause space’s shortening

**Gleno-humeral Joint:** Fig. 18 on page 25

- Normal value: 0-6mm
- >6mm suggests humerus head luxation

**Elbow**

*Anterior humerus line:* drawn along the anterior edge of the humerus. If this line does not pass by the medial third of capitulum, there is a probable fracture.

*Radial-Capitulum line:* drawn through the centre of radio diaphysis, and if does not cross the capitulum, we’re in presence of subluxation or luxation of the radial head. Fig. 19 on page 26

**Wrist**

Scaphoid-Lunate Instability:

- Wrist's ligament lesion most common and important
- Risk factors:
  - Abnormal inclination of radius articular surface
  - Luno-Triquetum synostosis
- It encloses:
  - Dynamic scaphoid-lunate instability (no x-ray findings)
• Scaphoid-lunate dissociation Fig. 20 on page 27
  • Disruption of inter-osseous scaphoid-lunate ligaments and extrinsic ligaments that stabilize the joint
  • Scaphoid-lunate normal angle: 30-60°
• Dorsal intercalated segment instability
  • When scaphoid-lunate angle >60°
• Palmar intercalated segment instability
  • When scaphoid-lunate angle <30° Fig. 21 on page 27
• Scaphoid-lunate advanced collapse (degenerative arthritis)

Hand

Metacarpal sign Fig. 22 on page 28

• The line that passes tangentially to the head of 4th and 5th metacarpals and should pass distally to 3rd metacarpal's head.
• This sign is considered positive when the line crosses the 3rd metacarpal head - useful on gonadal dysgenesis and Turner syndrome

Hip Joint

Normal values: Fig. 23 on page 29

• Superior: 4mm
• Supero-medial: 4mm
• Medial: 8-9mm

Inferior limit of normality: 3mm

Femoral Neck Angle: Fig. 24 on page 29

• Angle formed between the longitudinal axis of the femoral neck and the diaphysis axis of the same bone
• Growth variability (150° at birth - 125° in adult age)
• Normal values:
  • Adults: 120-130°
  • >130° - Coxa vara
  • <120° - Coxa valga
• In children normal values: 130-140°

Knee

Femoral-Tibial Angle:
• Formed by the intersection of both longitudinal axis of femur and tibia
• Growth variability (15º at birth; 0º at 18th month; valgus 12º at 2-3 years)
• Normal values: 173-177º
  • Genu valgum: <173º
  • Genu varum: >177º

Patella alta:

• Abnormal position of patella in relation to femur
• Associated with subluxation or displacement of patella

**Insall-Salvatti Index:** Fig. 25 on page 30
• Measures should take place with the knee in a 20º to 70º flexion
• Y: distance to the patellar tendon
• X: distance between the patella poles
• Normal values of Y/X: 0,8-1,2
  • >1,2 - patella alta
  • <0,8 - patella baja

**Caton Index:** Fig. 26 on page 30
• Ratio between:
  • A: Distance from the lowest point of patella to antero-superior edge of tibial plate
  • B: Patella articular surface length
• Normal A/B: 0,6-1,2
  • >1,2 - patella alta
  • <0,6 - patella baja

Femoro-Patellar Relations in Tangential Projections:

**Femoro-Patellar Index:**
• Ratio between the measures of medial and lateral femoro-patellar spaces
• Normal value to the ratio medial/lateral: #1,6
• In patients with chondromalacia a increasing medial femora-patellar space is observed with a femoro-patellar index increasing. Fig. 27 on page 31

**Brattström Trochlear Sulcus Angle:** Fig. 28 on page 31
• It measures the sulcus depth
• When it's >145º is associated with relapsing luxation of patella

**Merchant Congruence Angle:** Fig. 29 on page 32
• Relates patella’s position with the trochlear sulcus
• Formed by the trochlear sulcus's bisector and by the line drawn between the intercodylar sulcus and the articular surfaces of patella - normal value is lightly negative
• Lateral positive angles > 16° are abnormal and >23° are associated with relapsing luxation of patella

Foot

Calcaneus Bohler’s Angle:

• Evaluate calcaneus fracture
• Formed by the intersection of two lines: Fig. 30 on page 33
  • 1 - line from the highest point of calcaneus-cuboid joint until the highest point of the talus-calcaneus joint joint
  • 2 - line from the last point referred and passes tangentially to the upper edge of the calcaneus tuberosity
• Normal values: 20-40°

Calcaneus Soft Tissue Thickness Measure:

• **Kho-Wright-Doyle Method:** Fig. 31 on page 35
  • Line between the anterior and posterior angles of superior surface of calcaneus (A)
  • Measure take place on a line perpendicular to the first, and goes from the lowest point of calcaneus to the foot's surface (B)
  • Normal values: 25mm (M); 23mm(F)
  • If increased may be related with acromegaly

Pes Planus:

• Weight-bearing x-rays should be taken to better evaluation

• **Plantar Arch Angle (Dijan-Annonier):** Fig. 32 on page 35
  • Line from the lowest point of calcaneus to the lowest point of talus-navicular joint
  • Line from the talus-navicular joint to the lower edge of the lateral sesamoid
  • Normal values: 120-125°
  • >128° à Flat feet

• **Lateral Talus-Calcaneus Angle (Kite):** Fig. 33 on page 35
  • Normal values: 25-50°
  • >50° à Flat feet

• **Anterior-Posterior Talus-Calcaneus Angle:**
  • Normal values: 15-30°
  • >35° à Flat feet

