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Mid-Pontine Perpendicular Line (MPL) – A New Anatomical Reference Line Drawn on Mid-Sagittal MRI of Brain to Assess the Vertical Level of Floor of Pituitary Fossa (Sella Turcica) During TNTS Micro-Decompression of Pituitary Adenomas



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Abstract

Background and Objective: The assessment and grading of various vertical-levels of pituitary-floors in comparison to pons (Brain-stem) by drawing a new anatomical-line has not been studied earlier. The pituitary fossa floors are positioned at various vertical levels within sphenoid bone when observed on mid-sagittal MR-images of brain. An accurate pre-operative anatomical grading of level of pituitary-floor as high, medium or low by drawing Mid-Pontine Perpendicular-Line (MPL) on mid-sagittal MR-image brain is of significant value for direct surgical access to pituitary floor during micro-decompression of pituitary tumors *via* TNTS (Trans-Nasal-Trans-Sphenoidal)-route.

Methods and Materials: This retrospective-observational study was conducted on cranio-cerebral Magnetic-Resonance (MR) mid-sagittal-images of 342 cases of operated pituitary adenomas through Trans-Nasal Trans-Sphenoidal (TNTS) route from Jan 2014 to Dec 2023. On mid-sagittal MR-images of patient, sphenoid bone, pituitary fossa floor and pons were identified and Pontine-Line, Mid-Point of pons and Mid-Pontine Perpendicular Line (MPL) were drawn. The position of sellar-floor above or below the MPL was measured as high, medium or low.

Results: The analysis of imaging-measurements by marking Mid-Pontine Perpendicular-Line (MPL) of 342 pituitary-tumor patients revealed that 153(44.73%) had high pituitary (sellar)-floor, 115(33.62%) had medium pituitary (sellar)-floor and 74(21.63%) patients had a low pituitary (sellar)-floor. There were 17(4.97%) children, 167(48.83%) male-patients and 158(46.19%) females. The youngest male was 10-years and oldest 80-years. The youngest female was 12-years and oldest 72-years.

Conclusion: The precise preoperative anatomical knowledge about position of pituitary floor in relation to Mid-pontine Perpendicular-Line (MPL), whether high, medium or low, shall be of significant Surgical-value during TNTS procedures to access and decompress pituitary-tumors endoscopically or/and microscopically with better-outcome.

Keywords: Pituitary Fossa Floor Types; Mid-Pontine Perpendicular Line (MPL); Sagittal-MRI Brain

Highlights

- The analysis of MRI-Brain of 342 pituitary tumor patients operated via TNTS revealed different levels of pituitary fossa floors.
- The pons, as a reference point on the sagittal MRI-Brain, stood fixed in comparison to the changing positions of pituitary floor.
- Three types of floors noted were high, medium and low by marking a New Reference Line, called Mid-Pontine Perpendicular Line (PML).

• 153 (44.73%) patients had high pituitary (sellar) floor, 115 (33.62%) patients had medium pituitary (sellar) floor and 74 (21.63%) patients had a low pituitary (sellar) floor.

• There were 17 (4.97%) children, 167 (48.83%) male patients and 158 (46.19%) females.

Summary

The pituitary tumors originate from the pituitary gland at the base of skull within the cavity of sphenoid bone called sella turcica or pituitary fossa. However, there are many variations in the positions of these pituitary fossae and their floors in the level at which these are positioned in the sphenoid bone. The floor of the pituitary fossa is approached through nose to remove the pituitary tumors endoscopically and/or microscopically. The nasal septum is a guide for neurosurgeons to reach the sphenoid bone and its sinus. Once the sinus floor and the sinus Ostiae are identified, the pituitary floor is approached to remove the tumor. But the access to the pituitary floor is many times difficult due to the positioning of the pituitary fossa floor at different levels. If the level of the floor will be known before the start of the surgery, the access of trajectory from the nostril to the pituitary floor shall be fixed at a calculated angle. The common way to visualize the fossa and floor is by fluoroscopy (*X*-Rays). Being an invasive (*X*-Ray) option, the only other way to do it is to know the position of pituitary fossa floor level along with its lesion in relation to a reference point like pons (brain stem) which is fixed on the clivus. This is well depicted by the routine investigation MRI brain which detects the tumor. A newly devised line (Mid-pontine Perpendicular-Line) drawn from the mid-point of pons across the sphenoid bone shall mark the distance between pons and the pituitary fossa floor and thus the level whether high, medium or low type.

