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Original Article

The Prevalence of the Middle Clinoid Process: A Cross-Sectional Comparative Study in Patients with and without Pathology of the Sella Turcica

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Abstract

Background The middle clinoid process (MCP), particularly caroticoclinoid ring (CCR) type of the MCP, is an important part of the sphenoid bone for skull base surgery. Previous studies have shown a wide range of MCP prevalence affected by various factors. However, no study has investigated the association between the MCP and the presence of sellar lesions.

Objectives The main aim of this study was to evaluate the prevalence of the MCP in the Thai population and factors associated with its presence.

Materials and Methods We conducted a cross-sectional study on 400 sides from 200 patients (100 with and 100 without sellar lesions) using cranial computerized tomography scans. Demographic data and MCP characteristics were collected. The association between individual variables and the presence of the MCP was determined by univariate and multivariate analysis.

Results The MCP was identified in 168 of 400 sides (42%). Patients with sellar lesions had a significantly lower prevalence of the MCP compared with normal controls (29.5% versus 54.5%, $p < 0.001$). Of all MCP only 6% were the CCR type. Univariate and multivariate analysis showed that the absence of the sellar lesion was the only factor significantly associated with presence of the MCP (odds ratio: 2.86; 95% confidence interval: 1.90–4.32; $p < 0.001$).

Conclusion The prevalence of the MCP was relatively high in the Thai population, while the prevalence of the CCR was relatively low compared with previous studies. The absence of sellar lesions was the only factor associated with the presence of the MCP.

Keywords
- middle clinoid process
- caroticoclinoid ring
- prevalence
- skull base surgery
- cranial computerized tomography

Introduction

Anatomical knowledge is crucial for ensuring safe neurosurgical operations, particularly when dealing with skull base lesions that involve critical neurovascular structures. One such important landmark is the middle clinoid process (MCP), a small bony projection located near the anterolateral margin of the sella turcica on the sphenoid bone.[1–11] In ventral skull base approaches, such as endonasal transsphenoidal surgery, the MCP serves as a landmark for the

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anteromedial roof of the cavernous sinus. The base of the MCP is located just medial to the anterior genu of the cavernous segment of the internal carotid artery (ICA), while its tip is projected posterior to the genu, between the intracavernous and paraclinoidal segments of the ICA, toward the tip of the anterior clinoid process (ACP). The surgical removal of the MCP, known as middle clinoidectomy, enhances access to the parasellar region, including the cavernous sinus, and provides a more adequate exposure of the sellar turcica. However, performing this step of the skull base procedure requires meticulous surgical techniques and precise anatomical knowledge to avoid ICA injury.[2–4,10]

Additionally, the MCP may vary in size, with an important variant being the caroticoclinoid ring (CCR). The MCP is continuous with the ACP, forming an osseous ring surrounding the ICA, commonly referred to as the CCR. When performing anterior clinoidectomy from the transcranial approach or middle clinoidectomy from the transsphenoidal approach, it is crucial to identify the presence of the CCR preoperatively to avoid ICA injury caused by excessive manipulation or fracture of the CCR.[1–17]

Previous anatomical studies have reported a variety in the prevalence of the MCP. Many factors, such as race, gender, and age of the studied population, may cause differences in prevalence.[1–8,10–22] Furthermore, most previous anatomical studies were conducted in the normal population, whereas pathology around the sellar region could largely affect bony anatomy. Previous anatomical studies have indicated that the presence of a sellar lesion can impact normal structures, thereby influencing surgical planning.[23] In this study, the authors aimed to investigate the prevalence of the MCP in Thai patients, both with and without pathology of the sella turcica. Factors associated with the presence of the MCP were also studied.

