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ABDOMINAL IMAGING

ORIGINAL ARTICLE

Open- and closed-type congenital cholesteatomas of the middle ear: computed tomography differentiation and correlation with surgical staging

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PURPOSE

To investigate the differences in computed tomography (CT) features between closed-type congenital cholesteatoma (CCC) and open-type congenital cholesteatoma (OCC) of the middle ear and to evaluate the usefulness of preoperative CT examination for staging workup of congenital cholesteatoma (CC) in correlation with the surgical findings.

METHODS

We retrospectively reviewed the preoperative CT scans of the temporal bone obtained from 80 patients with surgically confirmed CC of the middle ear. All patients had a solitary lesion, except for one patient with two lesions, resulting in 81 CCs, which formed the basis of this study. We compared the CT features between CCCs and OCCs, focusing on their morphological characteristics, such as size, shape, location, and bone change. Based on the Potsic classification, the stage of CCs was determined at CT and surgery, and the results were compared between CCCs and OCCs.

RESULTS

Of the 81 CCs, surgery revealed 43 CCCs and 38 OCCs. On CT scans, CCC was frequently seen as a small (median: 3.15 mm), round to oval (65.1%) mass, most commonly located in the anterosuperior quadrant (74.4%) of the middle ear with less frequent ossicular erosion (14.0%). In contrast, OCC was frequently seen as a large (median: 6.70 mm), irregular (94.7%) mass, most commonly located in the posterosuperior quadrant (68.4%) of the middle ear with frequent ossicular erosion (55.3%). The size, shape, location, and presence of ossicular erosion were significantly different between the two types. Overall, the CT and surgical stages of CCs demonstrated good agreement (kappa value: 0.77) and the CT and surgical stages of OCCs were statistically significantly higher than those of CCCs ($P < 0.001$ in both).

CONCLUSION

CT is useful for preoperative determination of the types and staging of CC of the middle ear.

CLINICAL SIGNIFICANCE

Preoperative differentiation between CCC and OCC is important to avoid reoperation and prevent an extensive surgery. By providing valuable information on the morphology and extent of the lesions, CT is useful for not only the accurate preoperative determination of the type of CCs but also the accurate prediction of staging of the lesion, which should be important to preparing optimal treatment plans.

KEYWORDS

Congenital cholesteatoma, computed tomography, middle ear disease, potsic stage, temporal bone

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Congenital cholesteatoma (CC) is defined as a whitish mass behind an intact tympanic membrane without a history of tympanic membrane perforation, otorrhea, or previous ear surgery.[1] The annual incidence of CC is uncommon and reported to be 0.12/100,000 individuals.[2,3] It accounts for 2%–5% of all cholesteatomas and 4%–24% of cholesteatomas in children.[4,5] The condition occurs three times more frequently in male individuals than in female individuals and most frequently affects children aged 4–5 years. Early detection and surgical intervention is important to prevent extensive surgery and preserve hearing; because CC grows faster in children than in adults, disease progression would be facilitated if the diagnosis and treatment are delayed.[3,4,6] Although the most commonly affected location is known to be the anterosuperior quadrant of the middle ear, followed by the posterosuperior quadrant,[2,4] a predilection to involve the posterosuperior quadrant has also been reported, especially in Asian populations.[3,6,7]

The pathogenesis of CC is unclear and controversial, with the embryonic cell rest theory being considered the most plausible.[8,9] Although not particularly well known among radiologists, it is well known among otolaryngologists that there are two types of CC, closed-type congenital cholesteatoma (CCC) and open-type congenital cholesteatoma (OCC), which differ in their morphology and clinical course.[9] Histologically, the former presents as an epithelial cyst without exposure of keratin and the latter manifests as flat keratinizing epithelium continuous with middle ear mucosa without formation of an epithelial cyst.[6,8,10] Whether these two types have a different pathogenesis or are a different evolution of the same phenomenon is uncertain, but their clinical manifestations are different. Compared with CCC, OCC occurs in older age groups, is more difficult to identify behind an intact tympanic membrane, and involves greater difficulty in surgery.[8] Therefore, preoperative differentiation between CCC and OCC is important to avoid reoperation and prevent an extensive surgery.[2]

Main points

- Closed-type congenital cholesteatomas (CCCs) are smaller, more likely to be round to oval, most commonly located in the anterosuperior quadrant of the middle ear, and less frequently associated with ossicular erosion than open-type congenital cholesteatomas (OCCs).
- OCCs are larger, irregularly shaped, most commonly located in the posterosuperior quadrant of the middle ear, and more often associated with ossicular erosion.
- Computed tomography (CT) and surgical stages of OCCs are higher than those of CCCs.
- CT can help to accurately determine the type and stage of CC before surgery.

