American Journal of Otolaryngology and Head and Neck Surgery

Research Article
Published: 28 Jun, 2023

External Auditory Canal Angle and Cerumen Accumulation

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Abstract

Objectives: Cerumen in the External Auditory Canal (EAC) is a common incidental finding on head CT scans. However, the factors that predispose to Cerumen Accumulation (CA) have not been studied through imaging. We hypothesized that a steeper inferior angulation of the EAC would allow greater drainage of cerumen and decrease the rate of CA.

Materials and Methods: 303 CT scans performed over three days were reviewed to determine CA presence and the angulation of the EAC on coronal bone windows. The angle was measured from the plane of the roof of the EAC to the otic labyrinth to the midpoint of the junction between the bony and cartilaginous EAC. CA was graded 0 (no cerumen), 1 (less than 50% EAC filled), 2 (51%-99% filled) or 3 (complete opacification).

Results: CA was present in 87/303 (28.7%) patients and bilateral in 35/87 (40.2%). 122/603 (20.2%) ears showed CA. The mean angle of 24.2 ± 6.0 degrees in patients without CA was significantly higher than those with CA (22.02 ± 5.2) (p=0.0004). Logistic regression showed that for each degree increase in the angle of the EAC, the odds of having CA decreased by 6.5% (OR=0.935, p=0.002). In the 34 patients who had unilateral CA but both angles measured, the mean angle was lower in the CA ear compared to without CA (p=0.002). The angle also inversely impacted the grade of CA. Intra observer and inter observer measurement concordance was moderate to excellent.

Conclusion: A larger inferior angulation of the EAC is associated with a lower rate of CA.

Keywords: External auditory canal; Cerumen; Computed tomography; Impaction

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Received Date: *07 Jun 2023*
Accepted Date: *23 Jun 2023*
Published Date: *28 Jun 2023*

Citation:
Rafiee F, Hoseinyazdi M, Motaghi M, Yousem DM. External Auditory Canal Angle and Cerumen Accumulation. Am J Otolaryngol Head Neck Surg. 2023; 6(4): 1239.

Abbreviations

CT: Computed Tomography; EAC: External Auditory Canal; CA: Cerumen Accumulation; SD: Standard Deviation

Introduction

The External Auditory Canal (EAC) comprises a cartilaginous lateral one-third and a bony medial two-thirds portion. The primary function of the EAC is to conduct sound to the tympanic membrane [1]. Glandular secretions of the outer third of the EAC and the desquamated skin form cerumen or "ear wax". This hydrophobic and acidic cerumen protects the EAC epithelium and prevents infection [2]. Cerumen Accumulation (CA) represents an overabundance of ear wax in the EAC and has the potential to become symptomatic, and, in the extreme, may lead to a blockage of the EAC (cerumen impaction) and conductive hearing loss. Other symptoms of excessive CA include ear itching, fullness, otalgia, tinnitus, and dizziness [3,4].

Approximately twelve million patient visits due to the excessive CA and eight million cerumen removal procedures are reported in the United States each year [4,5]. Up to 6% of the general population is affected by accumulation of cerumen in the EAC [6,7]. However, the prevalence varies among different age groups and patients with various conditions [3,4,8,9].

Radiologists who review head CT and maxillofacial CT studies often see soft tissue in the EAC with such frequency that it may not even be mentioned in the report, unless the clinical history is that of hearing loss or directs one to that anatomy. CA is considered an incidental finding, and is readily dismissed as inconsequential. Still others wonder why it occurs with some regularity in a bilateral fashion.

Predisposing factors for CA and/or impaction include: 1) narrow or stenotic EAC (e.g., osteoma or exostosis), 2) hearing aids with elements that insert into the meatus 3) EAC trauma and resultant infection, 4) dermatologic conditions like seborrheic dermatitis, 5) excessive production of cerumen precipitated by anxiety, 6) ear canal hair, and 7) aging [6,8,10-12]. The composition of the ear wax may differ from person to person; individuals with a dryer wax are more prone to cerumen accumulation [13]. Nonetheless, the vast majority of people with CA do NOT have ANY of these risk factors. The cause of this condition remains a mystery [14].

We sought to determine the prevalence of cerumen accumulation in an Emergency Department population. We hypothesized that anatomic variants regarding EAC angulation could influence the drainage of cerumen from the ear, i.e., that an EAC in the upright (coronal) position that had a greater down slope on CT would lead to accelerated drainage of the cerumen and therefore patients with a steeper angle would be less likely to have cerumen accumulation.