Materials and Methods

The authors conducted a cross-sectional study to determine the prevalence the MCP in a patient population with and without sellar lesions. The study included 200 patients who were older than 18 years and treated at our institute from January 2018 to December 2022. Of 200 patients, 100 had sellar lesions, while the remaining 100 had no sellar lesion. All 100 patients with sellar lesions underwent preoperative cranial computerized tomography (CT) and were surgically treated at Siriraj Hospital. The other group of 100 patients without sellar lesions included patients presenting with headaches or head injuries, and cranial CT was performed for all these patients. Patients with a history of previous surgery or radiation therapy in the sellar region, recurrent sellar lesions, skull base fractures, or skull base defects due to any causes were excluded from the study.

The collected data were as follows.

1. Demographic characteristics, including age, gender, presence of sellar lesions, and type of sellar lesion.
2. Radiographic study of MCP. This was performed on bone window sequence of thin slice (1.25 mm or less) cranial CT in axial and sagittal planes. The MCP was clearly discriminated from the lateral portion of the tuberculum sellae through inspection on both planes. The results of the study of MCP on cranial CT were categorized into absence **(►Fig. 1)** and presence of MCP. In cases with the presence of MCP, the types of MCP were further classified into incomplete type of MCP (►**Fig. 2**), and CCR (complete type of MCP; ►**Fig. 3**). The incomplete type of MCP was defined as the presence of MCP on cranial CT, but the tip of MCP did not extend to attach to the ACP. On the other hand, the CCR was defined as presence of MCP on cranial CT with an extension of the tip of MCP to the ACP, resulting in a complete ring of bone around the ICA.
3. The characteristics of the MCP were independently classified by two authors (C.T. and S.A.), who were blinded to each other's assessments. In cases of discordant results between the authors, they engaged in discussion to resolve any discrepancies. The prevalence of the MCP in groups with and without sellar lesions, along with factors correlating to the presence of the MCP, was thoroughly investigated. This study received approval from the Institutional Review Board.

Statistical Analysis

The collected data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 25.0. Descriptive statistics were used to describe the demographic characteristics of the patients. Age was presented as either mean and standard deviation or the median and range (min, max), while qualitative data (gender, sellar pathology, and type of the MCP) were reported as number or percentages.

For the univariate analysis of the correlation between individual variables and the presence of the MCP, either the chi-squared or Fisher's exact test was used for categorical data, and the independent sample Mann–Whitney U test was used for numerical data. The strength of association was calculated by using odds ratio (OR) and 95% confidence interval (95% CI). A p-value of less than 0.05 was considered statistically significant. To address collinearity, multiple linear regression analysis was conducted. Parameters showing collinearity, defined as tolerance less than 0.2, and variance inflation factor greater than 5, were excluded from the binary logistic regression analysis.

Results

Patient Characteristics

Two hundred patients were enrolled in the study, including 100 with sellar lesions and 100 without sellar lesion. The median age of the participants was 52 years (range: 18–100). Among the 200 cases, 89 (44.5%) were male and 111 (55.5%) were female. The observed sellar lesions consisted of 53 (53%) pituitary adenomas, 28 (28%) meningiomas, 4 (4%) craniopharyngiomas, and 14 (14%) other types of lesions. The MCP was found in 168 (42%) of the 400 analyzed sides. Of all MCP cases, 158 (94%) were of the incomplete type and 10 (6%) were the CCR (complete type of the MCP). The average

