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Major Article

Impact of vaccination on the incidence of varicella hospitalizations in a state in Southeast Brazil

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Abstract

Introduction: This study aimed to analyze cases of complicated varicella and the impact of varicella vaccination in Minas Gerais, Brazil. **Methods:** This was a time series study of a territorial basis using data on varicella cases from 2010 to 2016, which was provided by the State Health Department of Minas Gerais on . Descriptive statistics were used for the analysis, and the generalized linear regression model proposed by *Prais-Winsten* was used for the time tendency, adopting a significance level of 5% and the integrated autoregressive modeling of moving averages. **Results:** There were 1,635 cases of varicella; out of which cellulitis (44%) was the predominant complication. The home-acquired cases were 38.9% and 464 cases (40.6%) were not previously vaccinated. There was a significant decrease in the incidence coefficient when comparing the pre- and post- immunization periods, from 1.95 cases/100,000 inhabitants in 2010 to 0.24 cases/100.000 inhabitants in 2016 ($p<0.05$). There was a higher incidence of cases recorded among males, with higher prevalence in the age group of 1-4 years (54.7%). Lethality was higher between 5-9 years of age (44%). Mortality was higher in the age group of 0-4 years and among females (2.58/100,000 inhabitants/year). The overall trend of the incidence coefficient was a decreasing one, with an annual percentage variation. **Conclusions:** The number of complicated varicella cases notified decreased, coincidentally, in the post-immunization period. However, the immunization coverage period was restricted for the assessment of the correlation between immunization coverage and incidence.

Keywords: Varicella. Hospitalization. Immunization. Health programs and plans. Vaccination.

INTRODUCTION

The varicella zoster virus is a member of the *Herpesviridae* family and is responsible for two main kinds of pathologies: varicella and herpes zoster[1]. According to Bastos et al., the distribution of the disease caused by the varicella zoster virus in South America has been the least investigated among all the populated continents. They also mentioned that studies carried out in South America could add valuable information on transmission patterns and global trends for this common viral situation[2].

The United States of America was the first country to incorporate the varicella vaccine into its National Immunization Calendar in 1995. Until 2006, the single vaccine dose schedule recommended for 12-15 months of age, showed an effectiveness of 70-90%. Nevertheless, the occurrence of outbreaks in schools led to the introduction of a second dose available for the age group between 4-6 years[3]. At the beginning of immunization in Italy, 21 regions adopted two doses at 13-15 months of age and between 5-6 years of age, with immunization coverage between 60-95%. The implementation of the vaccination occurred during 2003 to 2013, with a decline of 70-75% in the hospitalization rate[4]. In relation to South American countries, Uruguay adopted the vaccine against varicella in its immunization calendar in 1999, with a single dose schedule at 12 months of age, and with an immunization coverage of 88-96%. Thereby, the country reduced the rate of hospitalization due to the disease in the population in general by 81% and the number of hospitalizations due to varicella in kids between 1-4 years of age by 94%, from 1999 to 2005[5].

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From 2012 to 2017, 602.136 cases of varicella were reported throughout the Brazilian territory, with 2013 recording the highest numbers, with 197.628 cases and 9.553 hospitalizations[6]. In Brazil, the vaccine against varicella has been available since 2000 at the Reference Centers for Special Immunobiologicals (Centros de Referências para Imunobiológicos Especiais, CRIE). In 2002, it was included in the Indigenous Peoples' Immunization Calendar. In September 2013, it was introduced in the National Immunization Program (Programa Nacional de Imunizações, PNI) together with the MMR vaccine to decrease the number of hospitalizations related to the disease, with the schedule of a single dose at 15 months of age.

The National data shows that the chance of children vaccinated with a single dose developing moderate or severe varicella (characterized by the occurrence of 50 or more skin lesions) was 13 times smaller than in unvaccinated children; besides halving the likelihood of presenting with disease complications, the vaccinated individuals were 67% less hospitalized than the unvaccinated[7].

The expenses and the impact of the vaccine on the economy have been studied from the perspective of economic analysis in different countries. In a study conducted in a city in Northeast Brazil, it was observed that the value of the treatment for varicella cases was R$ 67,830.00; if this same population received the vaccination, the costs could be R$ 6,120.00, considering that the price of 1 dose of the vaccine for the public network was approximately R$ 24.00 for the PNI[8].