Materials and Methods

The study was approved for expedited review by the Institutional Review Board. The study was anonymized such that HIPAA compliance was assured, and consent was waived.

Two hundred consecutive CT scans of the brain, maxillofacial region, or neck that included the temporal bones were reviewed over a three-day period by the senior investigator of the research team, who is a fellowship trained neuro radiologist with 32 years of post-fellowship experience. Exclusion criteria included subjects who were less than 18 years old (n=21), who had surgery on both temporal bones (n=8) and if the scans showed motion artifact precluding adequate evaluation of both external auditory canals (n=6). An additional 103 consecutive studies were reviewed one week after the initial cohort in order to garner over 100 EACs that had cerumen accumulation. Of these 103, 30 (29.1%) had CA. For these 30 additional patients the angles of the EAC with CA present were measured (but not the un-opacified contralateral normal ear as the sample size for "normals" exceeded 300 ears).

The right and left temporal bones were evaluated in coronal reconstructed planes to measure the downward angulation of the external auditory canal. The 0.6 mm thick raw data axial CT sections through the EACs were reconstructed in the coronal plane in 0.6 mm sections in order to make this measurement. Although the scan plane was directed to the canthomeatal line on head CT versus straight trans axial on maxillofacial CT scans, the coronal reconstructions performed were perpendicular to the scan planes. The angle that was measured was derived from one ray taken along the plane of the roof of the external auditory canal. The ray along the EAC roof was projected through the tip of the scutum to the lateral border of the bone labyrinth. From that point the other ray of the angle passed through the midpoint of the external auditory canal at the junction of the bony and cartilaginous portions (Figure 1). Thus, the coronal image that was used was one that had both the plane of the EAC roof and the opening of the EAC at the bony-cartilaginous junction.

For each ear, the axial raw data and coronal reconstructed scans were graded for cerumen accumulation. Cerumen accumulation was graded on a scale of 0 (no cerumen), 1 (less than 50% diameter EAC filled), 2 (51%-99% filled) (Figure 2) to 3 (complete obstruction).

After a 10-day interval, 50 studies from the third day of the initial review (cases 150-200) were re-evaluated by the same investigator in order to assess intra observer variability. The angles of both ears were remeasured, and the cerumen accumulation grades were rescored.

Statistical analysis

Normality of the distribution of EAC angle measures was assessed using Shapiro-Wilk test and measures of central tendency and variability are reported accordingly. Spearman correlation test was used for assessing the correlation of CA existence on right and left side and Pearson correlation test was used for assessing the correlation of EAC angle on opposite sides. We used independent t-test for comparing the EAC angle between ears with and without CA. Logistic regression analyses were performed for evaluating the association between CA and EAC angle. Spearman correlation test and ordinal regression were used for investigating the relationship between accumulation grade and EAC angle. As the two observations for each patient (on right and left) were not independent, in all the regression analyses we clustered the data based on the patient ID to account for multiple observations for one individual and avoid bias.

EAC angle associations with CA and accumulation grade were also evaluated for right and left ear, separately, in order to assess whether the side of the ear plays a confounding or effect modification role in these associations.

As a sub-analysis and for removing almost all possible confounders, EAC angle measures were compared using paired T-test between the two ears of one person when one ear had CA and one did not.

To assess intra-observer and inter-observer agreement, we measured Kappa statistic for cerumen accumulation as a binary variable. Inter-Class Correlation (ICC) was used for assessing the agreement on accumulation grade and EAC angle measurements.

All statistical analysis was performed using STATA 16 software, Stata Corp. 2019. Stata Statistical Software: Release 16. College Station, TX: Stata Corp LLC.

Results

Cerumen accumulation was identified in 87 (28.7%) of the 303 different patients' CT scans. Of those with CA, 35/87 (40.2%) patients had accumulation in both ears. Three patients had a history of surgery on one ear and those ears were excluded from the study.

122/603 (20.2%) ears showed cerumen accumulation. 60 patients had accumulation on the left and 62 on the right. The existence of CA in the right and in the left ear were significantly associated with each other, with a correlation coefficient of 47.2% (p-value <0.001). Logistic regression showed 11.56 times higher odds of having CA in the opposite ear if one ear had CA (OR=11.56, p-value <0.001).

Cerumen accumulation was graded based on the CT scans of patients and 75/122 (61.5%) were grade 1, 40/122 (32.8%) were grade 2 and 7/122 (5.7%) showed grade 3 accumulation. The Spearman correlation test showed a correlation coefficient of 46.9% (p-value <0.001) between the accumulation grade on opposite sides.