In 2002, Potsic et al.[11] proposed a staging system for CC according to the extent of lesions (Table 1), which appears to correlate well with the severity of the disease and treatment outcome.[2] Computed tomography (CT) is widely considered the imaging modality of choice for the diagnosis of CC.[1,4,12] To the best of our knowledge, however, only a few studies have been reported on the role of CT in distinguishing OCC from CCC and determining preoperative staging.[5,12,13] Accordingly, the aims of this study are to investigate the different CT features of CC according to the subtypes and to evaluate whether CT staging may correlate well with surgical staging.

Methods

Study population

A search of the electronic medical records of Samsung Medical Center between January 1999 and February 2017 revealed 109 patients with surgically proven CC of the middle ear, among whom CT scanning was performed in 102. The diagnosis of CC was made by otolaryngologists on the basis of the criteria devised by Levine et al.[14] Of the 102 patients, 22 were excluded due to insufficient medical records (n = 20) and recurrent disease after surgery (n = 2). Finally, 80 patients (61 males and 19 females) aged 1–38 years (mean age ± standard deviation: 5 ± 5.6 years) were enrolled as the participants of this study (Figure 1).

All patients were operated on by two otolaryngologists. They classified lesions as CCC or OCC and determined lesion staging according to the Potsic classification (Table 1).

Computed tomography examination

CT of the temporal bone was performed on various models of multidetector helical CT scanners (GE Healthcare, Milwaukee, WI, USA) with variable mA, 120 kVP, 0.625–1.25-mm section thickness and section spacing, a field of view of 18 cm, and a high-resolution algorithm. Direct or reformatted coronal images were routinely obtained. All the images were viewed with the window width of 4000 HU and window level of 400 HU.

All CT scans were retrospectively reviewed by two neuroradiologists with clinical experience of 30 and 3 years, respectively, for the number, location, shape, and size of the lesion, and any disagreements were resolved by consensus. The presence of ossicular erosion, labyrinthine fistula, and mastoid involvement was also investigated. To determine the location of the lesion, we referred to the handle of the malleus and divided the tympanic cavity into four quadrants: anterosuperior, posterosuperior, anteroinferior, and posteroinferior quadrants, as shown in Figure 2. If two or more quadrants were involved by the lesion, we recorded all. The shape of the lesion was divided into round to oval and irregular. The size of the lesion was measured at its greatest diameter. To differentiate from simple inflammation, mastoid involvement was considered to be present when the lesion in the mastoid antrum was continuous with the middle ear lesion. CT staging was also determined using the Potsic classification.[11]

Research ethics standards compliance

This study was approved by the Institutional Review Board at Samsung Medical Center (IRB no: 2018-08-18-001, date: October 10, 2018), and informed consent was waived in accordance with the requirements of a retrospective study.

Statistical analysis

Statistical analysis was performed using SAS version 9.4 (SAS Institute) and R 4.0.2 (Vienna, Austria; http://www.R-project.org/). Wilcoxon's rank sum test was used to compare the age and size between the CCC and OCC groups. The chi-square test was used for comparing the gender distribution, shape, location, presence of ossicular

Table 1. Potsic staging for congenital cholesteatoma[11]

Stage	Description
I	Single quadrant: no ossicular involvement or mastoid extension
II	Multiple quadrants: no ossicular involvement or mastoid extension
III	Ossicular involvement: includes erosion of ossicles and surgical removal for eradication of disease; no mastoid extension
IV	Mastoid extension (regardless of findings elsewhere)