Throughout Brazil, varicella notification is made by completing the notification/conclusion form at all levels of health care, and it is then sent to the Health Departments for registration with the National Disease Notification System (Sistema de Informação de Agravos de Notificação, SINAN). In the state of Minas Gerais, the disease is reported by a second method through the Complicated Varicella Individual Form, recommended by the State Health Department of Minas Gerais (Secretaria do Estado da Saúde de Minas Gerais, SES/MG) when the patient needs hospitalization. Considering the magnitude of the state with 853 municipalities and the implementation of the vaccination in the basic vaccination calendar in 2013, it is necessary to monitor varicella cases, especially the complicated ones, and to verify the impact of vaccination in the state. Thus, this research aims to analyze the cases of the disease, with emphasis on its complicated form, and to evaluate the temporal trend of incidence and seasonality in the state of Minas Gerais, between 2010 and 2016.

METHODS

This is a time series study of a territorial basis, which uses the data from of the complicated varicella mandatory notification forms between 2010 and 2016, from cases recorded in the State of Minas Gerais, Brazil. The database was provided by the State Health Department of Minas Gerais (SES/MG).

Exploratory (descriptive) analysis of the data were performed based on the verification of absolute and percentage simple frequencies for categorical variables, using variables with a completeness level above 80%. The calculated indicators were incidence, mortality, and lethality coefficients by age and gender, expressed as number of cases or deaths per 100,000 inhabitants/year, and lethality expressed as a percentage, as shown below.

$$Incidence\ coefficient = \frac{Number\ of\ new\ notification\ cases\ in\ the\ year}{Estimated\ population\ on\ July\ 1^{ST}\ in\ the\ year}\ X\ 100{,}000$$

$$Mortality\ coefficient = \frac{Number\ of\ deaths\ from\ varicella\ in\ the\ year}{Estimated\ population\ on\ July\ 1^{ST}\ in\ the\ year}\ X\ 100{,}000$$

$$Lethality = \frac{Number\ of\ deaths\ from\ varicella\ in\ year}{Number\ of\ varicella\ cases\ in\ the\ year}\ X\quad 100$$

To characterize the temporal trends, a logarithmic transformation of the coefficients (Y) was performed since it allows for the reduction of the heterogeneity of the linear regression analysis residual variance, that is, of the values of the difference between the points of the average line and the points of the time series. In addition, this transformation contributes to the determination of the annual increase ratio. The procedure proposed by Prais-Winsten was used for generalized linear regression analysis, since it allows for the estimation of regression coefficients with correction of the first order temporal autocorrelation[9].

The equation of the time series regression can be described to associate the dependent variable and the year. Thus, for each year "i" included in the study period, we have: logY (i) = a + bi and logY $(i + 1)$ = a + b $(i + 1)$. The value of "a" corresponds to the intersection between the line and the vertical axis and the value of "b" corresponds to the slope of the line, which was estimated by linear regression analysis. Thus, by difference: logY $(i + 1)$ - logY(i) = b $(i + 1 - i)$ = b. In this way, it was possible to calculate the value of the "b" coefficient and the standard deviation "SD" of the regression analysis. The Annual Percent Change (APC) and the confidence interval (95% CI) can be calculated by using the following formulae: APC = -1 + 10^b and 95% CI from this rate = -1 + 10^ (b ± t * SD), where "t" is the tabulated value of the t distribution of Student. When the rate is positive, the time series is considered an increasing one, and when it is negative, it is a decreasing one; when there is no significant difference between its value and zero, it is considered stationary[9]. This statistical analysis was performed using the Stata 11.1 software.

Also, in order to analyze the temporal evolution (series) of the incidence of complicated varicella cases from January 2010 to December 2016 and to verify the seasonality of the disease, the series was decomposed every 12 months, in search of its trend elements (persistent increase or decrease) and seasonality (recurrence at periodic intervals of high or low values), employing a diagnosis obtained with the graphical visualization of the autocorrelation function (ACF: autocorrelation between different sequential values for specific series intervals) and partial autocorrelation function (PACF: autocorrelation among different sequential values by adjusting or removing certain correlations among other sequential values). This search also allows the identification of the presence of autoregressive processes (number of terms in the model that describe the dependence among successive values) and moving averages (number of terms that in the model describe the persistence of random noise among successive terms) in potential ARIMA adjustment models, when appropriate.

