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ORIGINAL RESEARCH

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Incidence and trends of middle ear cholesteatoma surgery and mastoidectomy in Australia—A national hospital morbidity database analysis

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Abstract

Objective: To investigate the incidence of middle ear cholesteatoma surgery and assess trends in mastoidectomy procedures in Australia.

Study design: Cross-sectional population-based study using data from the National Hospital Morbidity Database.

Methods: Admitted care episodes containing the principal diagnosis of middle ear cholesteatoma were analyzed for two 12-month periods of 2007–2008 and 2017–2018. Surgical admissions involving mastoidectomy were identified by procedure codes. Incidence rate per 100,000 person-years were compared between study periods.

Results: Of the 3855 middle ear cholesteatoma admissions, 3558 (92.3%) involved surgery, with the incidence rate for cholesteatoma surgical admissions estimated at 8.6 per 100,000 (95% CI: 8.2–9.0) and 8.1 per 100,000 (95% CI: 7.7–8.5) for 2017–2018 and 2007–2008, respectively. Population aged 10–19 years had the highest age-specific incidence rate at 12.5 per 100,000 (95% CI: 11.3–13.9) for 2017–2018. The 60 years and over age groups had the highest decennial percentage increase. Mastoidectomy procedures were consistently used in over half of all surgical admissions. An increase in the rate of canal wall up (CWU) mastoidectomy procedure related admissions was observed (rate ratio of 1.62 [95%CI: 1.41–1.86], P <.001) and was offset by a decreased rate of canal wall down (CWD) procedure associated admissions (0.69 [95% CI: 0.61–0.78], P <.001]).

Conclusions: The incidence rate of cholesteatoma surgery in Australia is estimated at 8.6 per 100,000. Mastoidectomy continues to play an essential role in cholesteatoma surgery with a trend favoring CWU over CWD mastoidectomy.

Level of evidence: 4

KEYWORDS
canal wall, cholesteatoma, epidemiology, incidence rate, mastoidectomy

1 | INTRODUCTION

Canal wall up (CWU) and canal wall down (CWD) mastoidectomy procedures are a unique feature of cholesteatoma surgery. The status of the posterior canal wall in the surgical management of middle ear cholesteatoma has been a topic of controversy in which advocates of CWU and CWD have long debated the advantages and disadvantages of their respective technique. Proponents of CWD procedures argue the more invasive surgical exposure afforded by CWD procedures is justified by the greater assurance it provides for successful single stage disease removal.[1] On the other hand, CWU procedures often necessitate a multi-stage approach to treatment and second-look procedures to address expected or unexpected residual and/or recurrent disease, with the inherent advantage of avoiding the ramifications of a CWD open cavity defect. Findings from systematic reviews generally support this notion of CWU surgery having higher rates of residual and recurrent disease than CWD surgery.[2,3]

There are also cholesteatoma procedures that do not involve mastoidectomy. These are used in the clearance of small volume limited disease.[4] Broadly, these *mastoidectomy sparing* procedures include tympanoplasty, atticotomy, or attico-antrostomy techniques.

In clinical practice, CWD, CWU, and mastoidectomy sparing procedures each have specific applications with the choice determined not only by the disease factors, but by factors including the surgeon's training and expertise, the patient's preference, and costs of treatment. However, the universal trend of minimizing surgical morbidity using principles of minimally invasive surgery is also influencing cholesteatoma surgery. Over the past decade, cholesteatoma surgery appears to be advancing with the popularization of terms such as functional minimally invasive cholesteatoma surgery and endoscopic ear surgery (EES) that is becoming part of the standard of practice around the world.[5–7] The hypothesis of this work was that cholesteatoma surgery in a developed country such as Australia has been evolving to consist of overall fewer mastoidectomy procedures and CWD procedures, and substituted by more CWU and *mastoidectomy sparing*

TABLE 1 Analysis of middle ear cholesteatoma surgical admissions according to 7-digit ACHI mastoidectomy procedure codes—an Australian national hospital morbidity database analysis

