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Distribution of Pathogenic Bacteria and Antimicrobial Resistance after Plastic Surgery for Microtia

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Background: Microtia, or congenital malformation (smallness or absence) of the outer ear, can be treated with ear prosthetics and/or surgery.

Methods: Between January 2011 and December 2021, following plastic surgery, microbial strains from patients with microtia were collected, identified, and counted. WHONET 5.6 was used to analyze in vitro drug resistance of the microbial strains, according to procedures outlined by the Clinical and Laboratory Standards Institute (document M100, 2021). Data regarding surgical techniques, the duration of infection, and other clinical details were also collected.

Results: A total of 261 patients were included in the study. Among these, 235 Gram-positive bacteria were detected, with *Staphylococcus aureus* (140/235) and coagulase-negative staphylococci (84/235) accounting for the majority. There were also 26 Gram-negative bacteria, of which *Enterobacter* (11/26) and *Pseudomonas aeruginosa* (7/26) were the most common. According to the results of testing for antimicrobial resistance, *S. aureus* was highly sensitive to cotrimoxazole, levofloxacin, vancomycin, chloramphenicol, and linezolid, whereas coagulase-negative staphylococci were highly sensitive to vancomycin and linezolid. Both were highly resistant to penicillin and erythromycin. In this study, the pathogenic bacteria involved in postoperative infections varied overall, but the most prevalent was *S. aureus.* The infections appeared mainly in the late postoperative period. A total of 24,548 procedures were performed in the same period, and the infection rate was 1.06%.

Conclusions: Gram-positive bacteria are the major cause of infection following plastic surgery for microtia. The bacterial species, degrees of antimicrobial resistance, and length of infection varied among the various surgical procedures. *(Plast Reconstr Surg Glob Open 2023; 11:e5442; doi: 10.1097/GOX.0000000000005442; Published online 28 November 2023.)*

INTRODUCTION

Microtia is a type of congenital dysplasia of the auricle, with abnormal structures ranging from minor structural abnormalities to total absence of the external ear, often accompanied by hearing loss. Microtia, the second most common congenital craniofacial abnormality after oral cleft, has a high incidence rate[1,2] and is a major body-surface birth defect. Patients with microtia not only have hearing impairment[3,4] but also have a significant risk of structural renal abnormalities.[5] In addition, microtia brings heavy psychological burdens, which may lead to feelings of inferiority or bullying from others. Thus, both the pursuit of improved hearing function and the desire for a more normal appearance boost the demand for plastic surgery. The major plastic surgery procedures for microtia include auricular reconstruction with two expanded flaps, auricular reconstruction with a single expanded flap, and the Nagata method. Infection is the most common complication after such plastic surgery, most often accounting for its failure. In recent years, owing to the abuse of antibiotics and the emergence of drug-resistant strains, the treatment of infection has become increasingly difficult. Therefore, to delay the emergence of drug-resistant strains and strengthen the effects of infection prevention and control, it is crucially

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important to select the most appropriate antibiotics. To do so, we analyzed the distribution and antimicrobial resistance of common infectious bacteria, identified the bacterial species most often associated with various procedures, and determined the common length of infection.

METHODS

Clinical Specimens

Data were retrospectively collected between January 2011 and December 2021 at the Plastic Surgery Hospital of the Chinese Academy of Medical Sciences and Peking Union Medical College from patients with microtia who had developed infections after plastic surgery for microtia.

Numbers for Each Type of Microtia

According to the four classes of microtia proposed by Marx and modified by Rogers, the number for microtia of grade I, II, III, and IV were 23, 10, 222, and 6, respectively.

Procedures

The three main auricular reconstruction procedures are as follows:

A. Auricular reconstruction with an expanded single flap.

In the first stage, a 50-mL tissue expander was embedded in the mastoid region and the retroauricular skin expanded. In the second stage, the autologous rib cartilage was harvested and the ear framework was fabricated. The expander was removed, and then the ear framework was implanted and enveloped by the expanded flap. In the third stage, the reconstructed ear was further trimmed, including the conchal cavity deepening and tragus reconstruction.[6]

B. Auricular reconstruction with two expanded flaps.

In the first stage, an 80-mL tissue expander was embedded in the mastoid region, and the retroauricular skin was expanded. In the second stage, the autologous rib cartilage was harvested, and the ear framework was fabricated. The expander was removed, and then the ear framework was implanted and enveloped by the expanded flap, a retroauricular fascial flap, and a free skin graft. In the third stage, the reconstructed ear was further trimmed, including the conchal cavity deepening and tragus reconstruction.[7]