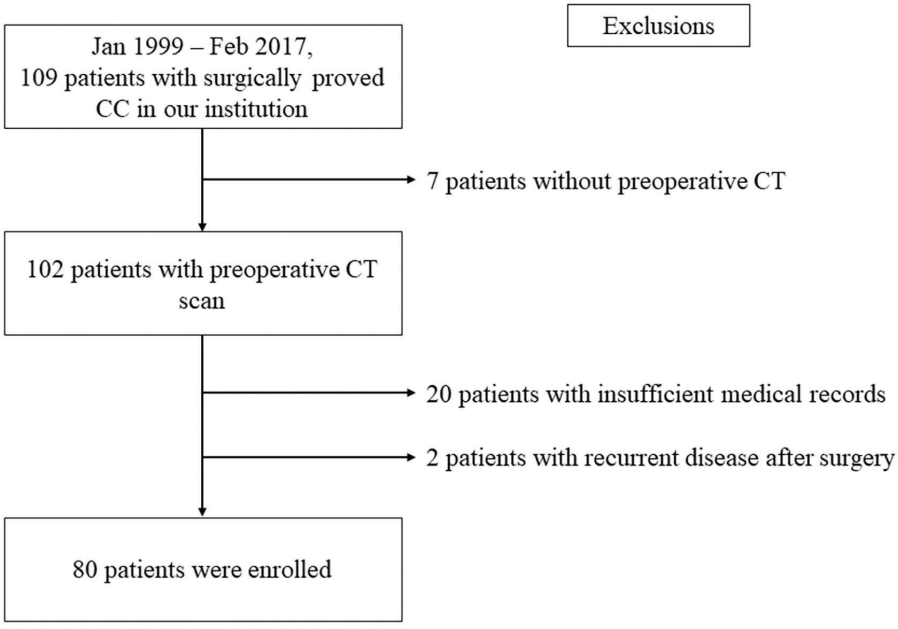

Figure 1. Flowchart of patient enrollment. CC, congenital cholesteatoma; CT, computed tomography.

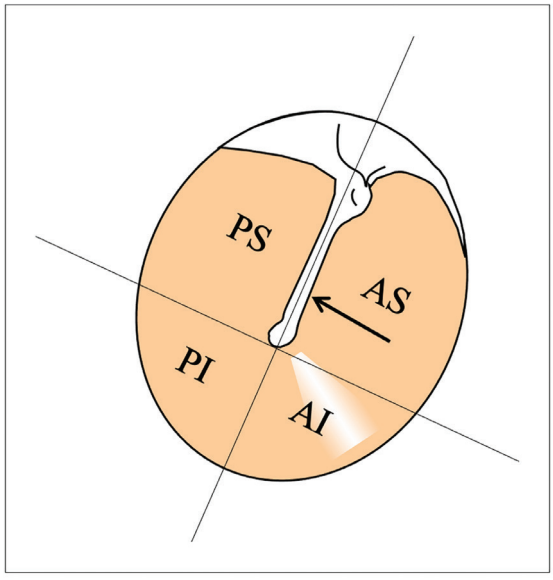

Figure 2. Schematic showing four quadrants of the tympanic cavity. We referred to the handle of the malleus (arrow) and divided the tympanic cavity into four quadrants, including anterosuperior (AS), posterosuperior (PS), anteroinferior (AI), and posteroinferior (PI) quadrants.

erosion, presence of mastoid inflammation, and presence of labyrinthine fistula between the two groups. Agreement on the CT and surgical stages was evaluated using Cohen's weighted kappa. A κ value ≤0.20 indicated positive but poor agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, good agreement; and ≥0.81, excellent agreement. The statistical differences in CT and surgical stages between CCCs and OCCs were evaluated using Fisher's exact test with the permutation method for multiple comparisons. For all statistical analysis, $P < 0.05$ was considered statistically significant.

Results

Comparison of demographic data between open- and closed-type congenital cholesteatomas

Overall, 80 patients had 81 lesions, including 43 CCCs and 38 OCCs (Table 2). One patient had two separate lesions in one ear, both of which were OCCs; all other patients had one lesion each. Males were affected more frequently than females in both groups (32 males and 11 females in the CCC group and 29 males and eight females in the OCC group), but there was no statistically significant difference between the two groups ($P = 0.631$). The ages of the OCC group (median age: 5 years; range: 2–38 years) were statistically significantly older than those of the CCC group (median age: 3 years; range: 1–16 years) ($P < 0.001$). The median time interval between CT examination and surgery was 29 days (range: 8–555 days) in the CCC group and 32 days (range: 1–322 days) in the OCC group, which, based on the Wilcoxon rank sum test, was not statistically significantly different ($P = 0.529$).