Adjustment was performed using:

a) The *ARIMA (p,d,q)* model, where *p* indicates the number of autoregressive terms, *d* the integration (trend) or difference degree applied to make the series stationary, and *q* the number of moving average terms, when applicable; in the eventual presence of seasonality, there is the possibility of adjustment to a SARIMA *(p,d,q) (P,D,Q)* or to an ARIMA seasonal model, where the parameters *P*, *D* and *Q* refer to the order of the seasonal periodicity terms of the series, if present; b) or simple exponential smoothing, in the absence of trend or seasonality of a series of original typically random data $x_1, x_2, x_3, \ldots x_t$, leading to the values obtained using the following equation:

$$s_o = x_o$$

$$s_t = \alpha \; x_t + (1 - \alpha \;) s_{t-1}, \; t \; > 0$$

Where s_t are the values smoothed by weighted averages of the original series values and α is the flattening or smoothing factor of the series, *x(t)*.

Vaccine coverage was obtained from the Unified Health System's Department of Informatics website (http://tabnet.datasus.gov.br/cgi/tabcgi.exe?pni/cnv/cpnimg.def). In order to compare incidence in the pre- and post- vaccination periods, the Student's t test was used for independent samples.

The study was approved by the Ethics Committee on Research with Human Beings, of the Federal University of Triângulo Mineiro (Comitê de Ética em Pesquisa com Seres Humanos da Universidade Federal do Triângulo Mineiro, CEP/UFTM), with opinion number 2.111.882.

RESULTS

Between 2010 and 2016, 1,635 cases of complicated varicella were recorded in the state of Minas Gerais. A higher risk was observed for males to have complicated varicella than for females, and the gender ratio for incidence was 1.2. The age group with the highest incidence was 1-4 years of age (54.7%), thus justifying the high number of "not applicable" for schooling (89.3%) and for not being pregnant (87.2%). The disease prevailed in white individuals (34.3%) (**Table 1**). The number of cases that acquired the infection at home waswere 38.9%. After the vaccination implementation of the vaccination in 2013, 40.6% of the reported cases were not vaccinated due low coverage. Vaccination coverage increased from 39.5% in 2013 to 91.8% in 2016.

Most of the reported cases (65.5%) presented with between 50 and 250 body lesions, and 75.4% were without the known risk factors for varicella, which include having immunodeficiency, being pregnant, or having chronic a disease.

Among the main complications secondary to varicella, cellulitis was the most common skin complication affecting 652 cases (44%), followed by impetigo with 623 cases (41.6%). Respiratory complications such as respiratory failure occurred in 84 cases (5.6%), primary varicella pneumonia in 81 cases (5.4%), and bacterial pneumonia in 68 cases (4.5%). Encephalitis was observed in 45 cases (2.9%), and in 131 cases (8.5%) edema stood out as the major change in the urinary tract. In relation to other complications, the following stood out: cardiac (1.3%), hematologic (4.6%), and hepatic (1.9%) conditions. Regarding the need for intensive care, it was necessary in 8.7% of the cases. Regarding the evolution of the disease, most cases (93%) were discharged from the hospital after treatment without sequelae.

Mortality was higher for the 0-4 year old age group in females (2.58/100,000 inhabitants/year) compared to that for the males (1.63/100,000 inhabitants/year). However, in the other age groups, there was an increase in mortality rates in males; mortality coefficient was 3.76 cases/100,000 inhabitants for males and 2.98 cases/100,000 inhabitants for females. Lethality was higher in males between 5-9 years of age (51.55 cases/100,000 inhabitants), followed by the age group between 15-19 years of age (33.34 cases/100,000 inhabitants).

There was a decrease in the incidence coefficient trend, with an annual variation percentage of -29.53% (95% CI: -15.83 - -40.99) prominent between 2014 and 2016 (**Figure 1**).