C. The Nagata method.

The first stage involves harvesting the rib cartilage and fabricating and grafting a three-dimensional costal cartilage framework. The second stage is the ear elevation operation.[8]

Identification of Microbial Species and Antimicrobial Resistance Test

The selected cases were studied in strict accordance with the Diagnostic Criteria for Nosocomial Infection of the Ministry of Health. All specimens were subjected to routine smear, Gram staining, inoculation culture, isolation, and identification according to the *National Clinical Laboratory Procedures* (4th edition). After the removal of duplicates, a total of 261 strains of bacteria were isolated. The clinical specimens for those strains came mainly from wound secretions and abscess extracts.

> **Takeaways**
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> **Question:** Our study mainly focused on the distribution of pathogenic bacteria and antimicrobial resistance after plastic surgery for microtia.
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> **Findings:** In this study, we included 261 cases of microtia and found the infectious strains that appeared after plastic surgery for microtia were mainly Gram-positive bacteria. We summarized the distribution of these strains, their sensitivities to common antibiotics, the types of bacteria common to different surgical procedures, and the differences in time to the onset of infection.
>
> **Meaning:** The results showed should help clinicians prevent and control infection after different plastic surgery for microtia.

Microbial samples were cultured and inoculated using blood and maikangkai dishes (Antu, Zhengzhou, China). Different types of samples were infected in the respective Petri dishes and incubated in the corresponding incubators for 18–24 hours, as needed, before being removed to observe colony morphology. According to normal microbiological techniques, the pathogens—including Gram-positive and Gram-negative bacteria—were detected by API identification strips (bioMérieux, France). Antibiotic susceptibility was tested by the Kirby–Bauer paper-flake diffusion method using susceptibility paper produced by Oxoid Co., Ltd., United Kingdom. The judgment standard was based on the 2021 Clinical and Laboratory Standards Institute document M100.[9] The 11 antibiotics used in the study included cefoxitin, cotrimoxazole, penicillin, clindamycin, tetracycline, levofloxacin, erythromycin, vancomycin, chloramphenicol, gentamicin, and linezolid. The quality-control strains included *Staphylococcus aureus* (ATCC25923), *Escherichia coli* (ATCC25922), *Pseudomonas aeruginosa* (ATCC27853), and *Enterococcus faecalis* (ATCC29212). The identified strains were stored at −80°C.

Statistical Analysis

Microsoft Excel 2016 (Microsoft Corp., Redmond, Wash.) was used to input and process the data, and the percentages were then calculated. The categorical data were represented using frequencies and percentages. WHONET 5.6 (Thomas O'Brien, John Stelling, WHO Collaborating Centre for the Surveillance of Antibiotic Resistance Brigham and Women's Hospital Microbiology Laboratory; Boston, Mass,) and SPSS 22.0 (IBM, Armonk, N.Y.) were used for data analysis. The detection rate of pathogenic bacteria was analyzed by trend chi-squared tests. *P* values less than 0.05 were considered statistically significant.

RESULTS

The Overall Distribution of Pathogens

From January 2011 to December 2021, a total of 261 strains of pathogenic bacteria were detected, of which 235

Table 1. Distribution of Pathogenic Bacteria Isolated after Plastic Surgery for Congenital Microtia (%)

