

Analysis of Epidemiological Characteristics of Varicella Before and After the Implementation of the Two-dose Varicella Vaccine Immunization Program in Banan District of Chongqing City

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Abstract: *Objective:* To explore the changes in the epidemiological characteristics of varicella before and after implementing the two-dose varicella vaccine (VarV) immunization program in the Banan District of Chongqing and to provide a reference for future epidemic prevention and control. *Methods:* The data of reported varicella cases in Banan District from 2014 to 2023 were collected and analyzed using the China Disease Prevention and Control Information System. Descriptive epidemiological methods were employed to assess the changes in the reported incidence of varicella before (2014–2018) and after (2019–2023) the implementation of the two-dose VarV immunization program. *Results:* The average annual reported incidence rate of varicella in Banan District from 2014 to 2023 was 81.53 per 100,000. From 2014 to 2018, the reported incidence rate showed an upward trend year by year (trend $\chi^2 = 223.96$, $P < 0.05$). However, the reported incidence rate decreased from 2019 to 2023 (trend $\chi^2 = 189.51$, $P < 0.05$). Before and after the adjustment of the immunization program, the reported incidence rate for the 5–9 years old group was 774.62 per 100,000 and 476.98 per 100,000, respectively, with a statistically significant difference ($\chi^2 = 161.26$, $P < 0.05$). The onset of varicella showed a bimodal distribution, with peak incidence periods in May–June and October–December. From 2014 to 2023, a total of 155,181 doses of VarV were administered in Banan District. The estimated annual vaccination rate for the first varicella vaccine (VarV1) from 2019 to 2023 was 86.28%, and for the second dose (VarV2) was 59.18%. The primary vaccination targets were the 5–9-year-old group, accounting for 64.21%. *Conclusion:* After implementing the two-dose VarV immunization program in Banan District, the vaccination rate increased yearly, and the reported incidence of varicella showed a downward trend. The incidence rate of varicella in children aged 5–9 years reduced significantly, but the overall downward trend for the entire population was not as pronounced. Therefore, it is necessary to increase the vaccination rate of VarV2.

Keywords: Varicella; Varicella vaccine; Immunization program; Epidemiological characteristics

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1. Introduction

Varicella, caused by the varicella-zoster virus (VZV), is a highly contagious respiratory infectious disease common in children under 14 years old. It is prone to outbreaks in collective settings such as childcare institutions, primary schools, and middle schools ^[1,2]. Vaccination with the varicella vaccine (VarV) can effectively reduce the morbidity and mortality associated with the disease. Studies have shown that a single dose of VarV provides an 86% protection rate, while two doses increase the protection rate to 98.3%. Furthermore, the risk of disease with two doses is 95% lower than with just one dose ^[3]. In domestic studies, 50% of individuals who receive one dose of VarV are protected from VZV infection ^[4], and the protection rate increases to 90% with two doses ^[5].

Since 2002, Chongqing has implemented self-paid vaccination for susceptible individuals aged ≥ 12 months with one dose of VarV. From 2014 to 2018, the number of public health emergencies (PHEEs) related to varicella in Chongqing increased annually, particularly in childcare institutions and schools ^[6]. Research has indicated that after one dose of VarV, the protection rate can reach 98% within the first 1 to 3 years, but it declines to 53% after 5 years ^[7,8]. This decline in protection is one reason for frequent varicella outbreaks in schools.

To better control the varicella epidemic, Chongqing issued the “Guidelines for Varicella Vaccine and Mumps Vaccine Vaccination in Chongqing” in September 2018, recommending a two-dose VarV immunization program. This program was implemented in the Banan District on October 1, 2018. This study analyzes the epidemiological characteristics of varicella before and after the adjustment of the VarV immunization program in Banan District, Chongqing, to provide a reference for formulating effective varicella prevention and control measures.

2. Materials and methods

2.1. Data sources

Reported varicella cases and demographic data from 2014 to 2023 were obtained from the China Disease Prevention and Control Information System. VarV vaccination data were acquired from the Chongqing Immunization Program Information Management System.