The number of reported cases decreased, and that may be related to the immunization process started in 2013. When comparing the annual average number of cases in the pre-vaccination (336.3; 95% CI: 165.8-506.8) and post-vaccination (103.6; 95% CI: -37.2-244.5) periods, a significant difference was observed (p<0.05). Similarly, when comparing the annual average of the incidence coefficients/100,000 inhabitants in the pre-vaccination (1.66; 95% CI: 0.78-2.52) and post-vaccination (0.5; 95% CI: -0.18-1.18) periods, a significant difference was also observed (p<0.05). By relating the average annual number of hospitalizations for complicated varicella in the pre-vaccination (303.6; 95% CI: 141.6-465.6) and post-vaccination (94.6; 95% CI: -37.1-226.4) periods, a significant difference (p<0.05) was observed (**Table 2**).

Figure 2 shows the monthly evolution of the number of complicated varicella cases. The values ranged, in the period prior to the vaccination in September 2013 (indicated by the vertical line in the graph), between 0-148 cases, with an average of 25.2 cases and a median of 8 cases. The cumulative total of cases before the vaccination was 1,107. In the period after the beginning of the vaccination, cases ranged from 1-84, with an average of 13.2 and a median of 6 cases. The cumulative total of cases during the vaccine period was 528 cases. There was an apparent pattern of periodicity or seasonality in the number of cases, with peaks occurring mainly in September of each year.

In the visual inspection shown in **Figure 3** of the predictor variable included in the model, there was no statistically significant effect, with no evidence of vaccine effect, at least in the adjusted model. It is important to observe that before the

TABLE 1: Sociodemographic characterization of cases of complicated varicella in the state of Minas Gerais, 2010-2016.

	2010		2011		2012		2013		2014		2015		2016		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Gender																
Male	213	24.2	201	22.8	134	15.2	178	20.2	80	9.1	48	5.5	26	3.0	**880**	**54.0**
Female	180	24.0	155	20.7	126	16.8	135	18.0	80	10.7	50	6.7	23	3.1	**749**	**46.0**
Age group (years old)																
<1	56	16.1	60	18.6	43	19.3	67	23.8	30	21.3	26	31.0	9	20.5	**291**	**20.0**
1-4	200	57.5	178	55.3	144	64.6	151	53.7	78	55.3	32	38.1	6	13.6	**789**	**54.7**
5-9	63	25.3	61	24.5	25	10.0	46	18.5	20	8.0	19	7.6	15	6.0	**249**	**17.2**
10-14	18	30.5	19	32.2	4	6.8	9	15.3	4	6.8	3	5.1	2	3.4	**59**	**4.1**
15-19	4	36.4	...	...	1	9.1	1	9.1	4	36.4	1	9.1	...	...	**11**	**0.8**
20-29	4	20.0	...	...	3	15.0	4	20.0	3	15.0	1	5.0	5	25.0	**20**	**1.4**
30-39	...	...	2	28.6	...	...	1	14.3	2	28.6	...	...	2	28.6	**7**	**0.5**
40-49	3	42.9	1	14.3	1	14.3	1	14.3	...	...	...	...	1	14.3	**7**	**0.5**
50-59	...	...	1	14.3	2	28.6	1	14.3	...	...	1	14.3	2	28.6	**7**	**0.5**
60-80 years old or more	...	...	...	...	...	...	...	...	...	...	1	100.0	2	100.0	**3**	**0.3**
Pregnant																
1st trimester	-	-	1	0.3	1	0.4	-	-	-	-	1	1.1	1	2.0	**4**	**0.3**
2nd trimester	-	-	-	-	-	-	-	-	1	1.0	-	-	-	-	**1**	**0.1**
3rd trimester	1	0.3	-	-	2	0.9	1	0.4	-	-	-	-	-	-	**4**	**0.3**
Unknown GA	1	0.3	-	-	2	0.9	1	0.4	-	-	-	-	-	-	**4**	**0.3**
No	25	6.8	32	9.9	36	15.5	18	6.3	2	1.9	1	1.1	7	14.3	**121**	**8.2**
Does not apply	325	88.3	278	85.8	182	78.1	257	90.2	99	94.3	92	96.8	39	79.6	**1272**	**87.2**
Unknown	16	4.3	13	4.0	10	4.3	8	2.8	3	2.9	1	1.1	2	4.1	**53**	**3.6**
Race																
Caucasian	144	43.1	113	37.2	76	34.9	68	26.2	33	34.0	21	22.1	10	20.4	**465**	**34.3**
Black	25	7.5	24	7.9	12	5.5	20	7.7	6	6.2	6	6.3	2	4.1	**95**	**7.0**
Asian	-	-	4	1.3	6	2.8	1	0.4	-	-	1	1.1	-	-	**12**	**0.9**
Brown-skinned	41	12.3	65	21.4	25	11.5	37	14.2	24	24.7	39	41.1	17	34.7	**248**	**18.3**
Indigenous	1	0.3	1	0.3	2	0.9	-	-	1	0.1	-	-	-	-	**5**	**0.4**
Unknown	123	23.1	97	18.2	97	18.2	134	25.2	33	6.2	28	5.3	20	3.8	**532**	**39.1**
Schooling																
Illiterate	4	1.1	-	-	-	-	1	0.3	-	-	-	-	1	2.6	**6**	**0.4**
Incomplete 1st-4th	3	0.8	2	0.6	1	0.4	-	-	-	-	6	6.9	1	2.6	**13**	**0.9**
Complete 4th	3	0.8	1	0.3	1	0.4	-	-	-	-	2	2.3	-	-	**7**	**0.5**
Incomplete 5th-8th	8	2.2	5	1.6	1	0.4	3	1.0	1	0.7	-	-	1	2.6	**19**	**1.3**
Complete ES	1	0.3	-	-	1	0.4	1	0.3	-	-	-	-	2	5.1	**5**	**0.3**
Incomplete HS	-	-	-	-	1	0.4	-	-	1	0.7	-	-	-	-	**2**	**0.1**
Complete HS	2	0.5	-	-	1	0.4	2	0.7	-	-	-	-	1	2.6	**6**	**0.4**
Incomplete HE	-	-	-	-	-	-	-	-	1	0.7	-	-	-	-	**1**	**0.1**
Complete HE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**	**-**
Unknown	11	3.0	36	11.5	8	3.3	19	6.6	8	5.7	6	6.9	10	25.6	**98**	**6.7**
Does not apply	332	91.2	269	85.9	226	94.2	262	91.0	129	92.1	73	83.9	23	59.0	**1314**	**89.3**