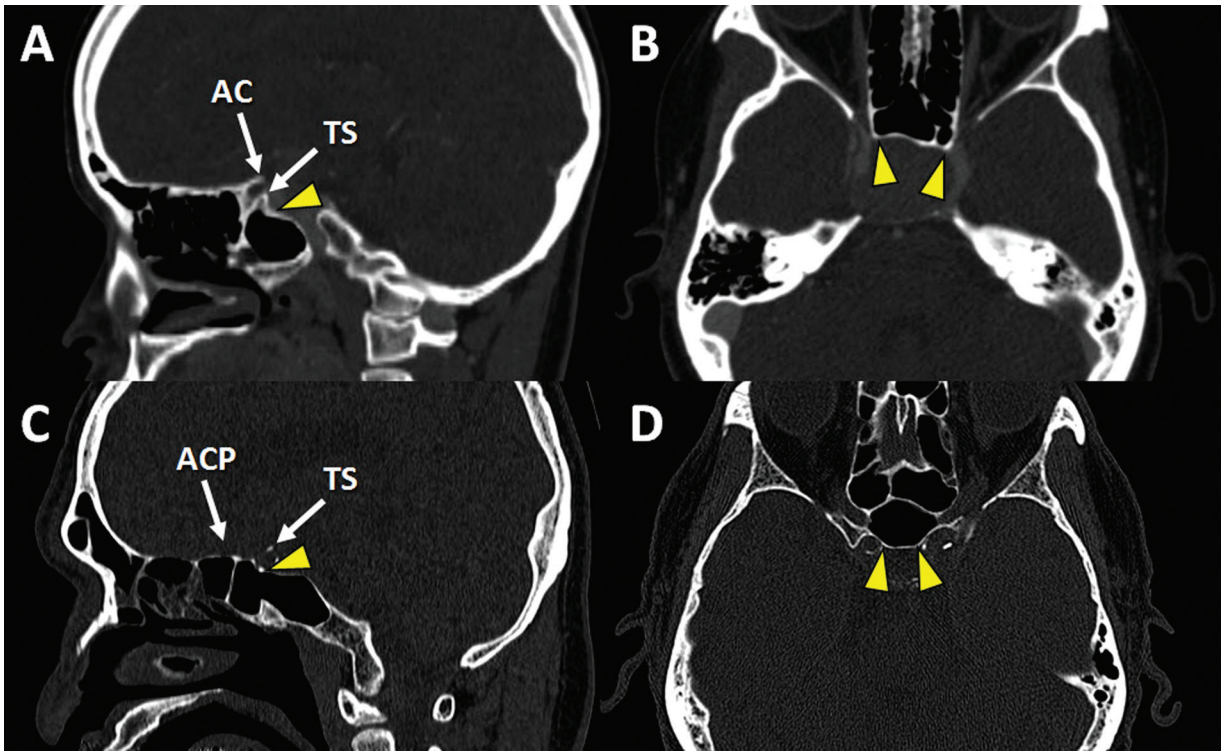

Fig. 1 Bone window of cranial computed tomography showing the absence of middle clinoid process (arrowhead) in a patient with a pituitary adenoma in sagittal (**A**) and axial planes (**B**), and in a patient without sellar lesion in sagittal (**C**) and axial planes (**D**). ACP, anterior clinoid process; TS, tuberculum sellae.

length of the MCP was 1.2 mm. Of all MCP cases, 10 (6%) cases have length more than 2 mm.

When comparing demographic variables between the groups with and without sellar lesions using univariate analysis, age and the presence of the MCP showed statistically significant differences ($p < 0.001$ and $p < 0.001$, respectively). However, there was no statistically significant difference in terms of gender, types of the MCP, and presence of the CCR between both groups (►**Table 1**).