2.2. Definition of varicella PHEE

According to the 2019 “Chongqing Public Health Emergency Classification and Grading Standards,” a varicella public health emergency event (PHEE) is defined as 10 or more cases occurring in the same school, kindergarten, or other collective unit within 7 days.

2.3. VarV immunization program

In 2002, the Banan District began providing VarV vaccination services. The initial immunization program recommended one dose for people susceptible to varicella aged ≥ 12 months. Since October 2018, the program has been adjusted to recommend two doses of VarV for susceptible individuals. The updated program specifies the first dose at 12–24 months old and the second dose at 4–6 years old. For adolescents and adults aged 13 years and older, two doses are recommended, with the interval between doses being ≥ 3 months. All vaccinations are provided on an informed, voluntary, and self-funded basis.

2.4. VarV vaccination rate estimation

The VarV1 and VarV2 vaccination rates of children in the 2015–2019 birth cohort, as of December 31, 2023, were calculated using the Chongqing Immunization Program Information Management System. The estimated VarV1 and VarV2 vaccination rates for 2019–2023 were also calculated. The vaccination rate for a given cohort

(%) = (number of actual VarV1 or VarV2 vaccinations ÷ number of vaccinations required) × 100%.

2.5. Statistical methods

Excel 2019 was used for data organization and visualization, Power BI Desktop (x64) for visual maps, and SPSS (version 26.0) for statistical analysis. Descriptive epidemiological methods were used to analyze the reported incidence of varicella and the distribution characteristics of the population, time, and region before (2014–2018) and after (2019–2023) the adjustment of the VarV immunization program. The χ^2 test and trend χ^2 test were used to compare incidence rates and trends, with $P < 0.05$ considered statistically significant.

3. Results

3.1. Overview of the epidemic

From 2014 to 2023, a total of 8,742 clinically diagnosed cases of varicella were reported in Banan District, with an average annual reported incidence of 81.53 per 100,000. The annual reported incidence ranged from 45.24 per 100,000 (in 2023) to 114.32 per 100,000 (in 2019). The difference in reported incidence between the two periods was statistically significant ($\chi^2 = 618.17$, $P < 0.05$). The reported incidence from 2014 to 2018 showed an increasing trend (trend $\chi^2 = 223.96$, $P < 0.05$), while the reported incidence from 2019 to 2023 showed an overall downward trend (trend $\chi^2 = 189.51$, $P < 0.05$), though the incidence in 2021 and 2022 was higher than the previous year (refer **Figure 1**).

From 2014 to 2023, 32 varicella public health emergencies were reported in Banan District, primarily in childcare institutions and schools. From 2014 to 2018, 17 cases were reported, including 13 in primary schools, three in middle schools, and one in childcare institutions, averaging 3.4 cases per year. From 2019 to 2023, 15 cases were reported, including nine in primary schools, five in middle schools, and one in childcare institutions, averaging three cases per year.

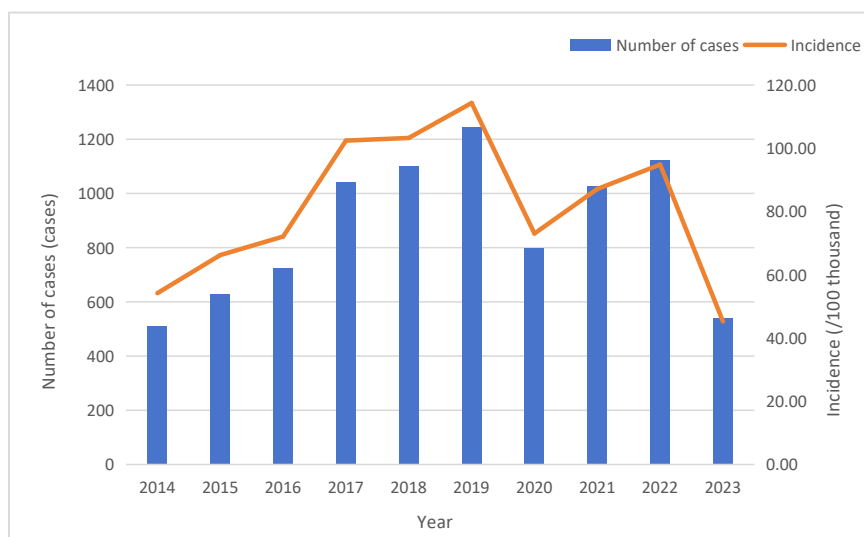


Figure 1. Number of reported cases and incidence of varicella in Banan District from 2014 to 2023.