Introduction

The pituitary Fossa (sella turcica - Turkish-saddle) is a saddle-shaped depression in the body of the sphenoid bone that houses the pituitary gland [1]. The word clivus in Latin means slope [2]. The synchondrosis of sphenoid and basilar occipital bones forms the clivus with superior basilar and inferior pharyngeal surfaces. The clivus is just behind the sphenoid sinus [3]. The surgical importance of clivus lies in the extended endoscopic endonasal approaches for its benign and malignant lesions [4]. The anatomical relation of the floor of pituitary fossa (sellar floor) to the Mid-pontine Perpendicular Line (MPL) from pons, as seen on the mid-sagittal MR T1, T2 W image, is a vital surgical milestone during TNTS procedures for the correct surgical trajectory to access the pituitary fossa tumors. The vertical level of the pituitary floor of each patient varies in relation to pons (brain stem). The lateral view cranial radiographs depict the bony sella and the clivus closely related antero-posteriorly, however high-resolution Cranial CT with 3D reconstruction reveals better surrounding structural positions and relations with different densities. But the sagittal MR T1, T2 weighted images are the best to identify structural and tissue morphology in clear dimensions with different intensities. The observations in the present retrospective study revealed high, medium and low levels of pituitary fossa floors in relation to a newly drawn anatomical line called Mid-pontine Perpendicular Line (MPL).

Methods and Materials

This observational study of cranio-cerebral mid-sagittal MR (Magnetic Resonance) imaging of 342 cases of operated pituitary adenomas via TNTS (Trans-Nasal Trans-Sphenoidal) route from Jan 2014 to Dec 2023 (over a period of 10 years) was carried out retrospectively in the department of neurosurgery (Table 1). All patients had absolute lateral basal cranial radiographs, CT brain with 3D reconstruction and MRI brain with standard pituitary protocol. Based on the fixed position of the pontine brain stem, resting on the dorsal surface of the clivus and serving as a reference point, the level of positions of pituitary fossa floors were assessed in relation to the Mid-pontine Perpendicular Line (MPL) of the pons on mid-sagittal MR images and categorized as high, medium and low sellar floors. Most prominent part of the brainstem, the pons is about 26 to 30 mms in height (length) on the mid-sagittal MR image and approximately 38 mms in transverse (width) on coronal image. The pons is about 16mm antero-posteriorly in axial view. The pituitary fossa (sella turcica) typically measures 5 to 16 mm in antero-posterior length, 4 to 12 mm in vertical height (depth) and 9 to 21 mm in width. The size of the sella turcica appears to increase with age and stabilizes by 18 years of age [5]. The pituitary gland usually has a height of 6 to 10 mm and a total volume of 400 to 500 mm^3. Analysis of a morphometric study on 400 patients found that the mean antero-posterior diameter, length and depth of sella turcica were 10.13 mm, 9.51 mm and 7.39 mm respectively [6]. However, authors reported the overall midpoint height of the sella turcica was 6.59 mm (SE = 0.13), overall length was 9.06 mm (SE = 0.15) and the overall volume of 845.80 mm^3 (SE = 288.92) [1]. The pituitary gland tumors usually reach the floor of the pituitary fossa, inside the sella turcica, leaving no potential space between the dura and the bone, thus compressing the dura against the bony floor of the fossa, lamina dura, which forms a part of the roof of sphenoid sinus (Figure 1).