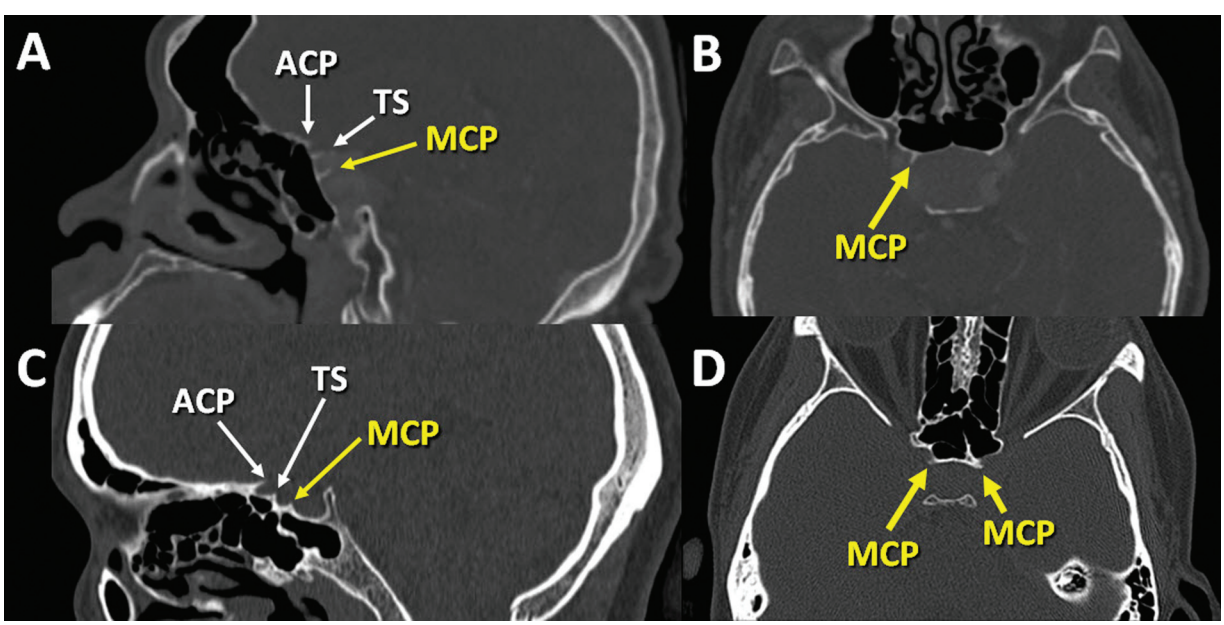

Fig. 2 Bone window of cranial computed tomography showing the incomplete type of MCP in a patient with a pituitary adenoma in sagittal (**A**) and axial planes (**B**), and in a patient without sellar lesion in sagittal (**C**) and axial planes (**D**). ACP, anterior clinoid process; MCP, middle clinoid process; TS, tuberculum sellae.