	2007–2008 (n = 1589)		2017–2018 (n = 1969)	
Admissions involving CWD mastoidectomy procedures[a]	590	(37.1%)	480	(24.4%)
(41557-00) MRM	233	(14.7%)	149	(7.6%)
(41560-00) MRM with myringoplasty	123	(7.7%)	86	(4.4%)
(41563-00) MRM with myringoplasty and ossicular chain reconstruction	127	(8.0%)	113	(5.7%)
(41564-00) MRM with obliteration of mastoid cavity and eustachian tube and closure of external auditory canal	12	(0.8%)	15	(0.8%)
(41566-01) revision of MRM	33	(2.1%)	54	(2.7%)
(41557-01) RM	18	(1.1%)	9	(0.5%)
(41560-01) RM with myringoplasty	13	(0.8%)	15	(0.8%)
(41563-01) RM with myringoplasty and ossicular chain reconstruction	14	(0.9%)	19	(1.0%)
(41564-01) RM with obliteration of mastoid cavity and eustachian tube and closure of external auditory canal	5[b]	(0.3%)	5	(0.3%)
(41566-02) revision of RM	12	(0.8%)	15	(0.8%)
Admissions involving CWU mastoidectomy procedures	311	(19.6%)	594	(30.2%)
(41545-00) mastoidectomy cortical	90	(5.7%)	112	(5.7%)
(41551-00) mastoidectomy by ICW with myringoplasty	120	(7.6%)	247	(12.5%)
(41554-00) mastoidectomy by ICW with myringoplasty and ossicular chain reconstruction	68	(4.3%)	159	(8.1%)
(41566-00) revision of ICW mastoidectomy	33	(2.1%)	76	(3.9%)
Admissions *without* mastoidectomy procedures (mastoidectomy sparing procedures)[c]	688	(43.3%)	895	(45.5%)

Note: Data presented are n (%).

Abbreviations: ACHI, Australian Classification of Health Interventions 5th and 10th edition; CWD, canal wall down; CWU, canal wall up; MRM, modified radical mastoidectomy; RM, radical mastoidectomy; ICW, intact canal wall technique.

[a]Two and five admission records for periods 2007–2008 and 2017–2018, respectively contained both CWU and CWD codes and were categorized according to their respective CWD mastoidectomy codes.

[b]Rounded to nearest 5 to preserve confidentiality of data.

[c]Category inclusive of tympanoplasty, atticotomy, and other nonmastoidectomy procedures.

procedures. The objective of this study is to investigate the hypothesis using retrospective data from an Australian national hospital database.

2 | MATERIALS AND METHODS

A cross-sectional comparative study using data obtained from the National Hospital Morbidity Database (NHMD) for two 12-month periods, July 1, 2007 to June 30, 2008 (2007–2008) and July 1, 2017 to June 30, 2018 (2017–2018) was performed. The NHMD is an administrative database maintained by the Australian Institute of Health and Welfare (AIHW), which collects and manages data relating to episodes of admitted patient care in Australia. The database has coverage of almost all hospitals in Australia, including public and private facilities.[8] The database contains demographic and clinical morbidity data associated with admitted patient care episodes which includes diagnosis codes and procedure codes categorized according to the International Statistical Classification of Diseases (ICD) and the Australian Classification of Health Interventions (ACHI) respectively.

2.1 | Definition of outcome measures

All admitted patient care episodes related primarily to the management of middle ear cholesteatoma were classified as *cholesteatoma admissions* and were identified using the principal diagnosis code "cholesteatoma of the middle ear" (International Statistical Classification of Diseases, 10th Revision, Australian Modification, [ICD-10, AM] diagnostic code E71). Records of admitted patient care episodes are inclusive of same-day and overnight care patients, and in accordance with the ICD coding guidelines, each episode of admitted patient care is coded with a solitary principal diagnosis code representing "the diagnosis established after study, to be chiefly responsible for occasioning the patient's episode of care."[9]

Within this dataset, all admitted patient care episodes containing procedure codes related to the administration of general or regional anesthesia (codes 92514-XX and 92509-XX) or sedation (codes 92515-XX) were classified as *cholesteatoma surgical admissions* representing patients who have undergone a surgical procedure during their hospital stay. Care episodes that contained anesthesia or sedation related procedure codes but were only accompanied by procedure codes relating to diagnostic imaging procedures (e.g., CT imaging procedure codes 560XX-XX and/or MRI imaging procedure codes 90901-XX) were excluded from the cholesteatoma surgical admissions count.

