5 Normative Measurements of the Craniocervical Junction on Imaging

Daniel Thomas Ginat and
Peleg M. Horowitz

5.1 Craniocervical Lines, Angles, and Measurements

- Chamberlain line (Fig. 5.1): Extends from the posterior margin of hard palate to opisthion (Fig. 5.1). The tip of the odontoid should be no more than 5 mm above this line and the anterior arch of C1 typically lies below this. Clivus height is the distance of the basion above Chamberlain line. These radiographic indicators are used to detect basilar invagination or impression. The McGregor line is an alternative to the Chamberlain line for the evaluation of basilar invagination when the opisthion is not apparent on radiographs and extends from the posterior margin of hard palate to inferior aspect of the occipital bone.

D. T. Ginat (✉)
Department of Radiology, Section of Neuroradiology, University of Chicago, Chicago, IL, USA
e-mail: dtg1@uchicago.edu

P. M. Horowitz
Department of Surgery, Section of Neurosurgery, University of Chicago, Chicago, IL, USA

D. T. Ginat (ed.), *Manual of Normative Measurements in Head and Neck Imaging*, https://doi.org/10.1007/978-3-030-50567-7_5

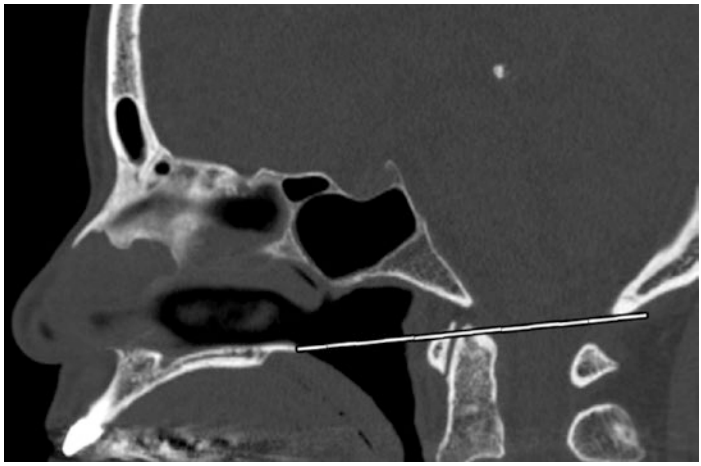

Fig. 5.1 Sagittal computed tomography (CT) image shows the Chamberlain line

- Wackenheim clivus baseline (Fig. 5.2): Line extrapolated inferiorly along dorsal surface of the clivus. The line should fall tangent to or intersect the posterior third of the odontoid and is used to detect basilar invagination or impression.

- McRae line (Fig. 5.3): Line from the basion to opisthion. The normal position of the tip of dens is 5 mm below this line and is used to detect basilar invagination or impression.

- Palatal line (Fig. 5.4): Line drawn parallel to the superior edge of the palatine process starting posterior to the anterior nasal spine. The normal mean height of the odontoid over the palatine line is 3.5 mm (range: 0–19.0 mm). In cases with platybasia, the mean is 15.5 mm (range: 7–26.0 mm).

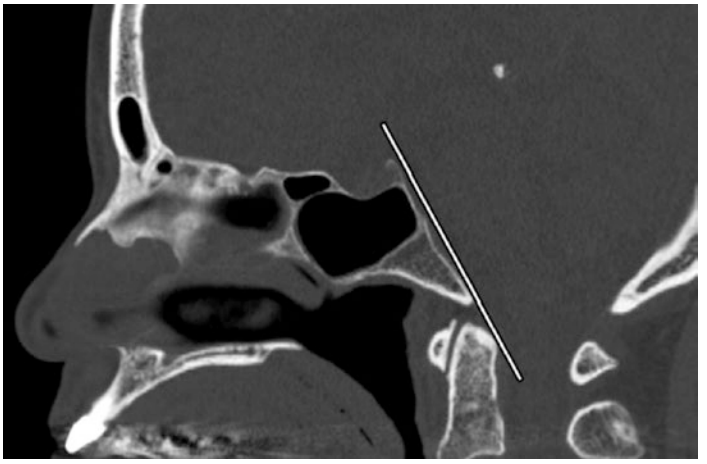

Fig. 5.2 Sagittal computed tomography (CT) image shows the Wackenheim clivus baseline