Comparison of computed tomography findings between open- and closed-type congenital cholesteatomas

The CT features of CCCs and OCCs are summarized in Table 2, with typical cases presented in Figures 3 and 4. The OCCs were statistically significantly larger than the CCCs (median: 6.70 mm vs. 3.15 mm; $P < 0.001$). While 28 (65.1%) of 43 CCCs were round or oval in shape, 36 (94.7%) of 38 OCCs had an irregular shape ($P < 0.001$). The anterosuperior quadrant [32/43 (74.4%)] was the most common site involved in CCCs, followed by the posterosuperior [12/43 (27.9%)], anteroinferior [5/43 (11.6%)], and posteroinferior [5/43 (11.6%)] quadrants, whereas the posterosuperior quadrant [26/38 (68.4%)] was most commonly involved in OCCs, followed by the anterosuperior [25/38 (65.8%)], anteroinferior [14/38 (36.8%)], and posteroinferior [11/38 (28.9%)] quadrants. Among these, involvement of the posterosuperior and anteroinferior quadrants was statistically significantly greater in OCCs than in CCCs ($P < 0.001$ and $P = 0.008$, respectively). The detailed sites involved in CCCs and OCCs are further characterized in Table 3. Compared with CCCs, OCCs more frequently involved multiple quadrants of the tympanic cavity, which was statistically significantly different ($P < 0.001$). While 36 (83.7%) of 43 CCCs involved a single quadrant, with the anterosuperior quadrant being most frequently involved in 27 cases, only 16 (42.1%) of 38 OCCs involved a single quadrant, with the posterosuperior quadrant being most frequently involved in eight cases. In the remaining seven (16.3%) of 43 CCCs and 22 (57.9%) of 38 OCCs, two or more quadrants were involved in the lesion. Involvement of the mastoid antrum was statistically significantly greater in OCCs than in CCCs [9/38 (23.7%) OCCs vs. 2/43 (4.5%) CCCs; $P = 0.013$]. In all 11 cases with mastoid

Table 2. Demographic data and computed tomography features of closed- and open-type cholesteatomas

	Closed-type cholesteatoma (n = 43 in 43 patients)	Open-type cholesteatoma (n = 38 in 37 patients)	*P* value
Sex			
Male	32	29	0.631
Female	11	8	
Age, yr			
Median [IQR]/range	3 [2.4]/1–16	5 [3.9]/2–38	<0.001
Time interval between CT and surgery, days			
Median [IQR]/range	29 [18.42]/8–555	32 [19.62]/1–322	0.529
Size, mm			
Median [IQR]/range	3.15 [2.60, 4.42]/1.1–22.0	6.70 [4.78, 10.07]/2.2–35.7	<0.001
Shape			
Round to oval	28 (65.1%)	2 (5.3%)	<0.001
Irregular	15 (34.9%)	36 (94.7%)	
Location			
Anterosuperior	32 (74.4%)	25 (65.8%)	0.396
Posterosuperior	12 (27.9%)	26 (68.4%)	<0.001
Anteroinferior	5 (11.6%)	14 (36.8%)	0.008
Posteroinferior	5 (11.6%)	11 (29.0%)	0.051
Mastoid involvement	2 (4.7%)	9 (23.7%)	0.013
Ossicular erosion	6 (14.0%)	21 (55.3%)	<0.001
Labyrinthine fistula	1 (2.3%)	1 (2.6%)	0.929

IQR, interquartile range; CT, computed tomography.