Cholesteatoma surgical admissions containing mastoidectomy procedure codes represent admitted care episodes that involved a mastoidectomy procedure. The ACHI procedure codes for mastoidectomy procedures vary according to the presence of adjunctive procedures that may be performed at the time of the mastoidectomy procedure (i.e., myringoplasty and ossicular chain reconstruction procedures and obliteration of mastoid cavity procedure). Specific codes are also available for revision mastoidectomy procedures (Table 1). The study defined *cholesteatoma mastoidectomy admissions* as episodes that contain mastoidectomy specific procedure codes. These admissions are further categorized into either *CWD admissions* or *CWU admissions* based on the mastoidectomy procedure code. Infrequently, episodes of care that were found to contain more than one mastoidectomy procedure code were allocated to the procedure code of greater surgical exposure or invasiveness. For example, the CWD procedure of modified radical mastoidectomy (MRM) would have precedence over CWU procedures, and similarly, the CWD procedure of radical mastoidectomy (RM) would be categorized over both MRM and CWU procedures.

The *mastoidectomy sparing admissions* were defined by those *cholesteatoma surgical admissions* that did not contain mastoidectomy procedure codes. Using this method, each *cholesteatoma surgical admission* was allocated to a mutually exclusive category of either *cholesteatoma mastoidectomy admissions* (with further classification into *CWU admissions* or *CWD admissions*) or as *mastoidectomy sparing admission* based on their procedure codes.

2.2 | Population estimates

The source population used to calculate the incidence rate for the 2007–2008 and 2017–2018 periods are the mid-year Australian Bureau of Statistics (ABS) Australian resident population estimates from the census years of 2006 and 2016, respectively.[10]

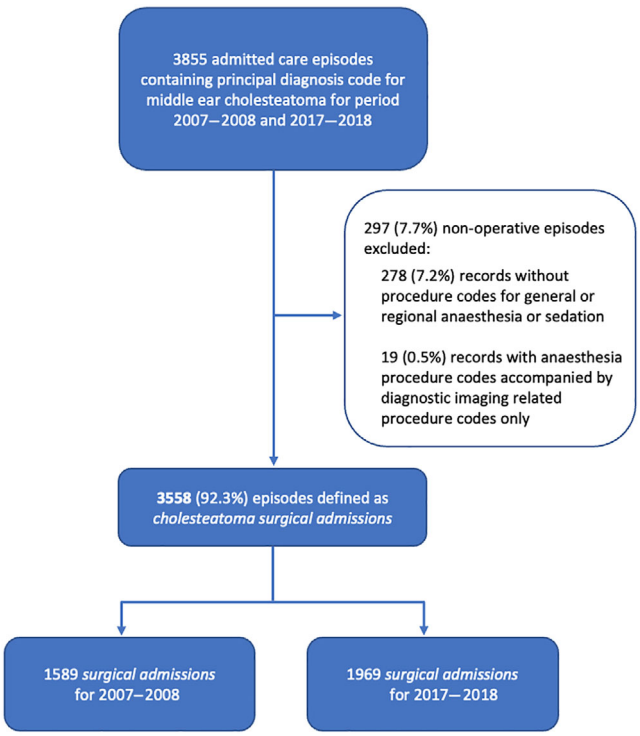

FIGURE 1 Allocation of middle ear cholesteatoma patient admitted care episodes into operative group and nonoperative admissions and for 2007–2008 and 2017–2018 study periods. 2007–2008 and 2017–2018 represent July 1, 2007 to June 30, 2008 and July 1, 2017 to June 30, 2018, respectively

TABLE 2 Overall age-standardized and age-specific incidence of middle ear cholesteatoma surgical admissions—an Australian national hospital morbidity database analysis

	2007–2008			2017–2018			Comparison			
Age (years)	n	Rate	(95% CI)	n	Rate	(95% CI)	DPC (%)	Rate ratio	(95% CI)	*P*-value
Overall[a]	1589	8.1	(7.7, 8.5)	1969	8.6	(8.2, 9.0)	23.9	1.07	(1.00, 1.14)	.13
0–9	201	7.8	(6.8, 9.0)	243	8.2	(7.2, 9.3)	20.9	1.05	(0.86, 1.27)	.63
10–19	294	10.8	(9.6, 12.1)	353	12.5	(11.3, 13.9)	20.1	1.16	(0.99, 1.36)	.06
20–29	168	6.4	(5.5, 7.4)	234	7.2	(6.3, 8.2)	39.3	1.13	(0.92, 1.39)	.22
30–39[b]	209	7.3	(6.3, 8.4)	246	7.5	(6.6, 8.5)	17.7	1.03	(0.86, 1.25)	.73
40–49	210	7.2	(6.3, 8.2)	239	7.6	(6.6, 8.6)	13.8	1.05	(0.87, 1.27)	.61
50–59	233	9.1	(8.0, 10.4)	243	8.2	(7.2, 9.3)	4.3	0.89	(0.74, 1.07)	.21
60–69	153	8.9	(7.6, 10.4)	230	9.2	(8.1, 10.5)	50.3	1.04	(0.84, 1.28)	.73
≥70	121	6.4	(5.3, 7.7)	181	7.3	(6.3, 8.4)	49.6	1.13	(0.90, 1.44)	.28