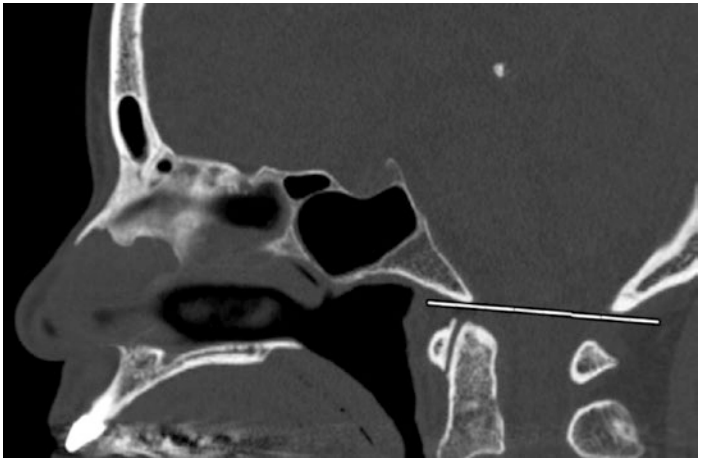

Fig. 5.3 Sagittal computed tomography (CT) image shows the McRae line

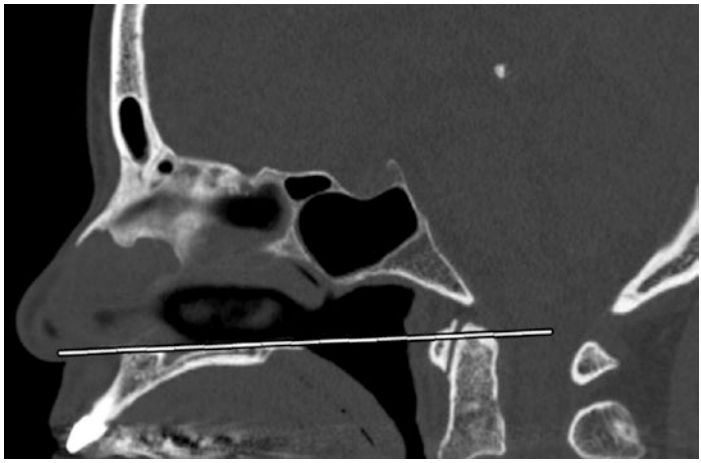

Fig. 5.4 Sagittal computed tomography (CT) image shows the palatal line

- Basal angle (Fig. 5.5): Angle subtended by the junction of the nasion–tuberculum and tuberculum–basion tangents. The normal ranges are as follows:
  - 116°–118°, 95% confidence limits for adults
  - 113°–115°, 95% confidence limits for children
  - Platybasia >143°

  A modified version of the basal angle formed by a line from the nasion and the center of the pituitary fossa and a line joining the anterior border of the foramen magnum result in the following normal mean angles:
  - 129° ± 6° for adults
  - 127° ± 5° for children

- Boogard angle (Fig. 5.6): Formed by the intersection of McRae line and Wackenheim line. The normal angle is 126° ± 6°. If the angle measures more than 136°, it is indicative of platybasia.