Mid-pontine Perpendicular Line (MPL) and the types of pituitary fossa (sellar) floor

In the present retrospective study, a Pontine Line was drawn on the pons from the ponto-mesencephalic sulcus to the ponto-medullary sulcus on a Mid-Sagittal MR image (Figure 2). The Mid-Point of the pons was fixed on the middle of this Pontine Line (Figure 3). Then a perpendicular (horizontal) line, called Mid-pontine Perpendicular Line (MPL), was drawn forwards anteriorly across the sphenoid bone from the Mid-Point of the pons (Figure 4). The MPL was marked as the reference anatomical line for the assessment of the level of position of the sellar floor in the mid-sagittal image. When the pituitary fossa floor (tip) reached to the MPL (Mid-pontine Perpendicular Line), it was called as the medium pituitary fossa floor. The pituitary fossa with its floor above this line (in millimeters -mm) was grouped as high and below the line (in mm) as low pituitary fossa floor (Figure 5a-c, 6, 7a-c). However pituitary fossa floors of both high and low levels were re-grouped as high or low up to 6mm, 7-10 mm and more than 10 mms high (above the MPL) or low (below the MPL) (Table 2, Figure 5a-c, 6, 7a-c). All measurements were carried out in the mid sagittal plane of MR T1, T2 images. The observations were analyzed, compiled and inferences drawn. The statistical law of variance was applied wherever necessary. The patients who presented with recurrences after the primary decompression of pituitary tumors *via* TNTS were excluded from the study, for the apprehensions of developing false pituitary floors. All other tumors and lesions of sellar and parasellar region like craniopharyngiomas, Rathke's cleft cyst, aneurysms and Empty sella syndrome etc., were excluded from the study. The patients of pituitary adenomas with craniofacial anomalies, spina bifida, Down's syndrome and Seckel's syndrome (dwarfism with severe microcephaly), due to the possible influence of

Table 1: Age (years) and sex distribution of 342 cases of operated pituitary adenomas.

Age group in yrs./Sex	10-20	21-30	31-40	41-50	51-60	61-70	71-80	Total
Males	09	28	41	43	28	24	03	176 (51.46%)
Females	08	21	43	58	30	05	01	166 (48.53%)
Total	17 (4.97%)	49	84 (24.56%)	101 (29.53%)	58 (16.95%)	29	04	342

*Youngest; male - 10 yrs and female - 12 yrs
*Oldest; male - 80 yrs and female - 72 yrs

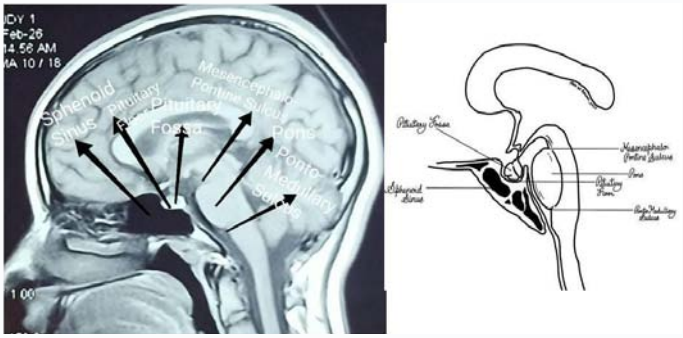


Figure 1: T1W image of MR brain sagittal view and the Sketch diagram shows related structures Sphenoid bone, Sphenoid sinus, Sella turcica, Pituitary gland, Clivus and Brain stem at the Base of Skull.