Species	*Staphylococcus aureus*	CoNS	*Streptococcus viridans*	*Enterobacter*	*Pseudomonas aeruginosa*	Other Pathogenic Bacteria	Total
2011	5 (71.4)	1 (14.3)	0 (0.0)	1 (14.3)	0 (0.0)	0 (0.0)	7 (2.7)
2012	9 (31.0)	9 (31.0)	1 (3.4)	4 (13.8)	2 (6.9)	4 (13.8)	29 (11.1)
2013	13 (41.9)	13 (41.9)	1 (3.2)	1 (3.2)	2 (6.5)	1 (3.2)	31 (11.9)
2014	12 (35.3)	15 (44.1)	1 (2.9)	2 (5.9)	1 (2.9)	3 (8.8)	34 (13.0)
2015	14 (56.0)	8 (32.0)	0 (0.0)	2 (8.0)	0 (0.0)	1 (4.0)	25 (9.6)
2016	21 (84.0)	3 (12.0)	0 (0.0)	0 (0.0)	1 (4.0)	0 (0.0)	25 (9.6)
2017	11 (52.4)	10 (47.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	21 (8.0)
2018	15 (50.0)	13 (43.3)	0 (0.0)	0 (0.0)	0 (0.0)	2 (6.7)	30 (11.5)
2019	16 (66.7)	5 (20.8)	0 (0.0)	1 (4.2)	0 (0.0)	2 (8.3)	24 (9.2)
2020	11 (57.9)	5 (26.3)	1 (5.3)	0 (0.0)	1 (5.3)	1 (5.3)	19 (7.3)
2021	13 (81.2)	2 (12.5)	0 (0.0)	0 (0.0)	0 (0.0)	1 (6.2)	16 (6.1)
Total	140 (53.6)	84 (32.2)	4 (1.5)	11 (4.2)	7 (2.7)	15 (5.7)	261 (100.0)
X^2	10.55	1.673	0.645	7.698	2.26	0.25	0.330
P	0.001	0.196	0.422	0.006	0.133	0.617	0.565

were Gram-positive. *S. aureus* and coagulase-negative staphylococci (CoNS) represented the majority and accounted for 85.8% of all pathogenic bacteria. Twenty-six strains were Gram-negative, including 11 strains of *Enterobacter* and seven of *P. aeruginosa*, as shown in Table 1. From 2011 to 2021, the overall proportion of *S. aureus* represented an increasing trend ($P < 0.05$), whereas *Enterobacter* represented a decreasing trend ($P < 0.05$). CoNS, *Streptococcus viridans, P. aeruginosa,* and other pathogens reflected no obvious trend ($P > 0.05$), as shown in Figures 1 and 2.

Sensibility of *Staphylococcus aureus* and Coagulase-negative Staphylococci to Common Antibiotics

According to the susceptibility results for *S. aureus* and CoNS (Table 2), *S. aureus* was highly sensitive to levofloxacin, vancomycin, chloramphenicol, and linezolid, whereas CoNS was highly sensitive to vancomycin and linezolid. Both were highly resistant to penicillin and erythromycin; no vancomycin-resistant strains were found. The sensitivity of *S. aureus* to cefoxitin and cotrimoxazole was much greater than that of CoNS. CoNS were 100% sensitive to linezolid, or slightly more so than *S. aureus*. There were 30 strains (22.4%) of methicillin-resistant *S. aureus* (MRSA) and 47 strains (58.8%) of methicillin-resistant CoNS (MRCNS), as shown in Table 2.

Distribution of Pathogenic Bacteria in Various Types of Surgical Procedures

Among the 261 cases of postoperative infection, there were seven first-stage auricular reconstructions with expanded single flap, 14 second-stage auricular reconstructions with expanded single flaps, no third-stage auricular reconstructions with expanded single flaps, 105 first-stage auricular reconstructions with