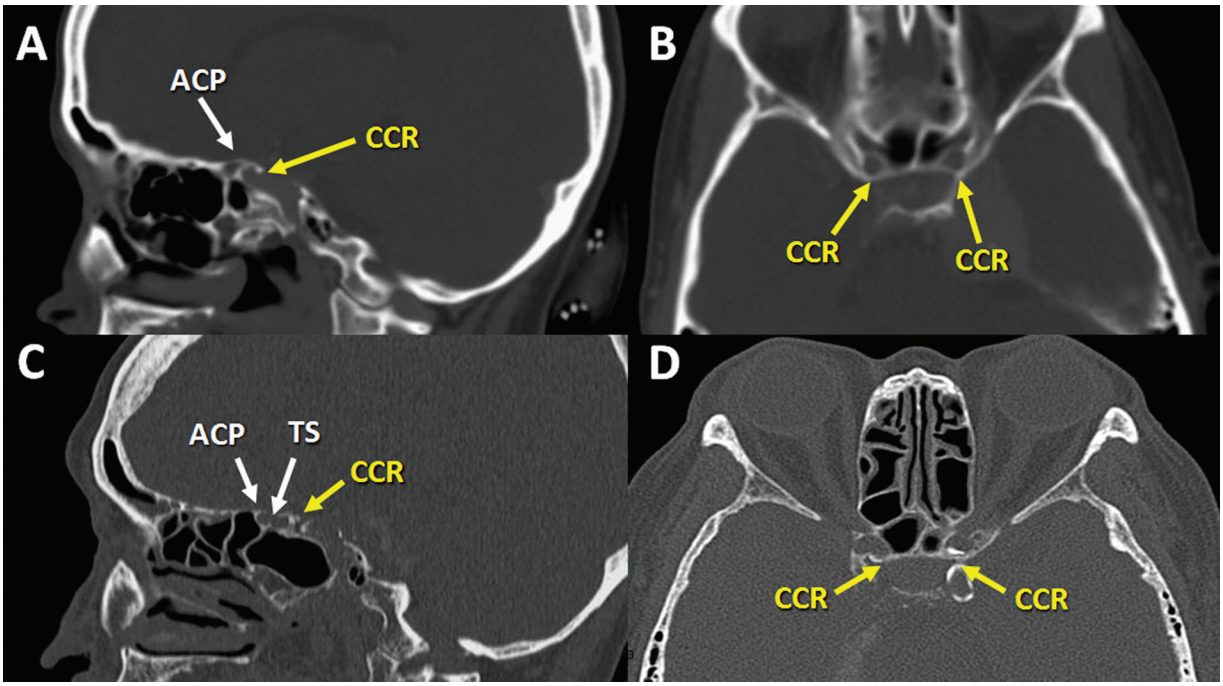

Fig. 3 Bone window of cranial computed tomography showing CCR (complete type of middle clinoid process) in a patient with pituitary adenoma in sagittal (**A**) and axial planes (**B**), and in a patient without sellar lesion in sagittal (**C**) and axial planes (**D**). ACP, anterior clinoid process; CCR, caroticoclinoid ring; TS, tuberculum sellae.

Factors Correlating with Presence of the MCP

Univariate analysis showed that the absence of a sellar lesion was the sole factor significantly associated with the presence of the MCP (OR: 2.86 (95% CI: 1.90–4.32), $p < 0.001$; ►**Table 2**). Multivariate analysis further confirmed that the absence of a sellar lesion remained significantly associated with the presence of the MCP (adjusted OR: 2.86; 95% CI: 1.90–4.32; $p < 0.001$; ►**Table 3**).

Discussion

In the field of neurosurgical techniques for skull base surgery, significant advancements have been made in dealing with extensive skull base lesions, both transcranially and endoscopically. These techniques have become widespread globally due to the globalization of neurosurgical education. However, some anatomical variances may still pose challenges for neurosurgeons, especially those with less experience. The MCP is one such anatomical structure that has received less attention compared with others, such as the ACP.[1–11] During ventral skull base approaches, the MCP can serve as a crucial landmark for identifying the anteromedial roof of the cavernous sinus. In cases requiring surgical accessing the parasellar region, middle clinoidectomy is required. Moreover, when the MCP is present, it can vary in size, with the CCR being an important variant. The CCR connects the MCP to the ACP, forming an osseous ring surrounding the ICA that can be vulnerable to injury during surgical manipulation or fracture of the CCR. Cases involving a prominent MCP or the presence of the CCR demand careful interpretation of imaging studies and meticulous surgical techniques.[2–4,10,17]

Most studies on the MCP were anatomical studies using dried human skulls or cadavers.[1,3,5–8,10–12,14,15,18–21] In contrast, we opted for an imaging study because, in our opinion, while anatomical studies have the advantage of three-dimensional perception, imaging studies have the advantage of "real-life" evaluation, especially in preoperative evaluation. Moreover, anatomical specimens are susceptible to damage during preparation. Additionally, anatomical studies are typically limited to normal skulls,[1–16,18–21] whereas our study aimed to include cases with relevant pathologies normally excluded from anatomical studies.

Previous studies have produced varying results regarding the prevalence of the MCP and CCR.[1–22] For instance, Sharma et al, in a study involving more than 2,700 dried skulls, reported that the MCP was present in 42% of the specimens (60% bilaterally). Of all the MCP cases, 27% were classified as the CCR (11.3% of overall specimens).[3] Fernandez-Miranda et al, in their investigation comprising radiographic reviews and anatomic specimens, identified the MCP in 60% and the CCR in 20% in both study groups.[2] Miller et al, using CT scans, reported an overall prevalence of the MCP at 36.7%, with 15.4% exhibiting the CCR, suggesting that imaging studies might yield a higher rate of the MCP and CCR detection.[4] Lee et al and Peris-Celda et al demonstrated lower MCP prevalence rates (15.7 and 21.1%, respectively) and lower CCR (4.1 and 3%, respectively).[7,8] Nonetheless, a systematic review conducted by Skandalakis et al revealed a considerable prevalence of the CCR (23.6% in each side from anatomical studies and 18.7% from imaging studies).[9]

Excluding cases with sellar pathology, our study revealed a prevalence of the MCP at 54.5%, which is toward the higher end of values reported in previous studies.[1–11] However,