For ears without CA, the mean angle was measured to be 24.2 ± 6.0 degrees and for ears with CA, it was 22.0 ± 5.2 degrees, significantly different (p value =0.0004). Logistic regression showed that for each one degree increase in the angle of the EAC, the odds of having cerumen accumulation decreased by 6.5% (OR=0.935, p-value =0.002).

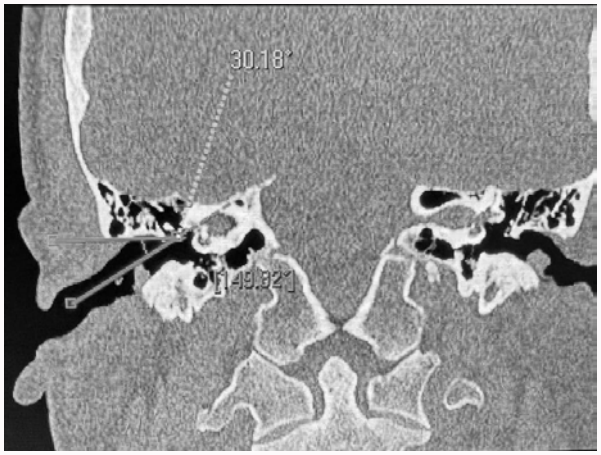

Figure 1: The EAC angle was measured by passing one ray from the roof of the EAC through the scutum to the bony inner ear labyrinth. The second ray passed from the labyrinth to the center of the EAC at its bony and cartilaginous junction. In this case the angle was 30.18 degrees.

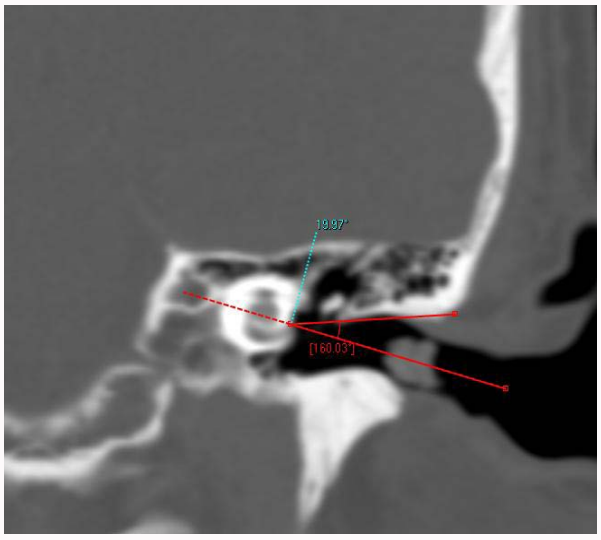

Figure 2: On this coronal reconstruction of the axial CT scans, the left EAC angle is 19.97 degrees. The degree of CA (black arrows) was graded as 2 (51-99%) on the left.

The EAC angle measures were available for 34 patients who had CA in just one ear. For these patients, the EAC angle of the ear with CA was compared to the angle of the other ear without CA, in the same person (to remove almost all possible confounders). The mean angle was significantly lower at 22.4 ± 5.6 degrees in the ear with CA accumulation compared to 25.3 ± 5.0 degrees in the ear without CA (p-value =0.002) (Figure 3).

As shown in Table 1, EAC angle measures were smaller for higher CA grades (p value =0.0015). There was a statistically significant negative correlation between CA grade and EAC angle with correlation coefficient of -0.18 (p-value<0.001). Ordinal regression analysis showed that the odds of having a higher accumulation grade compared to a lower grade is 7 percent lower for each one degree increase in EAC angle (OR=0.93, p-value =0.001).

The relationship between the grade of accumulation and EAC angle was also assessed for left and right ear, separately. The odds

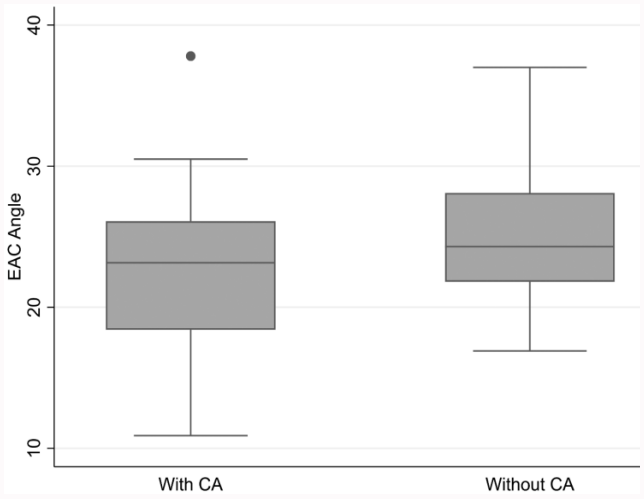

Figure 3: Box plot of EAC angle for patients with and without cerumen accumulation among 34 patients while their opposite ear served as control.

of having a higher accumulation grade compared to a lower grade is 5.5% and 8% lower for each one degree increase in EAC angle for left and right ear, respectively (OR=0.945, p-value =0.03 for left, and OR=0.92, p-value =0.002 for right). The side of the ear did not have any confounding or effect modification impact on the relationship between CA existence and EAC angle.