Note: 2007–2008 and 2017–2018 represent July 1, 2007 to June 30, 2008 and July 1, 2017 to June 30, 2018, respectively. Source population for 2007–2008 and 2017–2018 incidence rate calculation are the mid-year Australian census population of 2006 and 2016, respectively.
Abbreviations: CI, confidence interval; DPC, decennial percentage change; n, absolute number of surgical admissions; Rate, rate per 100,000 person-years.
[a]Age standardized rate.
[b]Median age group.

TABLE 3 Incidence rates of middle ear cholesteatoma surgical admissions categorized by mastoidectomy procedures—an Australian national hospital morbidity database analysis

	2007–2008			2017–2018			Comparison		
	(n = 1589)	Rate	(95% CI)	(n = 1969)	Rate	(95% CI)	Rate ratio	(95% CI)	*P*-value
Admissions involving mastoidectomy procedures[a]	901	4.5	(4.2, 4.8)	1074	4.6	(4.3, 4.9)	1.01	(0.93, 1.11)	.80
Admissions involving CWD procedures	590	3.0	(2.7, 3.2)	480	2.1	(1.9, 2.2)	0.69	(0.61, 0.78)	<.0001
Admissions involving CWU procedures	311	1.6	(1.4, 1.8)	594	2.5	(2.3, 2.8)	1.62	(1.41, 1.86)	<.0001
Admissions without mastoidectomy procedures[b]	688	3.5	(3.2, 3.7)	895	3.8	(3.6, 4.1)	1.10	(1.00, 1.22)	.05

Note: 2007–2008 and 2017–2018 represent periods July 1, 2007 to June 30, 2008 and July 1, 2017 to June 30, 2018, respectively. Source population for 2007–2008 and 2017–2018 incidence rate calculation are the mid-year Australian census population of 2006 and 2016, respectively.
Abbreviations: CI, confidence interval; Rate, rate per 100,000 person-years; CWD, canal wall down; CWU, canal wall up; n, absolute number of patients admitted episodes.
[a]Two and five admission records for periods 2007–2008 and 2017–2018, respectively contained both CWU and CWD codes and were categorized according to their respective CWD mastoidectomy codes.
[b]Category inclusive of tympanoplasty, atticotomy, and other nonmastoidectomy cholesteatoma procedures.

2.3 | Statistical analyses

Data were stratified using Microsoft Excel Version 2021 (Microsoft Corporation, Redmond, WA) and statistical analysis was performed using statistical software (StatsDirect; StatsDirect Ltd., England 2013). The annual incidence rate of cholesteatoma surgical admissions per 100,000 person-years were age-standardized by the direct standardization method to the WHO's World Standard Population.[11] The 95% confidence intervals for the incidence rates were calculated using the Poisson regression model. The Pearson chi-square test for 2 × 2 contingency tables was used to compare variables between the two time periods. Statistical significance was set to $P < .05$.

3 | REPORTING GUIDELINE

The study conforms to the STROBE statement.

4 | ETHICAL APPROVAL

This study was approved by the Human Research Ethics Committee of the Northern Sydney Local Health District, Sydney, Australia. Reference 2021/ETH01243.

5 | RESULTS

5.1 | Analysis of cholesteatoma surgical admissions

For the 2007–2008 and 2017–2018 study periods combined, there were 3855 patient admitted care episodes containing the principal diagnosis of middle ear cholesteatoma. 297 (7.7%) episodes were assessed as non-surgical and were excluded from the analysis. The remaining 3558 (92.3%) episodes were classified as surgical admissions (Figure 1).

5.2 | Incidence of cholesteatoma surgical admissions

A total of 1589 and 1969 cholesteatoma surgical admissions were recorded in Australia for 2007–2008 and 2017–2018, respectively. Adjusting for the size and age structure of the Australian census population (19.9 million and 23.4 million people in 2006 and 2016, respectively[9]), the estimated age-standardized incidence rate of cholesteatoma surgery was consistent between the two study periods at 8.1 per 100,000 person-years (95% CI: 7.7–8.5) in 2007–2008 and 8.6 per 100,000 person-years (95% CI: 8.2–9.0) in 2017–2018. Correspondingly there was no statistically significant difference in the incidence rates (rate ratio 1.07 (95% CI: 1.00–1.14, $P = .13$) (Table 2).