Source: Data obtained from the State Health Department of Minas Gerais. Calculations made by the author, 2017. *Value identification according to Andrade and Ogliari (2010). (-) Null by the very nature of the study. (...) There is no information about the value. Caption: GA: Gestational Age, ES: Elementary School, HS: High School, HE: Higher Education.

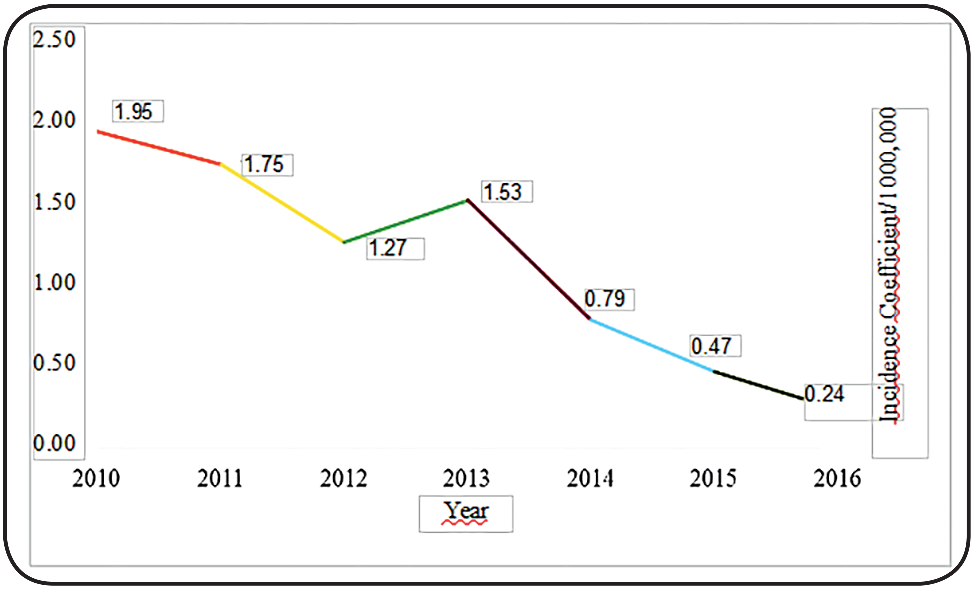

FIGURE 1: Time series of the incidence coefficient of complicated varicella. MG, Brazil, 2010-2016.