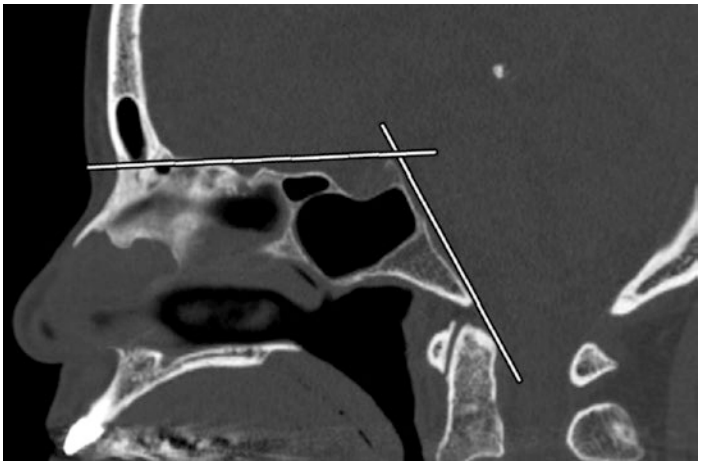

Fig. 5.5 Sagittal computed tomography (CT) image shows the basal angle

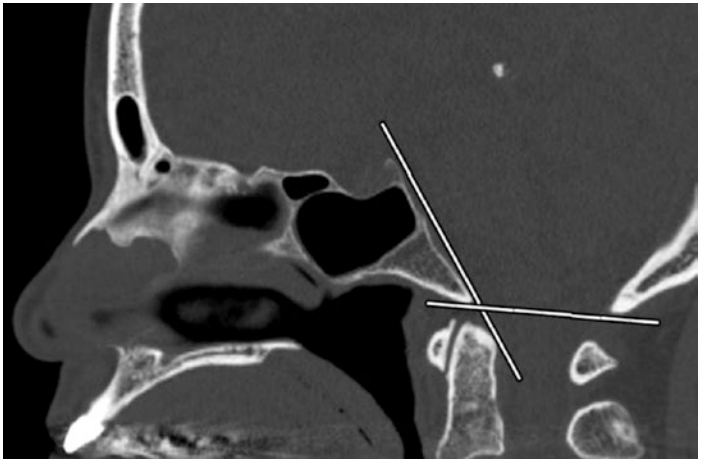

Fig. 5.6 Sagittal computed tomography (CT) image shows the Boogard angle

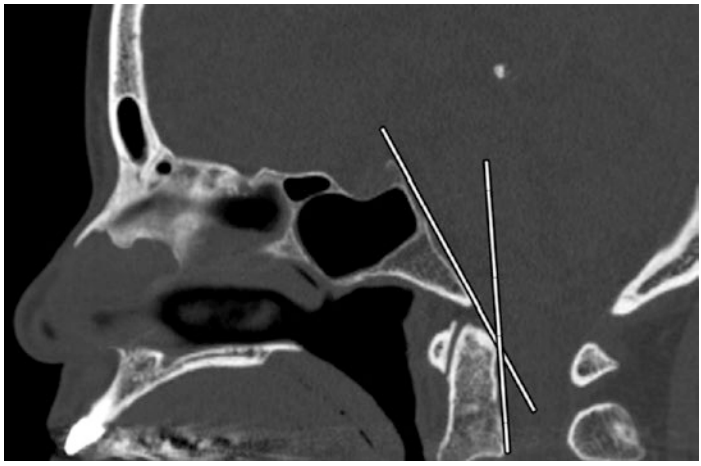

Fig. 5.7 Sagittal computed tomography (CT) image shows the clivoaxial angle

- Clivoaxial angle (Fig. 5.7): Formed by the intersection of the Wackenheim clivus baseline with a line drawn along the posterior surface of the axis body and odontoid process; it is a practical indicator for basilar invagination with high diagnostic value.

- Clivus canal angle (Fig. 5.8): The angle between the line extending from the top of the dorsum sellae to the basion and the line between the inferodorsal portions of C2 and the most superodorsal part of the dens. The angle normally varies from 150° in flexion to 180° in extension. An angle of less than 150° may be associated with ventral cord compression.

- Atlanto-occipital joint axis angle (Fig. 5.9): Formed at the junction of lines traversing the atlanto-occipital joints.
  - Average = 124°–127°
  - May approach 180° in severe occipital condyle hypoplasia

- Atlanto-occipital interval (Fig. 5.10): Distance between the posterior aspect of the anterior arch of the atlas and the dens.