5.3 | Cholesteatoma surgical admissions by age group and age-specific incidence

The age-specific incidence rate for cholesteatoma surgical admissions peaked in the 10–19 years age group at 11.2 per 100,000 person-years (95% CI: 10.1–12.6) for 2007–2008 and 12.9 per 100,000 person-years (95% CI: 11.6–14.3) for 2017–2018. Cholesteatoma surgical admissions was distributed across all age groups with a slight bi-modal pattern with a secondary peak in the 50–59 years age group (9.1 per 100,000 person years [95% CI: 8.0–10.4]) and the 60–69 years age group (9.2 per 100,000 person years [95% CI: 8.1–10.5]) for 2007–2008 and 2017–2018, respectively (Table 2). For both study periods the median age group was the 30–39 years age group.

The 60–69 years and the 70 years and over age groups experienced the greatest decennial percentage increases (50.3% and 49.6%, respectively). However, consistent with the rate changes in the other age groups, the change in incidence rates between the two periods in these age groups were not statistically significant (Table 2).

5.4 | Incidence of mastoidectomy and mastoidectomy sparing admissions

The allocation of individual cholesteatoma surgical admissions according to presence and absence of mastoidectomy procedure codes are presented in Table 1. A total of 901 and 1074 cholesteatoma mastoidectomy admissions were recorded for 2007–2008 and 2017–2018, respectively. There was no statistical difference in the incidence rates of cholesteatoma mastoidectomy admissions between the study periods (rate ratio of 1.01 ([95% CI: 0.93–1.11]), $P = .80$; Table 3). The increase in the absolute number of *mastoidectomy sparing surgical admissions* from 686 admissions in 2007–2008 to 895 admissions in 2017–2018 approached but did not reach statistical significance (rate ratio of 1.10 ([95% CI: 1.00–1.22], $P = .05$).

5.5 | Incidence of CWU versus CWD mastoidectomy admissions

A small number of admission episodes were found to contain both CWU and CWD procedure codes (2 episodes in 2007–2008 and

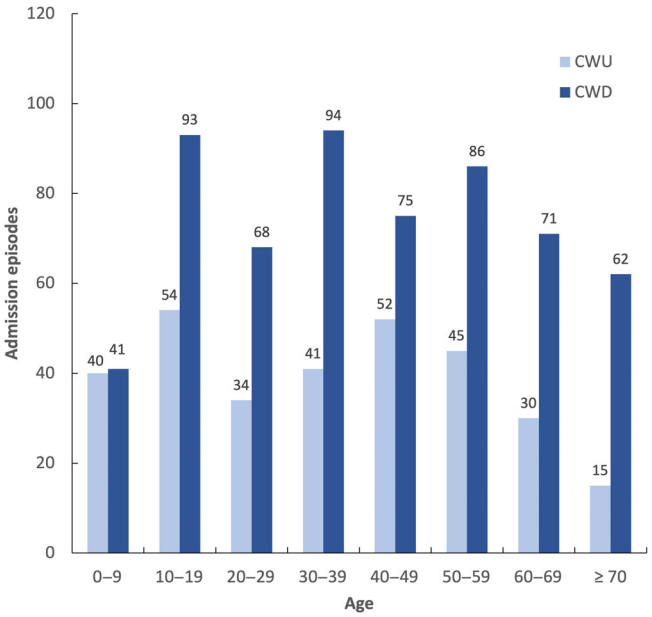

FIGURE 2 Age distribution of cholesteatoma admission episodes by involvement of canal wall down and canal wall up mastoidectomy for the period July 1, 2007 to June 30, 2008—an Australian national hospital morbidity database analysis. CWD, canal wall down mastoidectomy; CWU, canal wall up mastoidectomy