3.2. Population distribution

3.2.1. Age distribution

From 2014 to 2023, the average annual reported incidence rates (number of cases) by age group were:

- (1) 0–4 years old: 300.64 per 100,000 (1,314 cases)
- (2) 5–9 years old: 601.36 per 100,000 (2,690 cases)

- (3) 10–14 years old: 573.35 per 100,000 (2,402 cases)
- (4) 15–19 years old: 165.48 per 100,000 (972 cases)
- (5) 20–24 years old: 57.56 per 100,000 (428 cases)
- (6) 25–29 years old: 59.03 per 100,000 (415 cases)
- (7) ≥ 30 years old: 14.81 per 100,000 (521 cases)

The highest incidence was in the 5–9 years old group, and the lowest was in the ≥ 30 years old group. From 2014 to 2018, the highest reported incidence was 774.62 per 100,000 (1,448 cases) in the 5–9 years old group, and the lowest was 15.98 per 100,000 (194 cases) in the ≥ 30 years old group. From 2019 to 2023, the highest annual reported incidence was 591.65 per 100,000 (1,412 cases) in the 10–14 years old group, and the lowest was 14.20 per 100,000 (327 cases) in the ≥ 30 years old group (refer **Figure 2**).

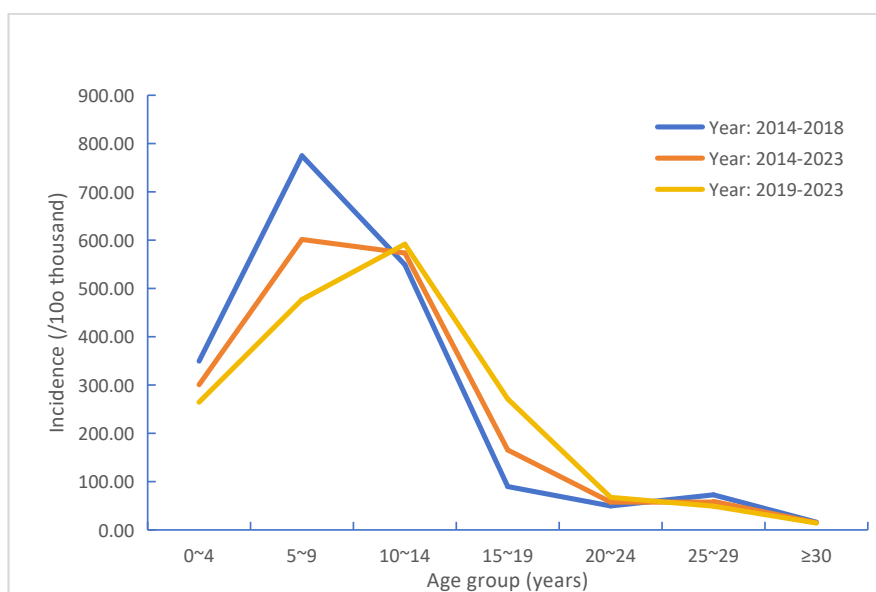


Figure 2. Age distribution of reported incidence of varicella in Banan District from 2014 to 2023.

Statistical analysis of the average annual reported incidence of varicella in the same age groups before and after the adjustment of the immunization program showed significant differences in the 0–4, 5–9, 15–19, 20–24, and 25–29 years old groups ($P < 0.05$), except for the 10–14 years old and the ≥ 30 years old groups (refer **Table 1**).