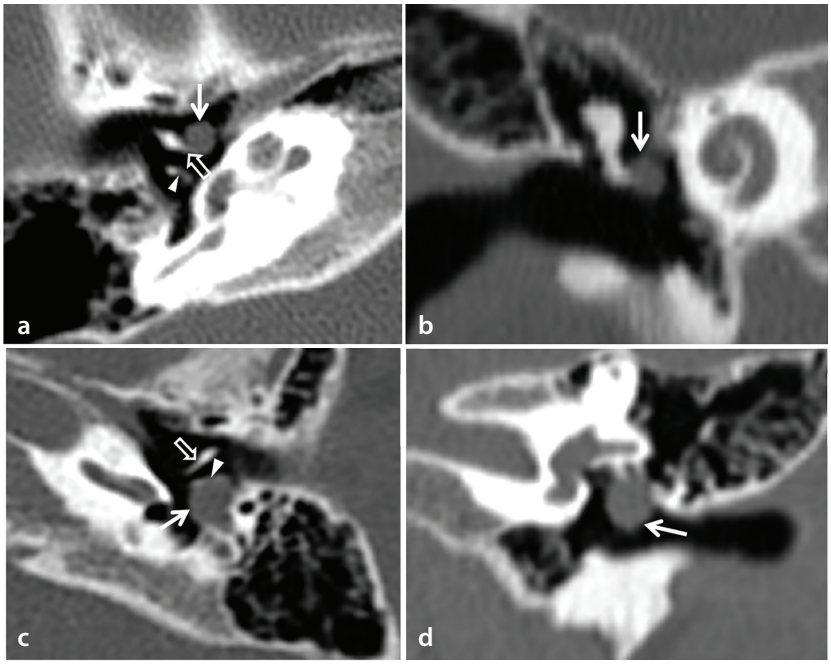

Figure 3. Typical examples of closed-type congenital cholesteatomas (CCCs). **(a, b)** Potsic stage I CCC in a 3-year-old boy. Axial **(a)** and coronal **(b)** computed tomography (CT) scans show a small well-defined round nodule (white arrows) confined to the anterosuperior quadrant of the right middle ear, anterior and superior to the handle of the malleus (open arrow in **a**), without evidence of ossicular erosion. Posterior to the handle of the malleus lies the long process of the incus (arrowhead in **a**). **(c, d)** Potsic stage II CCC in a 3-year-old boy. Axial **(c)** and coronal **(d)** CT scans show a well-defined ovoid mass (arrows) located in the posterosuperior and posteroinferior quadrants of the left middle ear, posterior to the long process of the incus (arrowhead) without evidence of ossicular erosion or mastoid involvement. Open arrow indicates the handle of the malleus.

involvement, the posterosuperior quadrant of the middle ear was also involved. The rate of ossicular erosion was also statistically significantly greater in OCCs than in CCCs [21/38 (55.3%) OCCs vs. 6/43 (14.0%) CCCs; $P < 0.001$]. The incus, especially its distal long process, was most commonly affected in all 27 cases with ossicular erosion, followed by the stapes in 18 cases and the malleus in four cases. Two or more ossicles were eroded in 16 of 21 OCCs and three of six CCCs. Labyrinthine fistula was present in one (2.3%) of 43 CCCs and one (2.6%) of 38 OCCs, with no statistically significant difference between the two groups ($P = 0.929$). The former occurred at the superior semicircular canal and the latter involved the basal turn of the cochlea and the lateral and superior semicircular canals.

Comparison of computed tomography and surgical stages between open- and closed-type congenital cholesteatomas

The results of the CT and surgical stages of CCs based on the Potsic classification are summarized in Table 4. At surgery, 81 CCs were determined as stage I in 44 (54.3%), stage II in nine (11.1%), stage III in 18 (22.2%), and stage IV in 10 (12.3%). Of all 81 CCs, the CT stage accorded well with the surgical stage in 65 cases (80.2%), including 37 (84.1%) of 44 stage I CCs, three (33.3%) of nine stage II CCs, 17 (94.4%) of 18 stage III CCs, and eight (80.0%) of 10 stage IV CCs. In the remaining 16 cases, the CT stage mismatched with the surgical stage, including underestimation and overestimation in eight cases (9.9%) each (Table 5). The eight cases of underestimation included six cases of stage I at CT, all of which proved to be stage II at surgery. The remaining one case of stage I and one case of stage III at CT proved to be stage IV at surgery (Figure 5a, b). The eight cases of overestimation included five cases of stage II and two cases of stage IV at CT, all of which proved to be stage I at surgery (Figure 5c, d). The remaining one case of stage IV at CT proved to be stage III at surgery.

Overall agreement between the CT and surgical stages was good, with a κ value of 0.77 (CI: 0.64–0.89) based on Cohen's weighted kappa. When 43 CCCs and 38 OCCs were analyzed separately, good agreement was also found between the CT and surgical stages in both groups, with κ values of 0.69 [confidence interval (CI): 0.43–0.94] and 0.73 (CI: 0.55–0.91), respectively, with the κ values not statistically significantly different ($P = 0.922$). Compared with CCCs, both the CT

and surgical stages of OCCs were statistically significantly higher when using Fisher's exact test ($P < 0.001$).

Discussion

The importance of preoperative discrimination between CCCs and OCCs lies in the fact that they are different in clinical behavior. Early diagnosis and treatment is critical to prevent disease progression, particularly in patients with OCCs.[3,4,6] However, only a few studies focusing on differentiation between CCCs and OCCs using CT have been reported.[5,12,13] Overall, the results of the present study are in good accordance with those of the previous studies. Compared with CCCs, OCCs statistically significantly more commonly affected the older age group and were larger in size and more irregular in shape.[4,5] Invasion of the mastoid antrum and the erosion of the ossicles were also statistically significantly greater in OCCs than in CCCs. These findings can be partly explained by their different morphology and embryonic pathogenesis. In contrast to CCCs, which appear as a well-formed cyst lined by an epithelial membrane, OCCs do not form a discrete cyst but usually present as a flat epithelium in the middle ear and thus can avoid early detection and facilitate the spread of lesions unnoticed. A higher recurrence rate was also reported in terms of OCCs.[5]