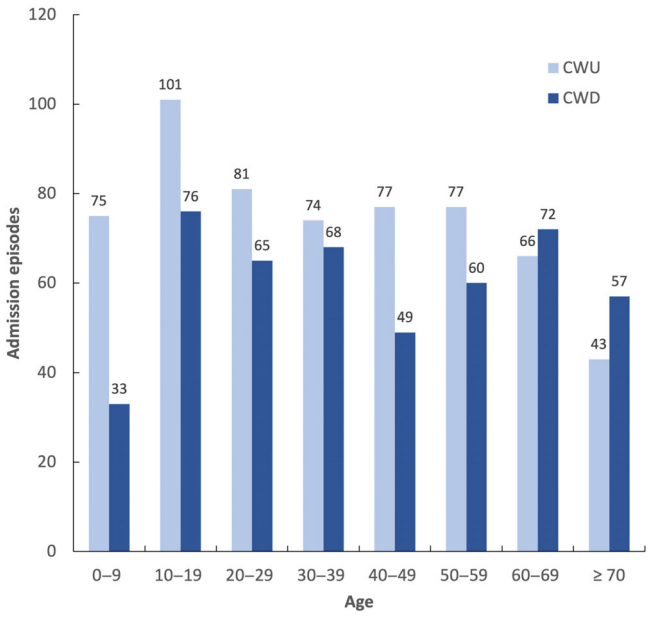

FIGURE 3 Age distribution of cholesteatoma admission episodes by involvement of canal wall down and canal wall up mastoidectomy for the period July 1, 2017 to June 30, 2018—an Australian national hospital morbidity database analysis. CWD, canal wall down mastoidectomy; CWU, canal wall up mastoidectomy

TABLE 4 Summary of population-based studies examining the incidence rate of cholesteatoma surgery[12–16]

Author (publication year)	Country	Study period	Study type	Method of case allocation	Incidence rates (per 100,000 person-years)
Kemppainen et al. (1999)[12]	Finland	1982–1991	Two central single centre retrospective study	Individual case record review	Mean incidence of 9.2 for 1982–1991
Hari et al. (2007)[13]	UK	1989–2005	Cross-sectional national database analysis (NHS)	Otology procedure code analysis	1334 and 1313 absolute numbers of modified radical mastoidectomies in 1989–1990 and 2004–2005, respectively
Djurhuus et al. (2010)[14]	Denmark	1977–2007	Cross-sectional national database analysis (DNHR)	ICD diagnosis and procedure code analysis	Male; 14.3 in 1982 and 8.5 in 2007 Female; 9.1 in 1981and 5.4 in 2007
Das-Purkayastha et al. (2012)[15]	Canada	1987–2007	Cross-sectional analysis of database from the Ministry of Health (Ontario)	Mastoidectomy procedure code analysis	6.93 in 1987 and 4.51 in 2007
Im et al. (2020)[16]	South Korea	2006–2018	Cross-sectional national database analysis (NHID)	ICW and OC procedure code analysis	7.15 in 2006 and 6.17 in 2018
Li et al. (2021)	Australia	2007–2008 and 2017–2018	Cross-sectional national database analysis (NHMD)	ICD principal diagnosis code and procedure code analysis	8.1 in 2007–2008 and 8.6 in 2017–2018

Abbreviations: DNHR: Danish National Hospital Register; ICD: International Classification of Diseases; ICW: intact canal wall mastoidectomy; NHID: National Health Information Database; NHMD: National Hospital Morbidity Database; NHS: National Health Service; OC: open cavity mastoidectomy.

5 episodes in 2017–2018). These admission records were allocated to their mastoidectomy code categories according to their CWD procedure code.

For the 2007–2008 period, CWU and CWD admissions accounted for 19.6% and 37.1% of total cholesteatoma surgical admissions, respectively and CWD procedures was utilized for the majority (65% [590 of 901]) of cholesteatoma mastoidectomy admissions. In 2017–2018, the number of CWU admissions represented 30.2% of total cholesteatoma surgical admissions while CWD admissions represented 24.4% of total cholesteatoma surgical admissions. CWU admissions surpassed CWD admissions for 2017–2018 (55.3% [594 of 1074]) (Table 3).

Incidence rate analysis for CWU and CWD admissions was performed to allow per capita rate comparison between the study periods. The incidence rate for CWU admissions increased by 62% from 1.6 per 100,000 to 2.5 per 100,000 person-years from 2007–2008 to 2017–2018 (rate ratio 1.62 [95% CI: 1.41–0.87], P <.0001). Over the same time period, the incidence rate for CWD admissions decreased by 39% from 3.0 per 100,000 to 2.1 per 100,000 person-years (rate ratio 0.69 [95% CI: 0.61–0.78], P <.0001; Table 3).

5.6 | Age distribution of CWD versus CWU mastoidectomy admissions

Figures 2 and 3 illustrate the age distribution of CWD and CWU admissions for 2007–2008 and 2017–2018, respectively. For the 2007–2008 period, the frequency of CWD admissions was significantly higher than the frequency of CWU admissions for all age groups except for the 0–9 years age group (40 CWU admissions versus 41 CWD admissions; Figure 2). In addition, during 2007–2008 there was a reduction in both CWD and CWU admissions with increasing age. The difference between CWD and CWU widen as age increased with CWD admissions reaching four times that of CWU admissions for the 70 years and over age group.