Table 1 Average annual reported incidence rates among different age groups before and after the adjustment of the immunization program in Banan District

Age group (years old)	2014–2018		2019–2023		χ^2 value	P-value
	Number of cases	Incidence rate (/100,000)	Number of cases	Incidence rate (/100,000)		
0–4	650	349.50	664	264.46	25.78	< 0.05
5–9	1448	774.62	1242	476.98	161.26	< 0.05
10–14	990	549.12	1412	591.65	3.26	> 0.05
15–19	307	89.74	665	271.09	284.40	< 0.05
20–24	204	49.61	224	67.40	10.11	< 0.05
25–29	215	72.62	200	49.14	16.02	< 0.05
≥ 30	194	15.98	327	14.20	1.71	> 0.05

3.2.2. Gender distribution

Among the varicella cases reported from 2014 to 2023, the male-to-female ratio was 1.08:1. The average annual reported incidence of varicella was 83.01 per 100,000 (4,547 cases) in males and 79.98 per 100,000 (4,195 cases) in females, with no statistically significant difference ($\chi^2 = 3.03, P > 0.05$).

3.2.3. Occupational distribution

Among the varicella cases reported in 2014–2018, 2019–2023, and 2014–2023, the top three occupations were students (59.58–63.46%), preschool children (14.20–17.39%), and diaspora children (7.71–8.61%) (refer **Figure 3**).

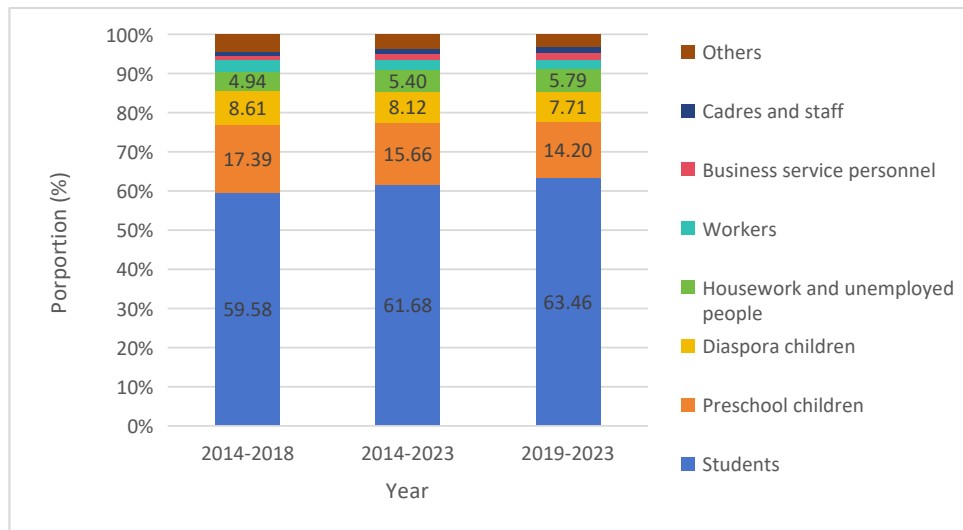


Figure 3. The occupational composition of reported varicella cases in Banan District from 2014 to 2023.

3.2.4. Time distribution

From 2014 to 2023, the incidence of varicella showed a “bimodal distribution”, with peak periods in May–June (97–138 cases) and October–December (105–109 cases), and low periods in February–March (30–31 cases) and August–September (33–40 cases) (refer **Figure 4**).