The CA and EAC angle measures were re-assessed on the CT scans of 50 ears, by the same observer at two different time points, separated by 10 days. The intra observer Kappa statistic for CA accumulation (binary) was 0.98 (p-value <0.001), demonstrating a strong level of intra-rater agreement. The intra-rater ICC was 0.90 (p<0.001) for CA grades and 0.88 (p<0.001) for EAC angle measurements. These values show excellent and good reliability, respectively. For assessing inter-observer agreement, 50 studies were read by two radiologists. The kappa statistic for cerumen accumulation as a binary variable was shown to be 0.96 (p-value <0.001), indicating excellent agreement. The ICC of the two raters for CA accumulation grade was 0.85 (p-value <0.001) showing good reliability and ICC of the two raters for EAC angle was 0.56 (p-value <0.001), indicating moderate agreement.

Discussion

Cerumen accumulation is caused by the breakdown of the self-cleaning mechanism of EAC [15]. When severe, CA can become symptomatic and lead to impaction against the tympanic membrane and subsequent conductive hearing loss. There is a continuum from no cerumen accumulation, to physiologic CA to symptomatic CA to cerumen impaction. Although otologists see many patients for ear wax hygiene, the understanding of why some people find CA problematic whereas some never have to deal with it is limited. This occurs in all age groups and both genders. No one has looked at the CT scans of patients with CA to try to shed light on this commonplace issue. We assumed that a steeper angulation of EAC in coronal view of temporal bone on head and neck CT scans could be associated with a decreased prevalence of CA since the gravitational affect in the upright position would permit more prompt drainage of cerumen and diminish the rate of CA.

This study confirmed that the angulation of the EAC is a potential risk factor for the accumulation of cerumen. The mean angle of those

Table 1: EAC angle measurements in ears with and without cerumen accumulation.

	Grade	Number of observations	Mean degrees	Std. Dev.	Median	Min	Max
Without CA	0	318	24.2	6.03	24	5.6	46
With CA	All	122	22	5.24	22.3	9.3	37.8
	1	75	22.9	5.2	22.9	9.3	37.8
	2	40	21.6	5.3	20.9	10.9	36.8
	3	7	19	4.4	18.9	10.9	23.5

The mean angle without cerumen accumulation (24.2 degrees) was larger than that with cerumen accumulation (22.0 degrees) (p value 0.0004). The higher the cerumen accumulation score, the lower the EAC angle (p value <0.001). CA: Cerumen Accumulation

patients with cerumen accumulation were significantly smaller than those of subjects without cerumen accumulation and this relationship was even more prominent in a subset of patients where the patients served as their own control. We also found that patients with smaller ear angles have a higher grade of CA, with greater association on the right side.

Horton et al. [12], reported that variation in the anatomy of the ear canal could lead to cerumen accumulation. Several conditions inhibit cerumen migration, including boney growth in the external auditory canal, such as exostosis or osteoma. Soft tissue masses such as hemangioma, cholesteatoma, lymphangioma, keratosis, history of previous trauma or otitis externa, and narrow or tortuous ear canals can lead, at the extreme, to cerumen impaction. However, these factors apply to a small portion of patients with CA.

The diagnosis of cerumen accumulation is generally made by direct otoscopy and is clinically graded into four types; type 1: No cerumen, type 2; non-obstructing cerumen accumulation, type 3; occluding cerumen, and type 4; fully occluding cerumen and debris [16]. We used a similar scale as what is clinically graded in our study.

CA can cause minor symptoms such as ear fullness and itchiness. When CA becomes more extensive it can affect hearing. Although symptomatic patients with cerumen accumulation could have several complaints mentioned above, several studies demonstrate that symptomatic cerumen accumulation results primarily from two major mechanisms: 1) pressure effect on the canal wall, which leads to ear discomfort, and obsessional attempts to clear CA by the patient, which could cause injury, inflammation, and otalgia, and 2) blockage of the sound wave from reaching the tympanic membrane, which eventually leads to hearing loss [10,17]. Removal is performed when the patient has significant hearing loss, feeling of fullness, itching, otalgia, tinnitus, and rarely imbalance. Sugiura et al. showed that hearing ability improved meaningfully after cerumen removal in the study group [18,19].