In 2017–2018, the number of CWU admissions were overall higher than CWD admissions for all age groups except for the older age groups aged 60 years and over, where CWD admissions exceeded CWU admissions. Figure 3 shows the greatest discrepancy between CWU and CWD was in the 0–9 years age group with the number of CWU admissions being 2.3 times higher than number of CWD admissions.

6 | DISCUSSION

Middle ear cholesteatoma is essentially a surgical disease that relies on surgical treatment to alter and prevent its natural history. The incidence rate of cholesteatoma surgery provides valuable insight into the epidemiology of cholesteatoma management with implications for both surgical competency standards as well as training and enables the scrutiny of the choice of surgical treatments on patient outcomes.

The surgical nature of middle ear cholesteatoma hospitalized care was demonstrated by the high proportion of middle ear cholesteatoma admitted care episodes involving either anesthesia or sedation. By excluding nonoperative cholesteatoma admission episodes, the rate of cholesteatoma surgery in Australia was estimated at 8.1–8.6 per 100,000 person-years for 2007–2008 and 2017–2018, respectively.

This incidence rate is comparable to the rate reported in other developed countries (Table 4).[12–16]

The incidence rate of a particular surgical treatment is generally influenced by the prevalence of the disease it treats as well as a population's accessibility to the health care. In the case of middle ear cholesteatoma surgery in Australia, sustained improvements in the population's access to health care in line with population growth may explain the constant incidence rate of cholesteatoma surgery across the study periods. In recent years, Australia has experienced an expansion of its medical workforce with an increase in primary and secondary healthcare workers by 19.4% over a 5-year period from 2013 to 2018.[17] More specifically, from 2010 to 2018, the number of practising Australian otolaryngologists has increased by 71% from 383 to 656 practitioners.[18]

The results show that the cases of cholesteatoma surgery and cholesteatoma mastoidectomy surgery in Australia were widely distributed among people of all ages. The highest incidence was in the 10–19 years age group. However, a secondary peak in incidence occurred in the older population and it was the 60 years and over age group, which had the greatest increase in absolute number of cholesteatoma surgical admissions. The study also found that a substantial proportion of mastoidectomy procedures were performed in the 60 years and over population, with the vast majority of mastoidectomies being CWD procedures in 2007–2008 and subsequently a more even distribution of CWD and CWU procedures was observed for the 2017–2018 period. While the increase in the absolute number of surgical admissions for older patients is in line with the effects of an aging Australian population,[19] the increased surgical candidacy of older patients may also be explained by a growing inclination to surgically manage older cholesteatoma patients. This inclination may be brought about by the expanded surgical (and nonsurgical) options for hearing augmentation following cholesteatoma surgery,[20] and by the increasing reports in the literature of favorable hearing outcomes in elderly patients following tympanoplasty procedures.[21–23]

In this Australian national hospital database study, there was evidence of an increased adoption of a less invasive approach to the management of cholesteatoma by reference to CWU procedures. Although there was not an overall reduction in the number of mastoidectomy related cholesteatoma surgical episodes, there has been a shift away from the previously CWD dominant approach and CWU has become the preferred approach to cholesteatoma mastoidectomy surgery over the study periods.

The trend toward more conservative cholesteatoma surgery through less reliance on CWD procedures was first noted by a UK study in 2007. In the analysis of National Health Services (NHS) data over a 15-year period from 1989 to 2005, the study found the rate of the mastoidectomy sparing procedure of atticotomies increase incrementally by 10 cases per year with no substantial change in the total number of mastoidectomies performed in NHS hospitals over time.[12]

In the presented data, despite the increase in the incidence of CWU surgery, there was no corresponding statistically significant increase in the overall rate of cholesteatoma surgical admissions or surgical activity detected. Therefore, the increased rate of CWU admissions did not result in detectable rates of hospitalization from second look and revision procedures to address known higher rates of disease recidivism associated with CWU surgery. Furthermore, the incidence rate of *mastoidectomy sparing admissions* approached, but did not reach, statistical significance. This observation may be explained by a trend in mastoidectomy sparing procedures, which would consist of both minimally invasive cholesteatoma procedures that includes tympanoplasty and atticotomy procedures, as well as hearing augmentation procedures following cholesteatoma surgery such as the ossiculoplasty procedures and hearing device implant procedures. Further specific subgroup analysis outside the present study may further clarify this emerging trend.