Table 1 Demographic characteristics (total $n = 200$ cases, 400 sides)

Variables	Analyzed numbers	Total cases	Comparison between groups		
			Patients with sellar lesions (100 case, 200 sides)	Patients without sellar lesions (100 cases, 200 sides)	*p*-Value
Age (years), median (range)	200 cases	52 (18–100)	49.5 (18–86)	56 (18–100)	< 0.001[a]
Age (years), *n* (%)	200 cases				0.015[a]
< 50		83 (41.5)	50 (50)	33 (33)	
≥ 50		117 (58.5)	50 (50)	67 (67)	
Gender, *n* (%)	200 cases				0.671
Male		89 (44.5)	43 (43)	46 (46)	
Female		111 (55.5)	57 (57)	54 (54)	
Sellar pathology, *n* (%)	200 cases				
Absent		100 (50)			
Present		100 (50)			
Types of sellar lesion, *n* (%)	100 cases with sellar lesions				
Pituitary adenoma		53 (53)			
Meningioma		28 (28)			
Craniopharyngioma		5 (5)			
Other lesions		14 (14)			
Presence of MCP, *n* (%)	400 sides				< 0.001[a]
Present		168 (42)	59 (29.5)	109 (54.5)	
Absent		232 (58)	141 (70.5)	91 (45.5)	
Types of MCP, *n* (%)	168 sides with MCP				0.742
Incomplete		158 (94)	55 (93.2)	103 (94.5)	
CCR		10 (6)	4 (6.8)	6 (5.5)	
Presence of CCR, *n* (%)	400 sides				0.522
Present		10 (2.5)	4 (2)	6 (3)	
Absent		390 (97.5)	196 (98)	194 (97)	

Abbreviations: CCR, caroticoclinoid ring; MCP, middle clinoid process.
[a]Indicates statistical significance.

most of the MCPs detected in our study were very small and not prominent. In cases where the MCP was present, we classified it into only two types, the incomplete type and CCR. Some previous studies further subdivided the MCP into additional subtypes. For example, Fernandez-Miranda et al classified the MCP into small and prominent (MCP extended more than half the diameter of the parasellar ICA) using CT angiography (CTA) criteria.[2] However, we were unable to apply this classification in our study due to the lack of CTA as a standard requirement. Sharma et al defined clinically relevant MCP as height greater than 1.5 mm^3, but we included all detectable MCPs since they had value as surgical landmarks. Given that the diameter of the cavernous ICA is approximately 4 mm, we employed a 2 mm cutoff criterion to define a "prominent" MCP. Our results revealed that the majority of MCPs were small, with an average length of 1.2 mm, and only 10 (6%) were considered prominent. Notably, only the CCR type had distinct clinical significance, making classification of the MCP into these two reasonable types sufficient for our analysis. The prevalence of the CCR was 3%, which aligns with the lower end of prevalence reported in previous studies.[1–22] As our study was an imaging study, this value excluded false negative errors that could occur in the preparation of anatomical specimens. We did not further classify the CCR into "complete" and "contact" subtypes, and instead, we included both subtypes under the term "CCR." The contact subtype is defined by the presence of a suture line between the tip of the MCP and ACP. Identifying this suture line through imaging studies may not be reliable. Previous studies also do not consistently classify the "contact" subtype of CCR in both anatomical and imaging studies.[2,4,8,15,17,19]

Table 2 Univariate analysis of factors correlating with the presence of the MCP (total $n = 200$ cases, 400 sides)