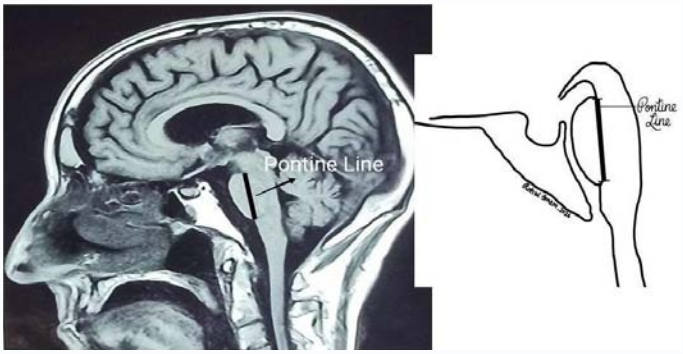


Figure 2: Sagittal MRI brain and the Sketch diagram depict the Pontine Line drawn between Mesencephalo-Pontine Sulcus and Ponto- Medullary Sulcus.

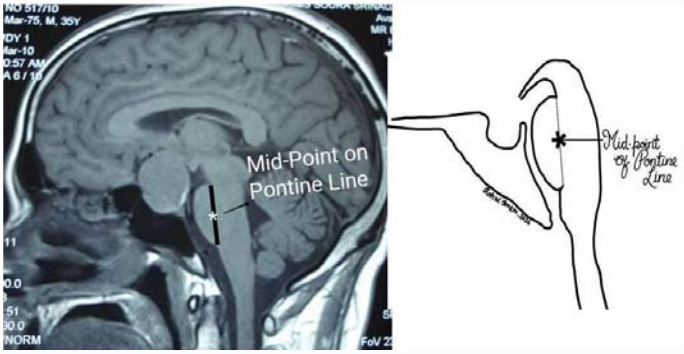


Figure 3: The Mid-Point on pontine line is shown in the Sagittal MRI brain and in the sketch diagram.

these anomalies on the shape and structure of sella turcica, were also excluded from the study.

Results

The study comprised of assessment of types of levels of pituitary fossa floors by Mid-pontine Perpendicular Line (MPL) marked on the mid-sagittal MR imaging of a total 342 pituitary tumor patients, each operated first time for the tumor decompression *via* TNTS route. Three types of sellar floor levels were noted as high, medium and low floors. There were 167 (48.83%) males, 158 (46.19%) females and 17 (4.97%) children. The age-group most involved, with 71.04% (243/342) patients, was 30-60 years and in this age-group there was a predominance of females with 38.29% (131/342) patients. The youngest male patient was a 10 years boy and oldest 80 years, while

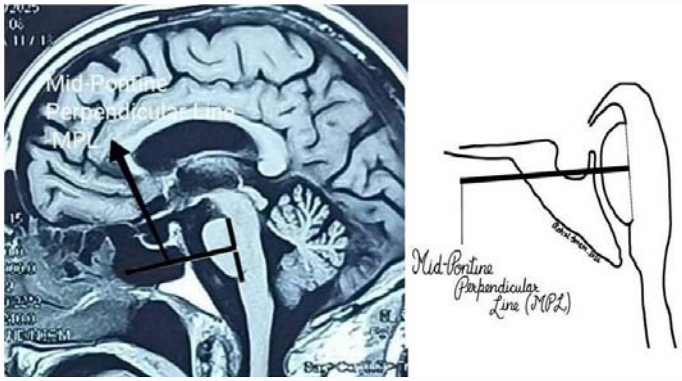


Figure 4: Mid-pontine Perpendicular Line (MPL) drawn from the mid-point on the pontine line across pons, clivus and sphenoid sinus as shown on sagittal MRI brain and in the sketch diagram.