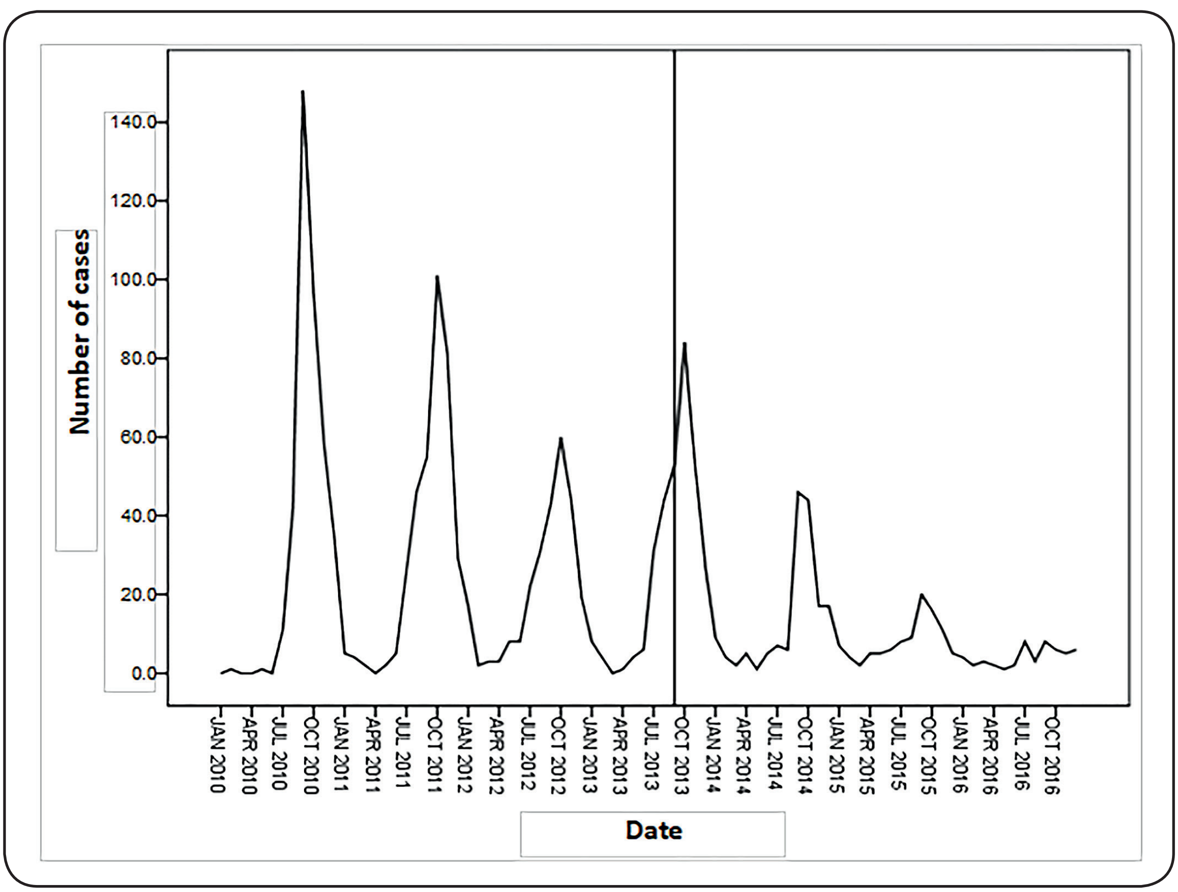

FIGURE 2: Temporal evolution (monthly) of the number of reported complicated varicella cases. MG, Brazil, 2010-2016.

TABLE 2: Comparison of the annual averages of the number of complicated varicella cases, of the incidence coefficients/100,000 inhabitants and of the annual average number of hospitalizations in the pre- (2010-2012) and post- (2014-2016) vaccination periods, MG, Brazil.