Variables	Analyzed numbers	Presence of MCP	Absence of MCP	OR (95% CI)	*p*-Value
Gender, *n* (%)	400 sides			1.12 (0.75–1.67)	0.574
Male		72 (42.9)	106 (45.7)		
Female		96 (57.1)	126 (54.3)		
Age (years), median (range)	400 sides	52.0 (18–100)	51.50 (18–98)	1.01 (0.99–1.02)	0.248
Age (years), *n* (%)	400 sides				0.465
< 50		67 (39.9)	101 (43.5)	1.16 (0.78–1.74)	
≥ 50		101 (60.1)	131 (56.5)		
Side of MCP, *n* (%)	400 sides			1.28 (0.86–1.91)	0.224
Right		90 (53.6)	110 (47.4)		
Left		78 (46.4)	122 (52.6)		
Sellar lesion, *n* (%)	400 sides			2.86 (1.90–4.32)	< 0.001[a]
Absent		109 (64.9)	91 (39.2)		
Present		59 (35.1)	141 (60.8)		
Types of sellar lesion, *n* (%)	100 cases with sellar lesions			1.21 (0.55–2.66)	0.647
Pituitary adenoma		25 (55.5)	28 (50.9)		
Nonpituitary adenoma		20 (44.5)	27 (49.1)		
Types of sellar lesion, *n* (%)	100 cases with sellar lesions			NC	0.493
Pituitary adenoma		25 (55.6)	28 (50.9)		
Meningioma		11 (24.4)	17 (30.9)		
Craniopharyngioma		1 (2.2)	4 (7.3)		
Other lesions		8 (17.8)	6 (10.9)		

Abbreviations: CI, confidence interval; MCP, middle clinoid process; NC, cannot be calculated; OR, odds ratio.
[a]Indicates statistical significance.

Table 3 Multivariable analysis of factors correlating with the presence of the MCP

Variables	Crude OR (95% CI)	*p*-Value	Adjusted OR (95% CI)	*p*-Value
Age	1.01 (0.99–1.02)	0.248	1.00 (0.99–1.01)	0.872
Female	1.12 (0.75–1.67)	0.574	1.17 (0.77–1.77)	0.464
Right side	1.28 (0.86–1.91)	0.224	1.30 (0.86–1.97)	0.209
Absence of sellar lesion	2.86 (1.90–4.32)	< 0.001[a]	2.86 (1.90–4.32)	< 0.001*

Abbreviations: CI, confidence interval; MCP, middle clinoid process; OR, odds ratio.
[a]Indicates statistical significance.

In terms of factors associated with the prevalence of the MCP, the presence of sellar lesions emerges as the first and most important, making our study unique. Sellar lesions significantly impact normal anatomy of the sella turcica. Mizutani et al conducted a study on the intercavernous sinus (ICS) in patients with normal sella turcica and those with sellar lesions. They found that the detection rate of ICS in cases of pituitary adenomas was significantly lower than in normal controls.[23] In our patients with sellar lesions, the prevalence of the MCP was significantly lower compared with cases without sellar lesions ($p < 0.001$). This difference might be attributed to bone remodeling in cases of slow-growing benign lesions and bone destruction in the cases of malignant diseases. Interestingly, we found no significant difference in the prevalence of the MCP between types of tumors (pituitary or non-pituitary tumors). Additionally, the prevalence of the CCR was not significantly different in the group with sellar lesions (2%), which may reflect the already low rate of CCR prevalence in the group without sellar lesions (3%).

The second factor we considered is race. Most previous studies were done in a single race, leading to a wide range of results between studies (even within the same racial group), which might reflect selection bias and measurement

Table 4 The literature review regarding prevalence of MCP and CCR in Asian population[7,13,15,17–22]

Authors	Year	Country	Study type	Number of sides	Presence of side with MCP, *n* (%)	Presence of side with CCR (including contact type), *n* (%)	Identification of small MCP	Classification of contact subtype
Lee et al[7]	1997	Korea	Dry skull	146	23 (15.7)	6 (4.1)	–	+
Gupta et al[18]	2005	Nepal	Dry skull	70	14 (20)	6 (8.6)	–	+
Shaikh et al[19]	2012	India	Dry skull	200	38 (19)	6 (3)	–	–
Ota et al[17]	2015	Japan	Cranial CT	144	18 (12.5)	9 (6.3)	–	–
Suprasanna et al[13]	2015	India	Cranial CT	190	42 (22.1)	18 (9.5)	–	+
Souza et al[20]	2016	India	Dry skull	54	12 (22.2)	5 (9.3)	–	+
Jha et al[21]	2017	India	Dry skull	216	33 (15.3)	12 (5.6)	–	+
Suprasanna and Kumar[22]	2017	India	Cranial CT	108	24 (22.2)	13 (12)	–	+
Priya et al[15]	2022	India	Dry skull	200	14 (7)	4 (2)	–	–
The present study	2023	Thailand	Cranial CT	400 (200 in group with sellar lesions; 200 in group without sellar lesions)	59 (29.5) in group with sellar lesions; 109 (54.5) in group without sellar lesions	2 (4) in group with sellar lesions; 3 (6) in group without sellar lesions	+	–