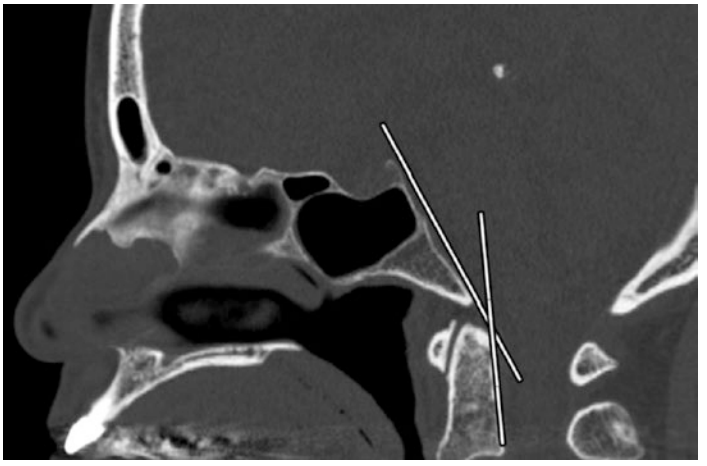

Fig. 5.8 Sagittal computed tomography (CT) image shows the clivus canal angle

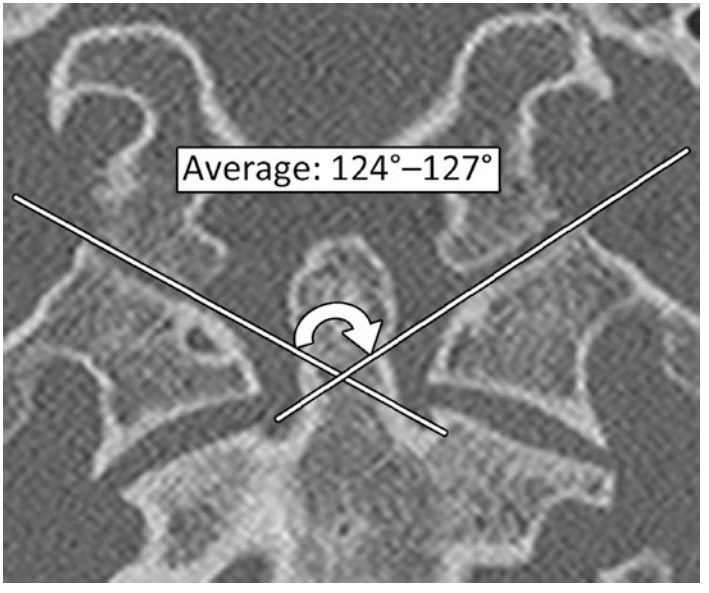

Fig. 5.9 Coronal computed tomography (CT) image shows the atlanto-occipital joint axis angle