	Pre-vaccination period	Post-vaccination period	
Number of complicated varicella cases	336.3	103.6	
95% CI	165.8 to 506.8	-37.2 to 244.5	
Standard deviation	68.6	56.7	
P-value			0.01
	Pre-vaccination period	**Post-vaccination period**	
Incidence coefficient	1.66	0.50	
95% CI	0.78 to 2.52	-0.18 to 1.18	
Standard deviation	0.34	0.27	
P-value			0.01
	Pre-vaccination period	**Post-vaccination period**	
Hospitalizations	303.6	94.6	
95% CI	141.6 to 465.6	-37.1 to 226.4	
Standard deviation	65.2	53.0	
P-value			0.01

Note: The year 2013 is related to the introduction of the vaccine in the public calendar, which is why it is not included in the analysis.

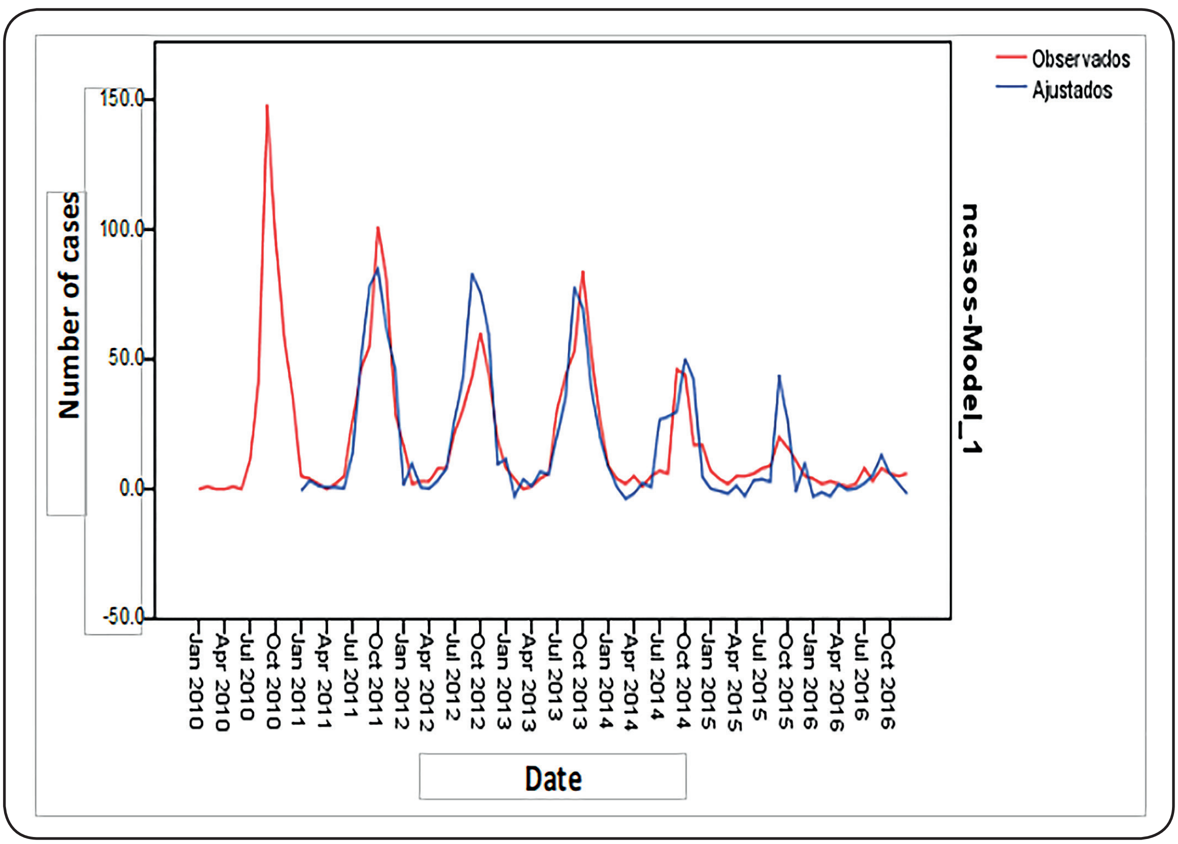

FIGURE 3: Number of cases of complicated varicella observed and adjusted by the SARIMA model (1,0,0) (0,1,0). MG, Brazil, 2010-2016.

vaccination started, the series had already showed a declining trend, indicating a natural decrease in the number of reported cases. It is likely that the effect of the vaccination has been obscured by the natural declining trend.