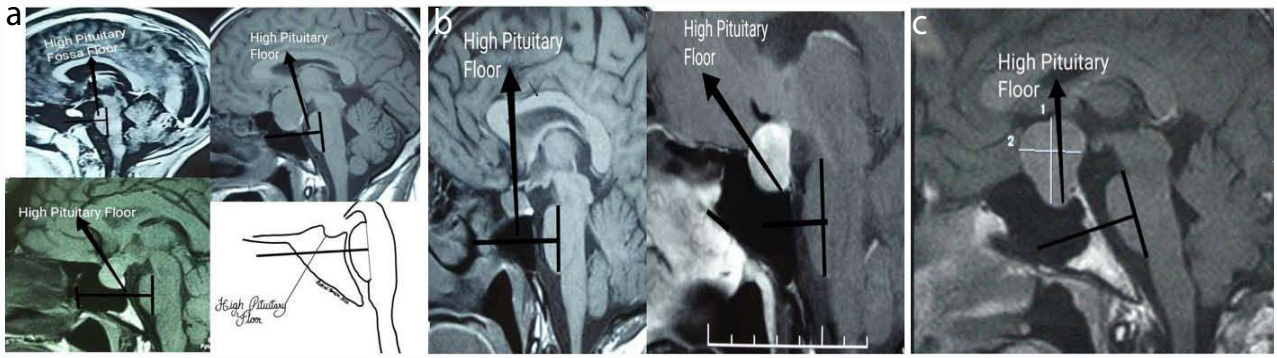


Figure 5: a) MRI brain and sketch diagram shows high type pituitary floors up to 6 mms above MPL; **b)** MR T1W sagittal planes of brain reveal as high as 7 to 10 mms pituitary floors above Mid-pontine Perpendicular Line (MPL) and **c)** Sagittal MRI brain shows high type pituitary floor, 11mms above MPL.

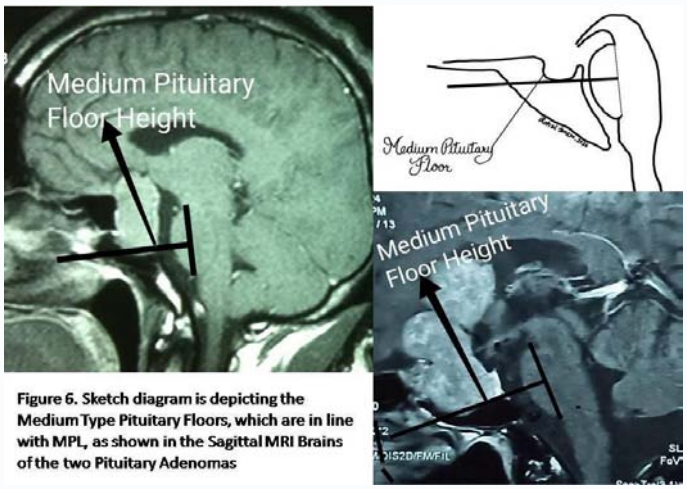


Figure 6: Sketch diagram is depicting the medium type pituitary floors, which are in line with MPL, as shown in the sagittal MRI brains of the two pituitary adenomas.

as the youngest female patient was a 12 years girl and the oldest 72 years. Among 153 (44.73%) patients with high sellar floor, about 64 (18.71%) had sellar floor up to 6 mm above mid-pontine line (MPL), 52 (15.20%) had 7-10 mm above MPL and 37 (10.81%) patients were with a sellar floor more than 10mm above MPL (Figure 5a-c). However, 115 (33.62%) patients had medium sellar floor which were positioned in line with the MPL (Figure 6). While 74 (21.63%) patients had a low sellar floor, of which 33 (9.64%) had a sellar floor up to 6mm below MPL, 23 (6.72%) patients with sellar floor 7-10mm below MPL and 18 (5.26%) had sellar floor more than 10mm below the mid-pontine line (Figure 7a-c). Overall, the most, 116 (33.91%), of the patients with high sellar floors had floors up to 10 mm above MPL while as fewer, 37 (10.81%), had pituitary floors more than 10 mm above MPL. Similarly low sellar floors up to 10 mm below MPL were found in 56 (16.36%) while pituitary floors more than 10mm below MPL were found in 18 (5.26%) patients. The high sellar floor was most common type, existing in a little lesser than half of all the patients while as the medium sellar floor was found in about one-