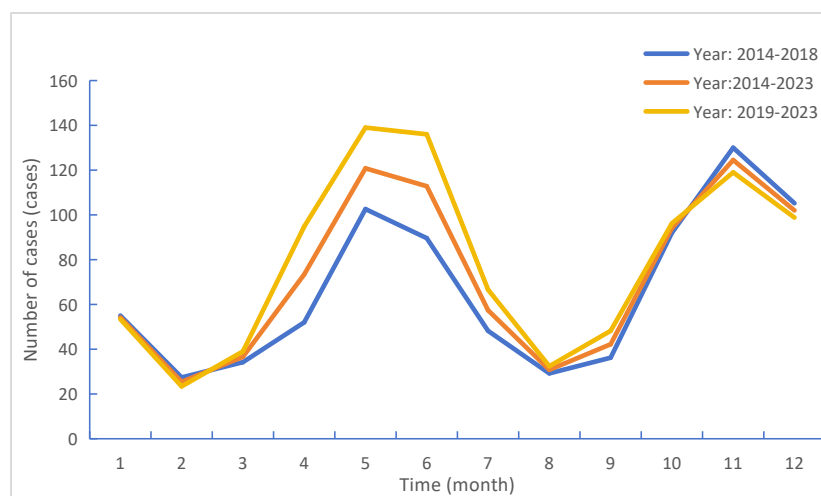


Figure 4. Time distribution of reported varicella cases in Banan District from 2014 to 2023.

3.2.5. Regional distribution

From 2014 to 2023, cases were reported in all streets/towns in Banan District. The areas with the highest number of reported cases in 2014–2018, 2019–2023, and 2014–2023 were Yudong Street, Lijiatuo Street, Longzhouwan Street, and Huaxi Street. The number of reported cases in these four streets was 2,088, 1,562, 1,387, and 1,223, respectively, accounting for 71.42% of the total reported cases.

3.2.6. VarV vaccination status

From 2014 to 2023, a total of 155,181 doses of VarV were administered in Banan District. After implementing the two-dose VarV immunization program, the number of VarV vaccinations increased. From 2019 to 2023, the estimated annual vaccination rate of VarV1 was 86.28%, with the lowest rate in 2019 (84.96%) and the highest in 2023 (88.5%). The estimated annual vaccination rate of VarV2 was 59.18%, with the lowest rate in 2023 (48.56%) and the highest in 2020 (66.19%) (refer **Figure 5**).

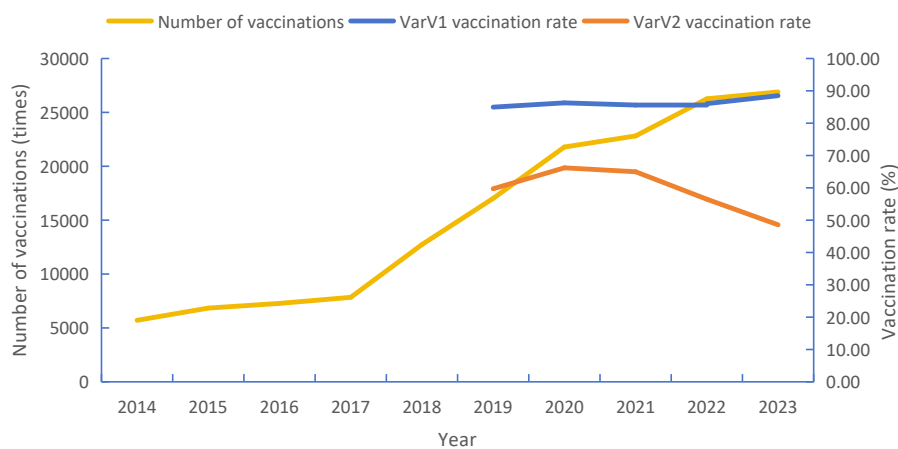


Figure 5. VarV vaccination in Banan District from 2014 to 2023.

From 2019 to 2023, 58,145 doses of VarV were administered. By age group, 16,162 doses (27.80%) were administered to those aged 12–24 months, 37,335 doses (64.21%) to those aged 5–9 years, 4,256 doses (7.32%) to those aged 10–14 years, 384 doses (0.66%) to those aged 15–19 years, three doses (0.01%) to those aged 20–24 years, three doses (0.01%) to those aged 25–29 years, and two doses (0.00%) to those aged ≥ 30 years. The main recipients of VarV2 were in the 5–9 years old group, accounting for 64.21% (refer **Figure 6**).