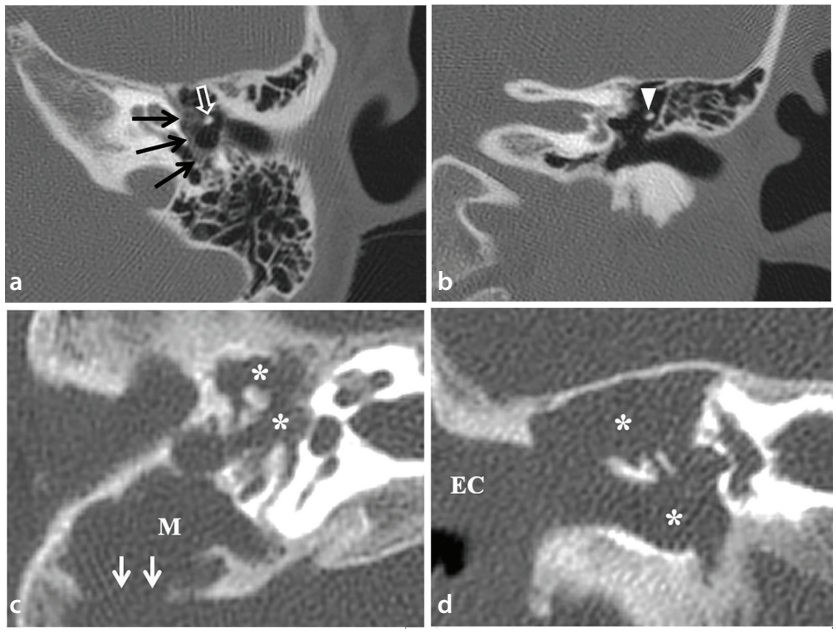

Figure 4. Typical examples of open-type congenital cholesteatomas (OCCs). **(a, b)** Potsic stage III OCC in an 11-year-old boy. Axial **(a)** and coronal **(b)** computed tomography (CT) scans show an irregular mass (white arrows) in the anterosuperior and posterosuperior quadrants of the left middle ear, anterior and posterior to the neck of the malleus (open arrow in **a**). Note that the stapes and the long process of the incus cannot be localized, which should be seen posterior to the neck of the malleus (open arrow in **a**) and inferior to the body of the incus (arrowhead in **b**), due to erosion by the mass. **(c, d)** Potsic stage IV OCC in a 12-year-old boy. Axial **(c)** and coronal **(d)** CT scans show a large irregular mass (asterisks) involving the whole parts of the right middle ear, which causes the ossicular erosion and extends to the mastoid antrum and air cells (M). The mass also involves the external auditory canal (EC) and causes the erosion of the sigmoid sinus plate (arrows in **c**).

Table 3. Detailed sites of involvement by congenital cholesteatomas on computed tomography

Site of involvement	Closed-type congenital cholesteatoma (n = 43)	Open-type congenital cholesteatoma (n = 38)
Single quadrant	36 (83.7%)	16 (42.1%)
AS	27	7
PS	5	8
AI	3	1
PI	1	0
Multiple quadrants	7 (16.3%)	22 (57.9%)
Two quadrants		
AS+PS	3	5
PS+PI	2	2
AS+AI	0	4
Three quadrants		
AS+AI+PS	0	2
AI+PS+PI	0	2
AS+PS+PI	0	2
Four quadrants	2	5

AS, anterosuperior; PS, posterosuperior; AI, anteroinferior; PI, posteroinferior.

The different biological behaviors between CCCs and OCCs might also be attributed to their different sites of predilection. Traditionally, CCs occur most frequently in the anterosuperior quadrant, then grow into the posterosuperior quadrant, erode the ossicles, and finally invade the mastoid.[15] However, this situation generally applies to CCCs, but not to OCCs. In contrast to CCCs, OCCs are more frequently reported to develop in the posterosuperior quadrant, which can delay otoscopic detection to make an early diagnosis.[8-10,16]

Likewise, the present study also revealed different predilection sites between CCCs and OCCs. While CCCs most commonly involved the anterosuperior quadrant (74.4%), followed by the posterosuperior quadrant (27.9%), OCCs occurred at almost the same rate in the anterosuperior (65.8%) and posterosuperior (68.4%) quadrants. Of the 36 CCCs that were confined to a single quadrant, the anterosuperior quadrant was the predominant site of involvement in 27 cases, whereas the posterosuperior quadrant was much less commonly involved, with only five cases. In contrast, of the 16 OCCs that were confined to a single quadrant, eight cases involved the posterosuperior quadrant, whereas seven cases involved the anterosuperior quadrant.