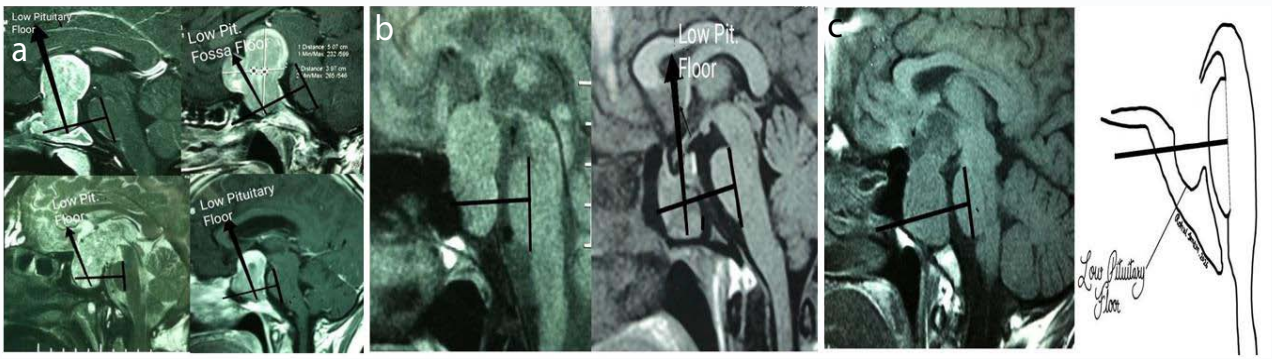


Figure 7: a) Sagittal MRI brains show low type pituitary floors, up to 6 mm below Mid-pontine Perpendicular Line (MPL); **b)** Low type pituitary floors, 7 to 10 mms below the Mid-pontine Perpendicular Line (MPL), are revealed in the two mid-sagittal planes of MRI brain in two patients of pituitary adenomas and **c)** Mid-sagittal MR T1WI brain and sketch diagram depicts the low type pituitary floor, 12 mms below Mid-pontine Perpendicular Line (MPL).

Table 2: Anatomical types of pituitary fossa (Sellar) floors in relation to Mid-pontine Perpendicular Line (MPL).

Level of Pituitary floor (mm)		No. and Gender of patients			Total	
		Male	Female	Children		
High (above MPL)	Up to 6 mm	31	29	4	64	153 (44.73%)
	7-10 mm	20	27	5	52	
	>10 mm	16	18	3	37	
Medium (In line with MPL)	In line with MPL	62	49	4	115	115 (33.62%)
Low (below MPL)	Up to 6 mm	18	14	1	33	74 (21.63%)
	7-10 mm	12	11	0	23	
	>10 mm	08	10	0	18	
Total		167(48.83%)	158(46.19%)	17(4.97%)	342	342

*MPL = Mid-pontine Perpendicular Line
*Youngest; male - 10 yrs and female - 12 yrs
*Oldest; male - 80 yrs and female - 72 yrs

third of all the pituitary tumors (Table 2).