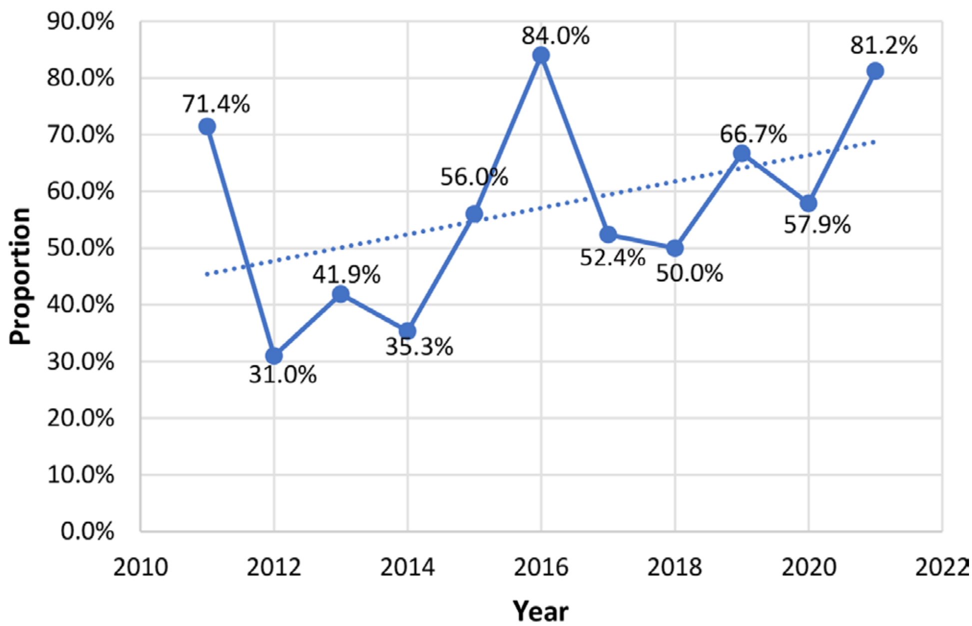

Fig. 1. Detection rate of *Staphylococcus aureus.*

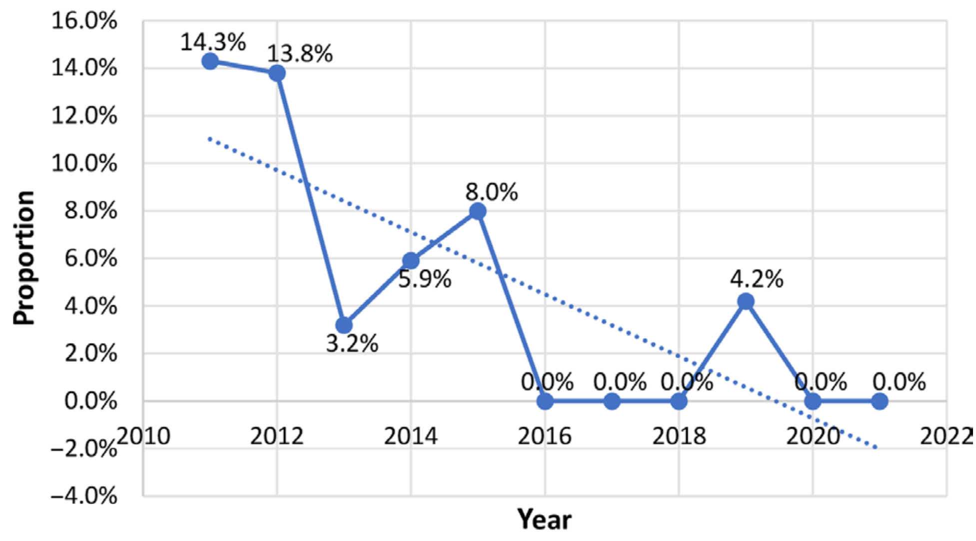

Fig. 2. Detection rate of *Enterobacter*.

Table 2. Sensitivity and Resistance to Common Antibiotics of *S. aureus* and CoNS

Antibiotics	*Staphylococcus aureus*		CoNS	
	Sensitivity (%)	Resistance (%)	Sensitivity (%)	Resistance (%)
Cefoxitin	77.6	22.4	41.2	58.8
Cotrimoxazole	91.9	6.7	46.3	45.1
Penicillin	4.3	95.7	8.3	91.7
Clindamycin	26.4	72.1	35.4	61.0
Tetracycline	78.5	20.0	70.4	29.6
Levofloxacin	94.7	4.5	71.4	15.6
Erythromycin	20.3	79.7	14.6	82.9
Vancomycin	100	0	100	0
Chloramphenicol	91.2	8.8	66.7	30.8
Gentamicin	80.1	19.1	64.6	35.4
Linezolid	99.2	0.8	100	0

two expanded flaps, 82 second-stage auricular reconstructions with two expanded flaps, 26 third-stage auricular reconstructions with two expanded flaps, 14 reconstructions in the first stage of the Nagata method, and 13 reconstructions in the second stage of the Nagata method. *S. aureus* was the dominant bacterial species in all surgical procedures, and CoNS were the second dominant strain. The proportion of *S. aureus* was the same in the first stage of auricular reconstruction with an expanded single flap and in the second stage of auricular reconstruction with an expanded single flap. The proportion of CoNS and *S. viridans* was the same in the second stage of auricular reconstruction with an expanded single flap. No patients were infected with *S. viridans* or *Enterobacter* after the first or second stage of the Nagata method, as shown in Table 3.

Time of Occurrence of Postoperative Infection

There were 212 available cases with clear records, of which 98 developed infections within a month after the surgery (early infection) and 114 developed infections beyond a month later (late infection). The major infective agent following various surgical procedures was always *S. aureus*, as shown in Table 4.