Pes Cavus:
• Great plantar flexion compensatory of the forefoot
• **Dijan-Annonier Angle** < 120° à pes cavus *Fig. 34 on page 36*
• **Kite Angle** < 25° à pes cavus *Fig. 35 on page 36*
• **AP Angle** > 35° à pes cavus

**Hallux Valgus:**

• Most common deformity of foot associated to the use of shoes (F)
• Lateral deviation of the proximal phalange over the 1st metatarsal's head
• **Angle:** *Fig. 36 on page 37*
  • Line along the 1st metatarsal axis
  • Line along the proximal phalange axis
  • **Values:**
    • Normal < 15°
    • 15-20° à light
    • 20-30° à moderate
    • 30-45° à severe
• Another important measures and normal values:
  • Inter-metatarsal angle: 8-12°
  • Metatarsus aductus angle: < 15°
  • Interphalange angle *Fig. 37 on page 38*

**Lower Limb Measurement**

**Orthoradiogram**

• 3 exposures (hip, knee, ankle) in one single big dimensions film

**Merril's Scanogram** *Fig. 38 on page 40 and Fig. 39 on page 40*

• 3 exposures (hip, knee, ankle) in one smaller dimensions film (the film is moved according to the joint)
• A) Highest point of femoral head à tangential line of femoral condyles - the difference is the femoral shortening
• B) Tangential line of femoral condyles à lowest point of tibia's articular surface - the difference is the tibial shortening
• C) Highest point of femoral head à lowest point of tibia's articular surface - the difference is the functional shortening
• Distance differences analysis (comparing direct and indirect measures):
  • 1) Difference between the limbs is the same, both in direct and indirect measures - shortening is real
• 2) Indirect measures indicate isometric limbs but direct measures indicate difference - shortening due probably to a asymmetric varus or valgus deformity
• 3) Both measures indicate to a difference - sum of deformity (real shortening plus varus/valgus deformity)
• Limitations of this method:
  • External fixators
  • Sagittal plan deformities of femur or tibia
  • Contractures with a flexed hip or knee joints

Scanogram with a millimetric rule (Bell-Thompson method): Fig. 40 on page 40
  • No significative advantages in relation to non-millimetric rule scanogram
  • Rule positioned on the tape (not on the film), so it does not keep up the magnification that long bones suffer, inducing in measure errors
  • By the need of strong immobilization, it's difficult to perform in children

Panoramic Radiogram: Fig. 41 on page 41
  • More advantageous
  • May be performed in weight-bearing position
  • Allow to study patients with shortening in result of angular deformities or limb misalignment
  • More detailed study by visualizing diaphysis deformities, joint narrowing or articular subluxation
  • Allow to measure knee’s angular deviations
  • One only exposure
  • Useful in situations in which there are big differences and in which the scanogram is limited

Images for this section:
Fig. 1: Increased sella
Fig. 2: Atlanto-Occipital Joint (AOJ)

Fig. 3: McRae line

Fig. 4: Chamberlain line

Fig. 5: McGregor line
**Fig. 6:** Wackenheim clivus line

**Fig. 7:** Ranwat Method
Fig. 8: Harris Method (Basion-Axis Distance)

Fig. 9: Wackenheim clivus line
Fig. 10: Anterior Atlanto-Odontoid distance
Fig. 11: Posterior Atlanto-Odontoid distance
**Fig. 12:** Cobb’s method
Fig. 13: Cobb's Method
Fig. 14: Reisser-Ferguson Method
**Fig. 15:** Greenspan Scoliotic Index

**Fig. 16:** Acromio-Clavicular Joint
Fig. 17: Sub-Acromial Space
Fig. 18: Gleno-humeral Joint
Fig. 19: Anterior humerus line - blue/ Radial-Capitulum line - red

Fig. 20: Scaphoid-lunate dissociation
Fig. 21: Palmar intercalated segment instability and Scaphoid-lunate advanced collapse
Fig. 22: Metacarpal sign

Fig. 23: Hip Joint

Fig. 24: Femoral Neck Angle
Fig. 25: Insall-Salvati Index

Fig. 26: Caton Index
Fig. 27: Femoro-Patellar Index
Fig. 28: Brattström Trochlear Sulcus Angle
Fig. 29: Merchant Congruence Angle
Fig. 30: Calcaneus Bohler's Angle

Fig. 31: Kho-Wright-Doyle Method

Fig. 32: Plantar Arch Angle (Dijan-Annonier)
Fig. 33: Lateral Talus-Calcaneus Angle (Kite)

Fig. 34: Dijan-Annnonier Angle
Fig. 35: Kite Angle
Fig. 36: Hallux Valgus
Fig. 37: Another important measures and normal values in foot

Fig. 38: Merril's Scanogram

Fig. 39: Merril's Scanogram
Fig. 40: Scanogram with a millimetric rule (Bell-Thompson method)
Fig. 41: Panoramic Radiogram
Conclusion

The issue is really important for the medical diagnostic. However it also represents a very useful tool for the radiographers daily practice, as the become important pieces in the diagnostic.

Personal information

References

- David LP. Orthopedic Principles - A resident's guide; Springer, 2005
- Charles A. Rockwood, Robert W., Md. Bucholz, Rockwood and Green's Fractures in Adults (2 Volume Set) 5th Ed By Lippincott Williams & Wilkins Publishers; September 30, 2001
- Skinner, H. Current Diagnosis & Treatment in Orthopedics; 3rd edition; Appleton & Lange; June 2003