Abbreviations: –, no; +, yes; CCR, caroticoclinoid ring; CT, computerized tomography; MCP, middle clinoid process.

criteria.[2,4,5,8–16] However, some studies directly compared different races, effectively reducing errors within the study and revealing a significant impact of race on MCP prevalence. For instance, Keyes found that the prevalence of MCP was 15% greater in white individuals compared with black individuals.[5] Sharma et al identified being white as a significant predictor of MCP presence (52% in white versus 30% in black, $p < 0.0001$) and greater MCP height.[3] Miller et al also found a significant increase in MCP frequency in white patients compared with black patients (41.3% in white vs. 19.4% in black, $p = 0.03$).[4] However, direct comparisons of Asian race with other races have not been explored in literature. Previous studies (►**Table 4**) in the Asian population focused on the CCR rather than directly on the MCP. It is likely that these studies only considered the prominent MCP as the "incomplete CCR," leading to a high chance that they did not include small MCP in their analyses.[7,13,15,17–22]Lee et al investigated the prevalence of the MCP and CCR in the Korean population and reported a relatively low prevalence rate of 15.7% for the MCP and 4.1% for the CCR.[7] Our study focused on the Thai population and found a relatively high prevalence rate of the MCP; however, most of the MCPs were small and not dominant, and the prevalence rate of the CCR was low. To the best of our knowledge, our study is the only investigation of the MCP in the Thai population.

The third factor we considered was age. Although skull size and shape tend to remain stable after 15 years of age,[24] some MCP studies have shown age-related effects. For instance, Sharma et al reported that increasing age (over 50 years) was associated with a higher prevalence of the MCP, possibly due to ossification of the CCR.[3] However, other studies have found no significant age-related effects, and CCR can be present even at a young age.[4,5] Our study found that the presence of the MCP was not associated with patients older than 50 years of age.

The fourth factor we explored was gender. In general, racial differences in skull morphology are more pronounced than gender differences within the same race.[25] Several studies have reported no significant difference in MCP prevalence between genders.[3–5,16] For example, Sharma et al found no significant difference in MCP prevalence when stratified by sex.[3] Miller et al also found no significant difference in MCP prevalence between males and females.[4] Keyes' study did not reveal significant differentiation of the CCR between genders of the same race.[5] Our study similarly found no significant difference in MCP prevalence between both genders.

The final factor we considered was side. Despite some controversy, certain studies have reported a higher frequency of the MCP on the right side.[3,7,11] A systematic review of CCR prevalence found that CCR was only slightly more common on the right side ($p = 0.05$).[9] Nevertheless, our study found no significant difference in MCP prevalence between both sides.

Limitations

The difference in the prevalence of the MCP between patients with and without sellar lesions may reflect the nature of cases in our institution, which is one of the largest tertiary care hospitals in Thailand. Therefore, the results of this study are specific to the Thai population and surgical cases conducted within our institution.

Conclusion

The MCP is an important structure in skull base anatomy for neurosurgeons. Our study on the prevalence of the MCP

detected by cranial CT scan revealed a relatively high prevalence rate of the MCP; however, most of them were incomplete and not prominent. In patients with sellar lesions, the prevalence of the MCP was significantly lower than cases without sellar pathology. The prevalence of the CCR was relatively low when compared with those of previous studies.

Conflict of Interest
None declared.

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