DISCUSSION

Microtia is a common malformation of the ear that has a detrimental effect on patients' hearing, psychology, social interactions, and overall lives. Normal function and shape of the ear are crucial to physical and psychological health; therefore, there is a growing demand for plastic surgery to correct microtia. Infection, a common complication of these procedures, affects the surgical result and the patient's prognosis. Hence, a profound understanding of the causes of infection, the distribution of pathogenic bacteria, and these organisms' antimicrobial resistance is vitally important in guiding the use of antibacterial drugs.

In this study, Gram-positive bacteria accounted for 90.0% of the infections that occurred after plastic surgery; *S. aureus* and CoNS constituted the majority. Some studies have found that in cases of microtia, the common bacterial community is consistent with that of the external auditory canal, whereas other studies have also shown that CoNS (*Staphylococcus epidermidis*) are the main bacterial groups found in the external auditory canal.[10,11] This is consistent with the dominant bacterial strain of infection after plastic surgery for microtia in our study. It is therefore speculated that the external auditory canal may be the main source of

Table 3. Risk of Infection after Various Surgical Procedures

Possibility	*Staphylococcus aureus* (%)	CoNS (%)	*Streptococcus viridans* (%)	*Enterobacter* (%)	*Pseudomonas aeruginosa* (%)	Other Pathogenic Bacteria (%)	No. Infected Cases
First stage of auricular reconstruction with expanded single flap	85.7	0	14.3	0	0	0	7
Second stage of auricular reconstruction with expanded single flap	85.7	7.1	7.1	0	0	0	14
Third stage of auricular reconstruction with expanded single flap	0	0	0	0	0	0	0
First stage of auricular reconstruction with expanded two flaps	54.3	37.1	1.0	1.9	1.0	4.8	105
Second stage of auricular reconstruction with expanded two flaps	42.7	36.6	0	6.1	4.9	9.8	82
Third stage of auricular reconstruction with expanded two flaps	46.2	30.8	3.8	15.4	0	3.8	26
First stage of Nagata method	71.4	14.3	0	0	14.3	0	14
Second stage of Nagata method	61.5	30.8	0	0	0	7.7	13

Table 4. Major Pathogenic Bacteria and the Number of Surgical Procedures following Infection

Technique	Period	Main Infecting Bacteria	No. cases	Total Number
First stage of auricular reconstruction with expanded single flap	Early stage	*Staphylococcus aureus, Streptococcus viridans*	2	6
	Late stage	*S. aureus*	4	
Second stage of auricular reconstruction with expanded single flap	Early stage	*S. aureus*	7	12
	Late stage	*S. aureus*	5	
First stage of auricular reconstruction with expanded two flaps	Early stage	*S. aureus*	39	90
	Late stage	*S. aureus,* CoNS	51	
Second stage of auricular reconstruction with expanded two flaps	Early stage	*S. aureus,* CoNS	29	62
	Late stage	*S. aureus,* CoNS	33	
Third stage of auricular reconstruction with expanded two flaps	Early stage	*S. aureus*	9	19
	Late stage	*S. aureus,* CoNS	10	
First stage of Nagata method	Early stage	*S. aureus*	6	12
	Late stage	*S. aureus, Pseudomonas aeruginosa*	6	
Second stage of Nagata method	Early stage	*S. aureus,* CoNS	6	11
	Late stage	*S. aureus*	5	

infectious strains and that ear infection may be related to contact with the skin flora during surgery.

The detection rates of MRSA and MRCNS after plastic surgery were, respectively, 22.4% and 58.8%; both figures are lower than those reported by the China Antimicrobial Resistance Surveillance System. According to the China Antimicrobial Resistance Surveillance System, the national detection rates for MRSA and MRCNS were 29.4% and 74.5%, respectively, indicating that clinicians have emphasized the prevention of infection in this type of surgery and have achieved great results. One study indicated that MRSA accounted for 16.9% of the strains in the external auditory canals of patients with microtia.[10] It has also been suggested that MRSA may be the endogenous flora at the surgical site or may have transferred from the nasal cavity.[12] If that were suspected before surgery, it would be advisable to culture samples from the nasal cavity and auditory canal to confirm the presence of MRSA and decide whether or not to use prophylactic antibiotics.[11,13] Moreover, routine use of chlorhexidine showers and topical mupirocin can be applied as effective tools for MRSA decolonization and the prevention of postoperative MRSA infections.[14,15] MRSA has broad-spectrum drug resistance and can easily colonize and infect wounds, leading to the continuous infection of wounds and delay in patients' postoperative recovery.[13,16,17] Therefore, we should emphasize the management of drug-resistant strains and use antibiotics rationally—according to their types, distribution, and antimicrobial resistance—by monitoring them and forestalling their increasing resistance to antimicrobials.