There have been reports on the ethnic differences in the predilection sites of CCs between Asian and Western popula-

Table 4. Computed tomography and surgical stages of congenital cholesteatoma based on Potsic staging

Surgical stage	Computed tomography stage				Total
	I	II	III	IV	
I	37 (30/7)	5 (1/4)	0 (0/0)	2 (1/1)	44 (32/12)
II	6 (5/1)	3 (0/3)	0 (0/0)	0 (0/0)	9 (5/4)
III	0 (0/0)	0 (0/0)	17 (5/12)	1 (0/1)	18 (5/13)
IV	1 (0/1)	0 (0/0)	1 (0/1)	8 (1/7)	10 (1/9)
Total	44 (35/9)	8 (1/7)	18 (5/13)	11 (2/9)	81 (43/38)

The numbers in parentheses are number of closed-type congenital cholesteatoma/number of open-type congenital cholesteatoma.

Table 5. Discrepant cases between computed tomography and surgical stages

	Computed tomography stage	Surgical stage
Underestimation (n=8)		
6	I	II
1	I	IV
1	III	IV
Overestimation (n=8)		
5	II	I
2	IV	I
1	IV	III

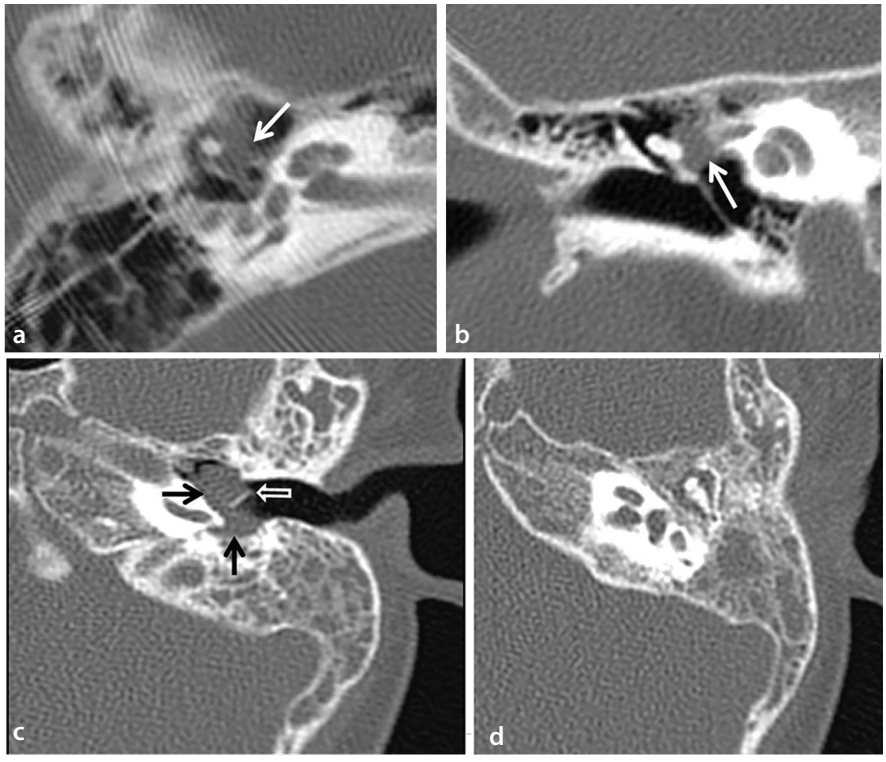

Figure 5. Examples of mismatch of Potsic stage between computed tomography (CT) and surgery. **(a, b)** A case of underestimation in a 9-year-old boy with open-type congenital cholesteatoma. Axial **(a)** and coronal **(b)** CT scans show an irregular mass (arrows) in the anterosuperior quadrant of the right middle ear without evidence of ossicular erosion or mastoid involvement, leading to stage I determined at CT. At surgery, however, a small sac of cholesteatoma was also found in the mastoid antrum, which resulted in surgical stage IV. **(c, d)** A case of overestimation in a 6-year-old boy with open-type congenital cholesteatoma. Axial CT scans show an irregular mass (black arrows in **c**) in the anterosuperior, posterosuperior, and anteroinferior (not shown) quadrants of the left middle ear, apparently extending to the mastoid antrum without evidence of the ossicular erosion, which led to stage IV determined at CT. However, surgery found that the cholesteatoma was limited only to the anterosuperior quadrant, with the other parts of the middle ear and mastoid antrum being occupied by the granulation tissue, which resulted in surgical stage I. The open arrow in **c** indicates the handle of the malleus.