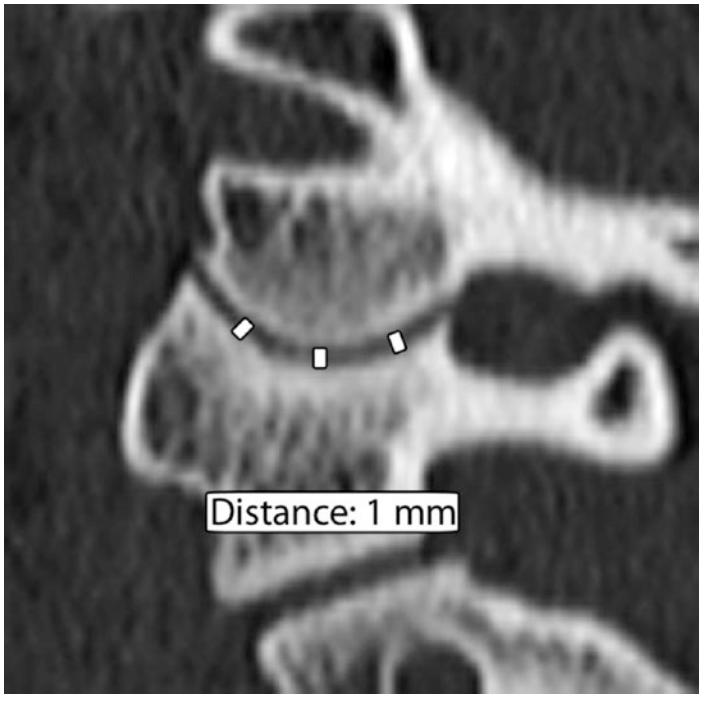

Fig. 5.10 Sagittal computed tomography (CT) image shows the atlanto-occipital interval

The mean value is 1.0 mm (95% of adults measure between 0.6 and 1.4 mm and 97.5% of children measure less than 2.5 mm at any point along the joint space).

- Basion-dens interval (Fig. 5.11): Shortest distance between the most inferior aspect of the basion and the nearest ossified point of the superior aspect of the dens in the midsagittal plane. If an os odontoideum is present, the measurement extends from the basion to the top of the os odontoideum. Widening can be a sign of craniovertebral junction injury, with a maximum of 9 mm in adults. In children, the basion-cartilaginous dens

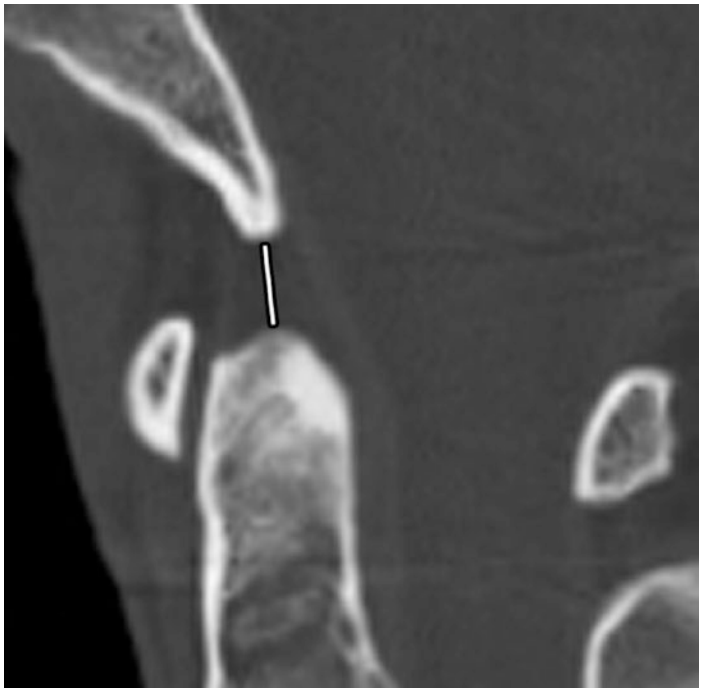

Fig. 5.11 Sagittal computed tomography (CT) image shows the basion-dens interval

interval is the counterpart that can be used with upper limits as follows:
- Ages 0–3 years: 5.3 mm
- Ages 3–6 years: 5.6 mm
- Ages 6–10 years: 7.2 mm

- Basion-axial interval (Fig. 5.12): Distance between the basion and the superior extension of the posterior cortical margin of the dens in the midsagittal plane. This measurement is normally less than 12 mm.

Fig. 5.12 Sagittal computed tomography (CT) image shows the basion-axial interval

- Atlanto-dens interval (Fig. 5.13): Line from the posterior aspect of the anterior arch of C1 to the most anterior aspect of the dens at the midpoint of the thickness of the arch in craniocaudal dimension; normal when less than 2 mm.