We found that *S. aureus* was highly sensitive to levofloxacin, vancomycin, chloramphenicol, and linezolid, whereas CoNS were highly sensitive to vancomycin and linezolid; no antibiotic-resistant strains of vancomycin were found, which may provide guidance for empirical drug use. Both *S. aureus* and CoNS were highly resistant to penicillin and erythromycin, suggesting that the clinical selection of these drugs should depend on the results of drug sensitivity tests. These drugs should be avoided or used with caution when they are being used experimentally. Although we found no vancomycin-resistant strains in *S. aureus* and CoNS, a small number of vancomycin-resistant *S. aureus* have been reported.[18,19] Therefore, vancomycin should be prescribed with caution in the clinic. In addition, reasonable treatment plans should be formulated to avoid the occurrence of vancomycin-resistant *Staphylococcus.*

Only 20 of the 37 cases of bilateral microtia in our study included clear records about the postoperative infection site. There were seven cases of infection on the right side, 11 cases of infection on the left side, and two cases of infection on both sides. The number of postoperative infections in the left- and right-side infection groups was similar and was also higher than that in cases of infection on both sides. Currently, no relevant literature explains this phenomenon. According to our clinical experience, we speculate that the infected side may be related to the habit of sleeping on the left or right side. Hence, we suggest that clinicians emphasize proper sleeping habits when they are explaining postsurgical precautions to patients.

In this study, *S. aureus* was the dominant bacterial species found to be present after all surgical procedures for microtia. No infections were found in the third stage of auricular reconstruction with an expanded single flap, which may be due to the limited number of cases treated with auricular reconstruction with an expanded single flap. In addition, in 212 of the 261 cases of infection, we were able to determine the time of postoperative infection, as 98 cases (46.2%) occurred within 1 month after surgery (early infection) and 114 cases (53.8%) occurred more than 1 month after surgery (late infection). The major infectious strain in both groups was *S. aureus*. Early infection after the first stage of auricular reconstruction with a single expanded flap or two expanded flaps may have been caused by skin damage during the process of flap expansion after expander implantation, leading to expander exposure or swelling,[20] whereas late infection after the first stage of auricular reconstruction with a single expanded flap or two expanded flaps may have been caused by the injection of normal saline into the expander. Infection of the second stage of auricular reconstruction with a single expanded flap or two expanded flaps may have been caused by flap injury.[20] Trauma may account for skin flap damage at any stage of the surgical procedures. Therefore, patients are advised to avoid compression of the surgical site, especially in the early stage after the operation. To hinder the late infection of the first stage of auricular reconstruction with a single expanded flap or two expanded flaps, it is important to pay attention to the thickness and softness of the expanded skin and to adjust the quantity and time interval between each injection. In addition, each part of the framework should be smoothly carved into a sleek shape, particularly the part touching the expanded skin flap,[20] to prevent the infection related to the second stage of auricular reconstruction with a single expanded flap or two expanded flaps.

To the authors' knowledge, this is the first study with the longest time span and the largest sample size on the distribution of pathogenic bacteria and their antimicrobial resistance after plastic surgery for microtia. In addition, our hospital is a leader in reconstruction of the auricle, attracting most of these patients for treatment. Thus, we were able to include a variety of cases in this study, which is representative to a certain extent. Unfortunately, some data may be limited; for example, only five cases included clear records of expander removal and reimplantation owing to infection after the first stage of auricular reconstruction with expanded flaps.

CONCLUSIONS

We found that the infectious strains that appeared after plastic surgery for microtia were mainly Gram-positive bacteria. We summarized the distribution of these strains, their sensitivities to common antibiotics, the types of bacteria common to different surgical procedures, and the differences in time to the onset of infection. These results should help clinicians prevent and control infection after plastic surgery for microtia.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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