For clinicians, cerumen accumulation is one of the most common ear complaints in the US and on CT scanning is a common, if under-reported, incidental finding. Symptomatic CA is seen in 10% of the pediatric population, 7% of normal healthy adults, 57% of older patients in nursing homes, and up to one-third of patients with mental retardation [4,20]. It is thought that cerumen epithelial migration decreases in the elderly as the cerumen becomes drier and the hair in the EAC becomes coarser [12]. Studies estimate that the prevalence of cerumen accumulation is about 6 to 18 million in the US, and 12 million office visits are performed annually for cerumen removal in the US [21] accounting for nearly 50 million dollars in Medicare expenses in 2012 [4]. We found, in this study population of patients undergoing CT scanning, that the prevalence of CA was 28.7% of patients and 20.2% of ears, noting that bilateral CA occurred in 40.2% of those with CA.

The differential diagnosis clinically for cerumen blockage of the EAC by CT includes: EAC cholesteatoma and keratosis obturans [22,23]. Clinical examination readily distinguishes these entities, although they may coexist. CA can sometimes be differentiated from these other entities by CT by showing internal foci of air [23,24].

In some cases, the conductive hearing loss will exacerbate symptoms of patients with cognitive decline. Demented patients may be unable to voice their EAC symptoms, non-verbal, unaware of their hearing loss, or non-communicative (autism) [25]. In such cases a finding of CA obstruction of the EAC by a radiologist may be useful to identify the source of unexplained auditory symptoms.

What is the clinical utility of the findings of this manuscript? Although many non-imaging studies have been performed to identify predisposing factors for cerumen accumulation, this study uniquely explores the relation between EAC angle and CA for the first time using high resolution CT imaging. Often an otologist is left with an unfruitful explanation to a patient as to why the patient must keep returning for cerumen removal from the ears. Patients are discouraged from using cotton swabs (Q-tips®: Unilever) in the ears which may impact the cerumen, but many patients deny using such swabs. Excessive hair in the EAC has been implicated, and some otologists have trimmed the hair in the external canal as an attempt to improve cerumen drainage (personal communication David M. Yousem). Hearing aids may obstruct the flow of cerumen and patients may be advised to restrict their use if cerumen impaction is recurrent. However, if it was determined that the predisposing factor in the patient was from a more horizontally oriented EAC where cerumen drainage is impeded, then these other recommendations (avoid cotton swabs, trim your ear hair, and stop using your hearing aid) will be less useful. This is not to say that the authors are advocating CT scanning for EAC angle measurements, but if it has previously been performed this information may be useful to the ENT clinician. It may also serve to quell patient anxiety over why the cerumen accumulates.

The study, however, has some limitations that, though present, are unlikely to change the basic findings described herein. We did not look at demographic features of the patients studied in part to maintain a blinded review without impact of age and gender on the observer's measurements. However, by using the non-obstructed ears in the 34 patients with unilateral CA as their own internal controls, we addressed the age and gender issues, and found an even stronger correlation between EAC angle and CA. We also did not address at all whether the CA was symptomatic, in part because the clinical histories of the patients scanned were not targeted to EAC symptoms. Most patients were being evaluated in the emergency department for conditions (falls, motor vehicle collisions, strokes) where a complete history is rarely pursued, and these symptoms are

rarely addressed in the electronic medical record unless the patient complains. We do not have otoscopic confirmation of the ear wax and a social history detailing cotton swab use was not performed. We also combined a case cohort methodology with a randomized prevalence analysis based on consecutive scans. The study was performed at a single institution and intra observer and inter observer variability was measured on a limited subset (n=50) of the original 200 studies. Nonetheless the kappa and ICC reliability/reproducibility measures were moderate to excellent. In this paper we do not correlate EAC angle, CA, and patient symptoms. Our study sought to address anatomic risk factors, albeit ones that a patient cannot alter, to better understand the potential pathophysiology of this common but poorly understood phenomenon, cerumen accumulation.

Conclusion

CA in the EAC can be seen in 28.7% of a random population of patients undergoing CT scans of the brain, head and neck. The greater the angle of the EAC – i.e., the more it slopes downward from medial to lateral - the lower the rate of CA, and the lower the degree of EAC opacification in those patients with CA. This information may help explain why some people, without other risk factors, accumulate cerumen.

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