- The Powers ratio (Fig. 5.14): Calculated by dividing the distance from the tip of the basion to the midpoint of the anterior

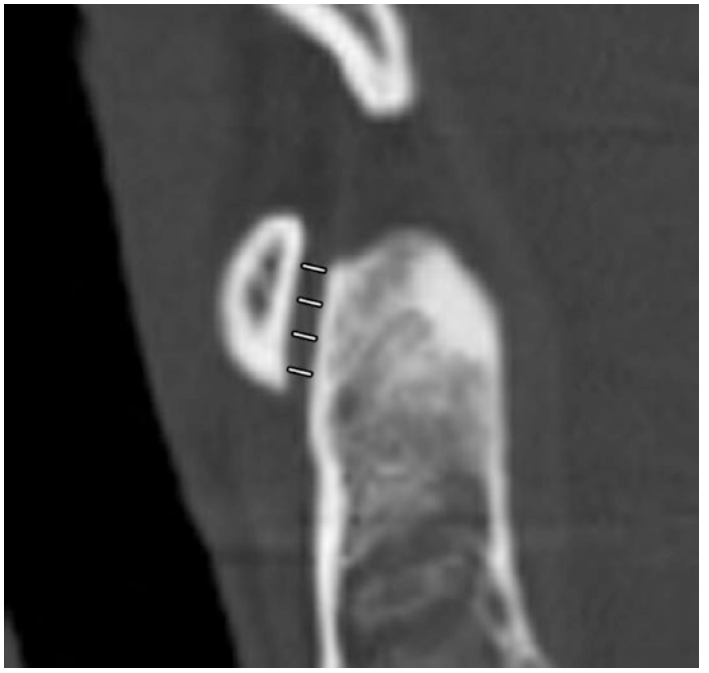

Fig. 5.13 Sagittal computed tomography (CT) image shows the atlanto-dens interval

aspect of the posterior arch of C1 by the distance from the tip of the opisthion to the midpoint of the posterior aspect of the anterior arch of C1 in the midline. It is used in the evaluation of atlanto-occipital dissociation and is considered normal when less than 1.

Practical Implications

- Congenital and acquired conditions that can manifest with abnormal craniocervical junction measurements include rheumatoid arthritis, osteomalacia, Paget disease, Chiari malformation, Klippel-Feil and Down syndromes, achondroplasia, mucopolysaccharidoses, osteogenesis imperfecta, as well as trauma.

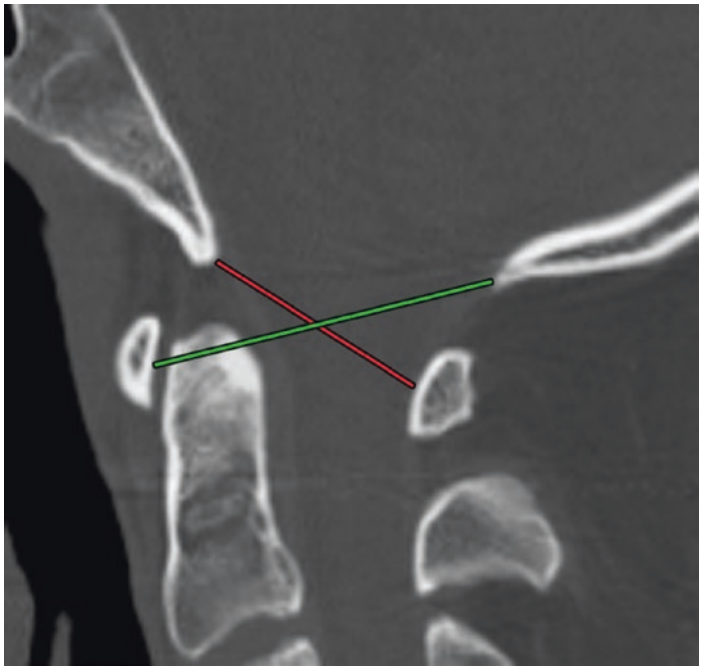

Fig. 5.14 Sagittal computed tomography (CT) image shows the lines between the tip of the basion to the midpoint of the anterior aspect of the posterior arch of C1 (red) and from the tip of the opisthion to the midpoint of the posterior aspect of the anterior arch of C1 (green) used to determine the Powers ratio