The shift from CWD to CWU approach to cholesteatoma surgery may also be influenced by the recent popularization of EES with the use of ear endoscopy as a stand-alone technique or as an adjunct to the traditional operating microscope.[24] A systematic review has also concluded that the use of ear endoscopy increases the likelihood of CWU surgery achieving low disease recidivism rates comparable to CWD surgery.[25]

To date, the ACHI coding schedule does not contain distinctive codes for endoscopic ear procedures and consequently this study was unable to validate the practice of EES in Australia. However, a 2019 survey of members of the Australian Society of Otolaryngology Head and Neck Surgery found that 43% of respondents performed EES as part of their practice.[26] The increased use of the oto-endoscope in ear surgery in recent times, together with the capabilities of diffusion weighted magnetic resonance imaging to detect residual and recurrent cholesteatoma as a nonoperative alternative management option to second look procedures,[27] may help explain the absence of a significant increase in total cholesteatoma surgical activity that would be expected from the increased rates of CWU procedures.

Contrary to this study's hypothesis, there has been no change in the incidence of mastoidectomy procedures between the study periods. Both periods consistently showed that mastoidectomy procedures continue to play an essential role in cholesteatoma surgery with mastoidectomies being performed in over half of all middle ear cholesteatoma surgical care episodes. Without individual clinical data, it is difficult to ascertain the extent of which the clinical decision-making process for mastoidectomy or the selection between CWD and CWU is influenced by clinical factors versus surgeon preference and institutional factors.

Noting an estimated 42% (273 of 656) of practising Australian otolaryngologists commenced their practice in the last decade, it remains unknown how widely a functional approach to cholesteatoma surgery is being utilized by more experienced senior practitioners or whether such trend is largely influenced by the cohort of younger practitioners. Furthermore, the volume of cholesteatoma surgery tends to be concentrated among a subgroup of practitioners with otology subspecialty interest and training and the trend may reflect the practice of this subgroup.

Strengths of this study include the sample size based on national data, comparability of data between time periods, and an inclusion and exclusion criteria that allowed the all-encompassing capture of all surgical activities related to middle ear cholesteatoma.

A limitation of this study was its inability to address the rate of revision surgery and disease recidivism. Despite the ACHI having designated codes for revision mastoidectomy procedures, these codes do not provide a true representation of the rate of revision mastoidectomy surgery given that in practice, mastoidectomy codes that are not itemized as "revision" procedures are also used for the coding of revision mastoidectomy procedures. Furthermore, there are no designated codes for nonmastoidectomy involving cholesteatoma procedures (e.g., tympanoplasty and atticotomy procedures) assigned to the management of residual or recurrent disease. Further data-linkage studies may be able to better assess recidivism rates and other important patient morbidity parameters associated with the shift toward conservative approaches to surgery. These may include the comparison of the frequency of office-based procedures and diagnostics tests used during the disease surveillance period, associated financial costs as well as overall differences in patient satisfaction.

Other limitations include the known constraints with national hospital database research.[28] The ICD-10-AM and ACHI codes were assigned for health care billing purposes and are not validated to individual case records and may be susceptible to misclassification and coding errors. There is also the potential of selection bias in relation to the choice of study periods. Understandably small year to year fluctuations in incidence rates may occur but this should not affect the trends over a longer 10-year period. In addition, to the best of our knowledge, during these periods, Australia did not experience any major economic, political, or public health policy changes or infectious disease pandemics that would have confounded the trend of the cholesteatoma surgical activity of the nation.

7 | CONCLUSIONS

In conclusion, the age-standardized incidence rate of middle ear cholesteatoma surgery in Australia is estimated at 8.1–8.6 per 100,000 person-years for 2007–2008 and 2017–2018, respectively. The burden of cholesteatoma surgical activity is distributed among persons of all ages with a peak incidence in the 11–19 years age group. Contrary to the growing trend of minimally invasive ear surgery, the incidence per capita of mastoidectomy and mastoidectomy sparing procedures has remained unchanged between 2007–2008 and 2017–2018. Mastoidectomy procedures were being utilized in over half of all cholesteatoma surgical admissions with an estimated incidence of 4.6 per 100,000 person years. More importantly, since 2007–2008 there has been a shift toward more conservative cholesteatoma surgery with the frequency of CWU procedures exceeding CWD procedures.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the Australian Institute of Health and Welfare. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the corresponding author with the permission of the Australian Institute of Health and Welfare.

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