tions.[3,6,7,10,13,17] According to a meta-analysis reported by Hidaka et al.[7], the overall estimate of anterosuperior quadrant involvement was smaller than that of posterosuperior quadrant involvement in Asian populations (0.54 vs. 0.69), compared with Western populations (0.76 vs. 0.59). We have no clear explanation for these racial differences. It may simply result from the different timing of detection in different studies, as there are recent reports showing the anterosuperior quadrant to be the most common site of early CCs in Asian populations.[3,7,17] The ethnic difference may also be attributed to different genetic affinity between races.

The staging system proposed by Potsic et al.[18] essentially depends on the disease extent and is reported to correlate well with the disease severity and outcome prediction. The authors demonstrated that the higher the stage is, the higher the rate of residual disease and the worse the postoperative hearing.[4,11,18] In addition, cases with early diagnosis were likely to be confined to a single quadrant, whereas cases with delayed diagnosis were more likely to involve multiple sites.[18] Based on 71 patients with CCs, Takagi et al.[3] reported that the preferred surgical approaches and types of tympanoplasty were different according to the different stages of CCs. According to the authors, the majority of CCs in Potsic stages I and II could be removed using a transcanal approach, whereas most CCs in Potsic stages III and IV are treated by a planned two-stage operation or a canal wall-down procedure.[3] Likewise, Yamatodani et al.[19] reported that multi-stage procedures were increasingly needed for higher-stage CCs, with a trend toward a higher rate of residual disease and a lower rate of hearing improvement. The authors also observed a greater proportion of OCCs in advanced cases. Based on the accurate preoperative staging, less invasive treatment can be performed for CCs in the early stage, as Lee et al.[17] applied minimally invasive transcanal myringotomy in patients with CCs in Potsic stages I and II, with a recurrence rate of 13.8%.

In the present study, CT staging accorded well with surgical staging [80.2% (65/81)], with good overall agreement (κ: 0.77). Our results are comparable to those obtained by Choi et al.[5], who reported an alignment between the preoperative CT and surgical stages in 70.4% (50/71). In the present study, the CT and surgical stages also revealed good agreement even when CCCs and OCCs were analyzed separately. As expected, both the CT and surgical stages of OCCs were statistically significantly higher than those of CCCs. The significance of the results of the present study is that the type and stage of CCs can be predicted on CT scans before surgery, which can help the surgeon choose the best treatment option to achieve the best clinical outcome for the patients.

Despite overall good agreement between the CT and surgical stages, there were 16 discrepant cases, including eight cases of underestimation and eight of overestimation (Table 5). Of these 16 cases, 11 occurred in a combination of stage I at CT and stage II at surgery (n = 6) or stage II at CT and stage I at surgery (n = 5). These 11 cases of mismatch stemmed from the differences in the number of the involved quadrants determined by CT and surgery, and would not have a significant impact on the patients' treatment. The remaining five cases of mismatch between CT and surgery were related to CT interpretation of the presence or absence of mastoid involvement, because differentiation between mastoid inflammation and mastoid involvement by CCs can often be difficult. Two cases of stage IV at surgery were interpreted as stage I and stage III at CT, respectively. In contrast, three cases of stage IV at CT were finally proven to be stage I in two cases and stage III in one case.

The present study has several limitations. First, this is a retrospective study in which an exact 1:1 CT and surgical correlation is limited. Second, the mean time interval between CT examination and surgery was relatively long (mean: 54 days; range: 1–555 days), meaning the possibility of the interval change of the lesion could not be excluded. Third, we did not analyze the clinical course of the patients, such as the type of surgery, hearing outcome, and disease recurrence. Information on the clinical outcome would be helpful for further understanding the importance of preoperative CT examination for differentiating between CCCs and OCCs, as well as its staging workup.

In conclusion, CCs of the middle ear are classified as CCCs and OCCs, which differ in terms of morphology and clinical course. By providing valuable information on the morphology and extent of the lesions, CT is useful not only for accurate preoperative determination of the type of CCs but also accurate prediction of lesion staging, which should be important to preparing optimal treatment plans.

Footnotes

Conflict of interest disclosure

The authors declared no conflicts of interest.

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