- Reference to craniocervical metrics is useful for identifying suspected cases of atlanto-axial separation (Fig. 5.15) and occipital-cervical dislocation (Fig. 5.16), which otherwise may not be accompanied by other abnormalities on CT, yet can be associated with a high rate of neurologic morbidity and mortality if undiagnosed.
- Basilar invagination refers to developmental anomalies of the craniovertebral junction in which the superior aspect of the odontoid extends above the foramen magnum, while basilar

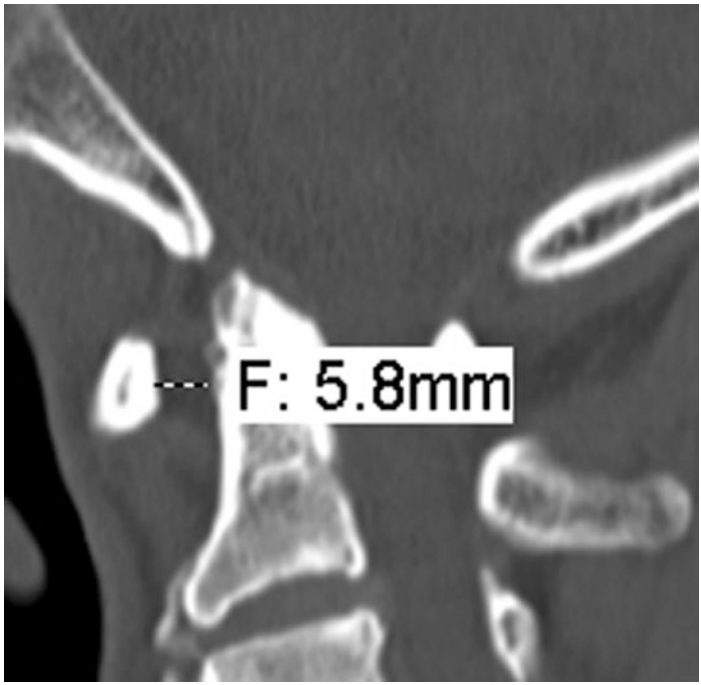

Fig. 5.15 Atlanto-axial separation. Sagittal computed tomography (CT) image shows widening of the atlanto-axial interval in a trauma patient

impression refers to acquired conditions of the craniovertebral junction in which the superior aspect of the odontoid extends above the foramen magnum (Fig. 5.17). This can be accompanied by compression of the spinal cord.

- Platybasia is flattening of the central skull base (Fig. 5.18). This can be accompanied by basilar invagination and other craniocervical junction abnormities. Given the altered anatomy, a transnasal approach may be preferable to a transcervical endoscopic approach for accessing the craniocervical junction in patients with platybasia.

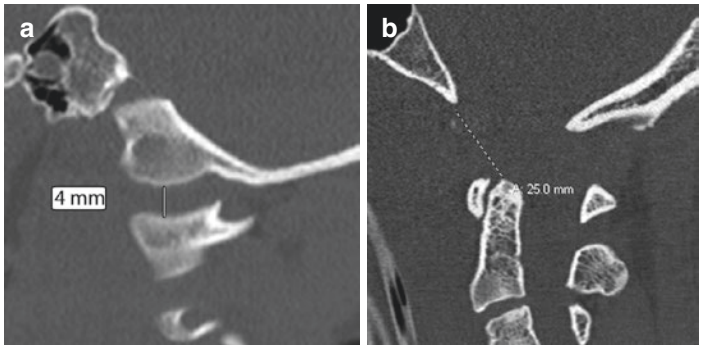

Fig. 5.16 Atlanto-occipital dislocation. Sagittal computed tomography (CT) image shows wide separation between the occipital condyle and lateral mass of C1 in a pediatric trauma patient (**a**) and widening of the basion-dens interval in an adult (**b**)