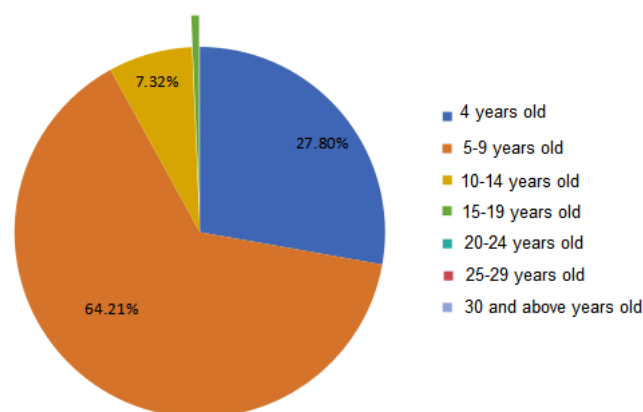


Figure 6. Age composition of VarV2 vaccinations from 2019 to 2023.

4. Discussion

The average annual reported incidence of varicella in Banan District from 2014 to 2023 was 81.53 per 100,000, higher than the national average (55.05 per 100,000)^[9] and Hunan Province (43.89 per 100,000)^[10] but lower than the incidence levels in Jiangsu Province (178.44 per 100,000)^[11] and Shanghai (88.36 per 100,000)^[12]. Vaccination status, meteorological conditions, air pollutants, and socioeconomic factors are all critical factors affecting the epidemic characteristics of varicella^[13]. Banan District followed the policy closely and began implementing a two-dose VarV immunization program in October 2018. From 2014 to 2019, the reported incidence of varicella in Banan District increased year by year, which may be related to the fact that Chongqing City included varicella in the management of Class C infectious diseases since August 2014 and took measures to strengthen diagnosis, monitoring, and reporting. After the immunization program was adjusted, the number of VarV vaccinations increased year by year, and the trend of increasing reported incidence of varicella was reversed, which is consistent with the results of other domestic studies^[14,15]. However, the downward trend could have been more apparent, especially in 2019, when the incidence peaked in the past ten years and others.

In 2019, a policy transition period, the VarV2 vaccination rate did not increase significantly, and the number of cases in the varicella public health emergency was significant, resulting in an increase in the overall number of cases in 2019 compared with other years. The VarV2 vaccination rate was highest in 2020. Due to the strict epidemic prevention and control measures taken during the COVID-19 pandemic, such as wearing masks, strengthening disinfection, and reducing population gatherings, the virus transmission route was cut off. From 2021 to 2022, the VarV2 vaccination rate decreased, and the COVID-19 prevention and control policy was gradually adjusted. In addition to taking control measures for local outbreaks, work, gatherings, public transportation, etc., returned to normal, with the three basic links of varicella transmission, and the reported incidence of varicella increased.

The incidence of varicella in the 5–9-year-old group from 2019 to 2023 was significantly lower than in 2014–2018, consistent with the research results of Qiu C *et al.* (2020) and Wang Q *et al.* (2020)^[15,16]. This trend aligns with the fact that the main vaccination targets of VarV2 are the 5-9-year-old group, indicating that vaccination with VarV2 can effectively reduce the incidence of varicella in collective units such as childcare institutions and primary schools. The proportion of varicella cases in children aged ≤ 9 years has decreased yearly since 2020: 46.17% in 2020, 43.23% in 2021, 43.02% in 2022, and 23.84% in 2023. The onset of varicella has shown a trend of later age, consistent with the research results of Gu R *et al.* (2023)^[17], which may be due to the reduced susceptibility of children vaccinated with VarV2. The average annual reported incidence of varicella in the 15–19 age group increased significantly from 2019 to 2023 compared with 2014 to 2018, suggesting an increased risk of exposure for this population. Some studies have reported that among cases with a clear history of VarV immunization, the number of cases increased significantly 3–5 years and 5–10 years after vaccination^[18]. It is speculated that the increase in the reported incidence of varicella in the 15–19 age group may be related to this, but the specific reasons require further investigation and research.