Discussion

This observational retrospective study was carried out on the sagittal images of 342 patients of pituitary adenomas, including 17 (4.97%) children, operated via TNTS route in the department of neurosurgery under a standard protocol over a period of 10 years. It revealed high, medium and low positional variations in the floor of pituitary fossa. Some authors undertook a systematic review and meta-analysis involving 18,364 patients, reporting four sella turcica shapes in which the most commonly occurring variants are the normal ST (sella turcica) 55.56%, the U-shaped 73.58%, the circular type 42.29% and non-bridging 55.64% sella turcica. Authors assert that various morphometric characteristics of the ST may be applied in clinical practice to evaluate its shape, dimensions, and normal or pathological variants [1]. The present study measured the level of position of the sellar (pituitary) floors in the sphenoid bone in relation to the Mid-pontine Perpendicular Line (MPL) from the pons and found three types of sellar floor levels. The authors of a study noted atypical sella shapes such as J-shaped, deep and flattened dorsum sellae in individuals with craniofacial syndromes including Down syndrome, William's syndrome and Axenfeld-Rieger syndrome [7]. The authors linked these anomalies to disrupted sphenoid ossification and neural crest migration, which is supported by the embryological models from a histological study [8]. In a CT-based study it was found that most pneumatizations originated from the sphenoid sinus (81.8%), while pneumatization of the anterior clinoid process was noted in 9.2% individuals and some extending from the ethmoid sinus (10.9%) [9]. The present study found high sellar floors in 153 (44.73%), medium in 115 (33.62%) and low sellar floors in 74 (21.63%) patients. All the operated patients of pituitary adenomas *via* TNTS route with recurrences, patients with abnormal craniofacial syndromes or with disproportionate features of base of skull were excluded from the study. A morphometric study was conducted on 2726 skulls and found clinically relevant middle clinoid processes in 42% of specimens and classified these into three categories. These were Incomplete (69% of all middle clinoid processes), Carotico-clinoid Ring (27%) where middle clinoid processes join the anterior clinoid process without forming a true ring and Contact (4%) as bony projections [10]. Authors of a study reported on the variations in posterior clinoid processes based on 100 dry human skulls. The posterior clinoid process was classified as normal (78%), elongated (16%) and pneumatized (6%) [11]. The present study revealed that most, 33.91%, of the patients with high sellar floors variations had floors up to 10 mm above MPL while as fewer, 10.81%, had pituitary floors more than 10 mm above MPL. Similarly low sellar floors up to 10 mm below MPL were found in 16.36% while pituitary floors more than 10mm below MPL were found in 5.26% patients (Table 2). It is reported that sellar bridges, which are osseous connections between the clinoid processes of the sphenoid bone and represent important anatomical variants, typically are formed through the ossification of intracranial ligaments and include the Carotico-Clinoid Bridge (CCB) and Inter-Clinoid Bridge (ICB). These bridges host additional foramina that guide neurovascular structures and neurosurgical