Fig. 5.17 Basilar invagination. Sagittal computed tomography (CT) image shows marked extension of the dens above the foramen magnum, well beyond the Wackenheim clivus line, in a patient with rheumatoid arthritis

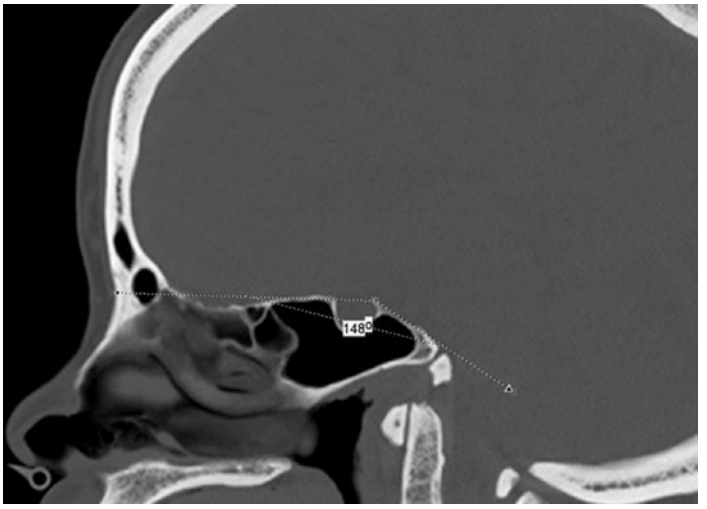

Fig. 5.18 Platybasia. Sagittal computed tomography (CT) image shows an obtuse basal angle and clival hypoplasia

Further Reading

Batista UC, Joaquim AF, Fernandes YB, Mathias RN, Ghizoni E, Tedeschi H. Computed tomography evaluation of the normal craniocervical junction craniometry in 100 asymptomatic patients. Neurosurg Focus. 2015;38(4):E5.

Bertozzi JC, Rojas CA, Martinez CR. Evaluation of the pediatric craniocervical junction on MDCT. AJR Am J Roentgenol. 2009;192(1):26–31.

Botelho RV, Ferreira ED. Angular craniometry in craniocervical junction malformation. Neurosurg Rev. 2013;36(4):603–10; discussion 610.

El-Sayed IH, Wu JC, Dhillon N, Ames CP, Mummaneni P. The importance of platybasia and the palatine line in patient selection for endonasal surgery of the craniocervical junction: a radiographic study of 12 patients. World Neurosurg. 2011;76(1–2):183–8; discussion 74–8.

Ji W, Wang XY, Xu HZ, Yang XD, Chi YL, Yang JS, Yan SF, Zheng JW, Chen ZX. The anatomic study of clival screw fixation for the craniovertebral region. Eur Spine J. 2012;21(8):1483–91.

Koenigsberg RA, Vakil N, Hong TA, Htaik T, Faerber E, Maiorano T, Dua M, Faro S, Gonzales C. Evaluation of platybasia with MR imaging. AJNR Am J Neuroradiol. 2005;26(1):89–92.

Rojas CA, Bertozzi JC, Martinez CR, Whitlow J. Reassessment of the craniocervical junction: normal values on CT. AJNR Am J Neuroradiol. 2007;28(9):1819–23. Epub 2007 Sep 24.

Singh AK, Fulton Z, Tiwari R, Zhang X, Lu L, Altmeyer WB, Tantiwongkosi B. Basion-cartilaginous dens interval: an imaging parameter for craniovertebral junction assessment in children. AJNR Am J Neuroradiol. 2017;38(12):2380–4.

Xu S, Gong R. Clivodens angle: a new diagnostic method for basilar invagination at computed tomography. Spine (Phila Pa 1976). 2016a;41(17):1365–71.

Xu S, Gong R. Clivus height value: a new diagnostic method for basilar invagination at CT. Clin Radiol. 2016b;71(11):1200.e1–5.