From the perspective of time distribution, the onset of varicella before and after the adjustment of the immunization program showed a “bimodal distribution,” with May–June and October–December being the peak periods of varicella and February–March and August–September being the low-incidence periods. This pattern is consistent with the high incidence of respiratory infectious diseases in late spring, early summer, and winter and spring. Additionally, May–June and October–December mark the start of the school semesters for children in childcare and students. This period is more than a month away from the start of school, and the source of infection may have appeared in the group. The accumulation of different degrees of sources of infection and the gathering of susceptible people also provide conditions for spreading the disease. Moreover, the varicella virus

can easily survive, spread, and replicate due to the dry climate, low temperature, large temperature difference, and poor indoor ventilation in winter and spring. February and August are winter and summer vacations, which reduce the chance of contact for susceptible people ^[6,13,19]. March and September are the early days of school, and it takes time for the accumulation of sources of infection to lead to an outbreak.

From the perspective of regional distribution, chickenpox cases in Banan District mainly occurred on the four streets of Longzhouwan, Yudong, Huaxi, and Lijiatuo. These four streets are the core urban areas. They have a large permanent population of 788,200, accounting for 66.87% of the district's total population. These streets are also areas where educational resources, medical resources, shopping and entertainment venues, and public facilities are concentrated. They are densely populated, socially active, and have a large mobility of people, increasing the probability of infectious diseases.

The World Health Organization (WHO) recommends that countries with a significant public health burden caused by varicella include VarV in their routine immunization programs and maintain vaccination rates above 80% ^[20]. According to WHO data, as of 2019, 50 of the 194 WHO member states have included VarV in their routine childhood immunization programs ^[21]. However, in most provinces and cities in China, VarV is implemented on an informed, voluntary, and self-funded basis. The need for residents to pay for it themselves affects the vaccination rate and fails to establish a solid and lasting immune barrier. The results of this study showed that the estimated annual vaccination rate of VarV1 in Banan District from 2019 to 2023 was 86.28%, and the estimated annual vaccination rate of VarV2 was 59.18%. The VarV2 vaccination rate was low, and the implementation effect of the two-dose immunization program was poor, failing to achieve an effective immune barrier. A prospective cohort study in Shanghai showed that although more than 80% of students were vaccinated with VarV1, varicella cases still occurred in schools, and vaccination with VarV2 as a post-exposure prophylaxis measure can effectively control the epidemic ^[22]. In recent years, Shanghai, Tianjin, Jiangsu, and other provinces and cities have included VarV in provincial immunization plans and implemented a two-dose VarV immunization strategy, all of which have achieved good protection effects ^[23].

In summary, after adjusting the immunization program in Banan District, the rising trend of reported incidence of varicella was partially controlled, especially in the 5–9-year-old group. However, the annual reported incidence rate did not decrease significantly. The onset of varicella has shown a trend of later age, and public health emergencies frequently occur in childcare institutions and primary and secondary schools. Childcare institutions and primary and secondary schools are still the focus of varicella prevention and control, but varicella prevention and control in high schools and universities cannot be ignored. Varicella-related knowledge publicity and education should be carried out through multiple channels and methods to enhance awareness of prevention and control among the population, especially in densely populated areas with high personnel mobility. It is recommended that the government include VarV in the immunization plan. Medical institutions and schools in the jurisdiction should further improve the VarV vaccination rate of children of school age, including the VarV2 vaccination rate, by checking the vaccination certificates of children entering childcare and school and establishing an effective immune barrier to control the epidemic of varicella.

The limitation of this study is that the period from 2020 to 2022 was affected by the COVID-19 pandemic. The epidemic prevention and control measures taken may have impacted the spread and incidence of varicella to varying degrees, affecting the evaluation of the VarV vaccine's effect. Additionally, the two-dose VarV immunization program in Banan District was implemented relatively late, limiting the analysis of the relationship between vaccination rate and incidence rate. The specific effect and durability of implementing the two-dose VarV immunization program still need continued observation and in-depth analysis in subsequent years.

Disclosure statement

The authors declare no conflict of interest.

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