approaches to the skull base [12]. It is revealed in a study that a statistically significant difference occurs between the linear dimensions of the two genders with significant linear correlation between age and the dimensions of sella turcica below 18 years of age [6]. The study concluded that the results obtained could be utilized as normative data of sella turcica for Indian population. The highest number of persons belonged to the age group 26-40 years, comprising 41.5 % males and 42% females respectively. The youngest male in the study group was aged 2 years and the oldest male in the study group was aged 93 years. The shape of the sella turcica can be classified into three groups- U shape in which the tuberculum and dorsum sellae are at the same height (55%), J shape where the tuberculum is lower than dorsum sella (25%) and shallow (20%) where the depth is minimum [6]. The present study comprised of 167 (48.83%) males, 158 (46.19%) females and 17 (4.97%) children. The age-group most involved, with 243 (71.04%) patients, was 30-60 years and in this age-group there was a predominance of females with 131 (38.29%) patients. The youngest male patient was 10 years and the oldest was 80 years, while as the youngest female patient was 12 years and the oldest 72 years. The shapes and sizes of sella have been reported in studies on Saudi and Greek subjects with different skeletal types on lateral cephalometric radiographs. The five morphological variants described include oblique anterior wall, bridging of sella turcica, double contour of the floor, irregularity in the posterior part of the floor and pyramidal shape of the dorsum sella. These studies also found increase in size of sella turcica on lateral cephalometric radiographs in patients leading to an incidental diagnosis of pituitary adenoma [13-15]. Several authors reported that the shape of the sella may be altered in conditions like spina bifida, Down's syndrome and Seckel's syndrome. These abnormalities in shape of sella turcica were detected antenatally in foetuses [16-18]. The present study found that 115 (33.62%) patients had medium sellar floor which were positioned in line with the MPL (Figure 6). A study reported empty sella syndrome, Rathke's cleft cyst and aneurysms in the vicinity of sellar region, as other causes of enlarged sellar dimensions [19]. However, a small sized sella may be seen in or as a consequence of primary hypopituitarism, Sheehan's syndrome (post-partum pituitary necrosis) and other causes of pituitary apoplexy [20]. It is reported that the size of sella turcica on lateral cephalometric radiographs was studied in Norwegian population aged 6-21 years. They found that while the length of the sella turcica was almost constant, the diameter and height increased with age. They did not find any difference between males and females with respect to the depth and diameter of sella turcica. However, length was found to be larger in males [21]. A study on 180 Saudi patients described the shape and size of sella turcica and found that the linear dimensions obtained were 2.02 to 2.73 mm larger than that obtained in the Norwegian group. The report did not find any statistically significant difference between the two genders and found larger sella sizes in older age groups [15, 21]. In the present study 153 (44.73%) patients with high sellar floor, about 64 (18.71%) had sellar floor 3-6 mm above Mid-pontine Perpendicular Line (MPL) and 52 (15.20%) had 7-10 mm floor above MPL. In a similar study on 184 Greek subjects with age range of 6-17 years, authors provided quantitative data for the objective assessment of shape of the sella turcica in addition to the linear dimensions. Only anterior sella height was found to be significantly different in their study, being larger in females. They also found a statistically significant correlation between age and size of the sella, with size of the sella increasing with age [5]. In South Indian population, a study found average length and depth of sella turcica as 9.15 mm and 7.3 mm but a statistically significant difference in length of sella turcica between males and females [22]. In a recently performed morphometric study of the sella turcica, using computed tomography, reporters found that the average length was 10.3 mm and the depth 6.3 mm. the computed tomography has higher contrast resolution compared to lateral cephalometric radiographs allowing easier and accurate measurements. Capability of multi-dimensional reconstruction has helped in minimizing the effects of patient position on the plane of image used for the measurement [23]. While 74 (21.63%) patients in present study had a low sellar floor out of which about 33 (9.64%) had a sellar floor 3-6mm below MPL and 23 (6.72%) patients had a sellar floor 7-10 mm below MPL. This study confirmed the reports of the several above studies that the variations in the size and structure of the sphenoid bone containing pituitary (sellar) fossa with its floor are found in the different populations and different ages.

Conclusion

The measurements of the sellar (pituitary) floor by the lateral cephalometric radiographs along with 3D-CT and reconstruction has been of immense value in the past for many decades but the cranio-cerebral MRI in all planes has increased the significance of these measurements and structural morphologies multifold. The present study explores the accurate pre-operative anatomical relations between the positions of pituitary (sellar) floor and the Mid-pontine Perpendicular Line (MPL), a Noval anatomical line drawn from the mid-point of fixed pons (brain stem) on the clivus, which revealed three types of pituitary fossa (sellar) floor levels as high, medium and low. This shall be of significant value during TNTS procedure of a particular patient to accurately access and decompress the pituitary tumors endoscopically and/or microscopically with good results. The advantage of assessing the type of level of pituitary floor is specific to MR image of a specific patient not a general rule for all patients. Although the study was limited to only pituitary adenoma patients, a community study may be a future trend.

Compliance with Ethical Guidelines

Ethical Code/NEW/INST/2021/1556. Institutional Ethical Committee Sher -i- Kashmir Institute of Medical Sciences (SKIMS), Srinagar, Kashmir, India.

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Author Contributions

Conception and design; ARB and RUI. Data Collection; RUI and SUI. Data Analysis and Interpretation: ARB and SUI. Drafting the article: ARB and RUI. Critically revising the article: ARB, RUI and SUI.

Reviewing submitted version of manuscript: ARB and SUI. Approving the final version of the manuscript: All authors have approved the final version of the manuscript.

Conflict of Interest

None.

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