DISCUSSION

In Brazil, 45.495 hospitalizations for varicella were registered in the Hospitalization System (Sistema de Internação Hospitalar, SIH-SUS) from 2008 to 2012. There were 811 deaths during this period. Mortality rate ranged from 0.09-0.05/100,000 inhabitants. The largest number of hospitalizations was concentrated in the age group of 1-4 years[7]. Similar results were observed in Minas Gerais, where of the 1,635 reported cases of complicated varicella, the most prevalence was observed in the age group was of 1-4 years (54.7%), and 57 cases evolved to a death outcome (3.4%).

There was a slight male predominance (54%) for hospitalizations due to the disease in Minas Gerais. A similar result was observed in a survey conducted in Recife hospital in 2005, where a slight prevalence was observed in males (53%)[8]. Another study conducted in the Haidian District in China found a total of 23,497 cases of varicella during 2007 and 2015, with 57.20% being male[10].

The origin of the infection was related to the home (38.9%), with no risk factors (84.1%) and no immunization (40.6%). A study conducted in a Portuguese hospital between 2000 and 2012, with a sample of 105 children hospitalized with varicella, found school transmission in 22 cases, followed by family communicant transmission in 21 cases, which is similar to the findings of this study. Of the hospitalized children, 71.4% were previously healthy, and none had previous vaccination for varicella, which is sold in Portugal since 2004, but it is not part of the National Vaccination Program (Programa Nacional de Vacinação, PNV)[11].

In Minas Gerais, there were skin complications secondary to varicella: cellulitis (44%) and impetigo (41.6%). Regarding the number of body lesions, 65.5% had between 50 and 250 lesions, characterizing the cases as moderate to severe, which justifies hospitalization and notification. A study conducted at a University hospital in Recife/PE, from 2004 to 2005, reported a high proportion of dermatological complications (77.3%), with cellulitis being predominant (48.1%), corroborating with the present study[8].

Pneumonia was the second major complication, and respiratory failure was the most prevalent (5.6%). A retrospective study conducted between 2000 and 2012 in a pediatric hospitalization department found 81 cases of hospitalizations in which 12 evolved to develop pneumonia[11].

A study conducted at a School Health Center located in the inland of the state of São Paulo, evaluating how informed the elderly population were about a type of vaccine, concluded that it is of great importance that health professionals, especially nurses, undertake further epidemiological studies to assess the vaccine's coverage rate. It also highlighted the importance of nursing professionals in the adoption of health care strategies aiding in the success of immunization programs[12].

In the pre-vaccination period, varicella was associated with a significant number of deaths and hospitalizations. The introduction of the tetraviral vaccine in the PNI has raised expectations of a positive impact, especially on children. Vaccination is justified in the country, and epidemiological follow-up of the cases is needed during the next few years. This would make it possible to discuss the inclusion of a second dose in the program, and to rethink the initial age of vaccination, considering that most of the complications and deaths occur in children less than one year old, and that the vaccine is currently offered at 15 months of age[13].

This study has the use of secondary data of state coverage as a limitation, which makes it impossible to search for incomplete or missing information, and to compare it with other states. The short period of implantation of the vaccination in the PNI made it difficult to verify the relation between disease incidence and vaccination coverage.

CONCLUSION

In Minas Gerais, there was a higher incidence of varicella between 1-4 years of age, and the main reason for hospitalizations was the skin complications related to the disease. There was a decrease in the number of cases, incidence, and hospitalizations in the post-vaccination period. There was an apparent pattern of periodicity or seasonality in the number of cases, with peaks occurring mainly in September in each year. The decrease in the incidence rate after 2014 may have been due to the satisfactory vaccination coverage, reaching a percentage of 91.82% in 2016. The disease had already presented a declining trend in the pre-vaccination period, which was possibly accentuated due to the inclusion of free vaccination.

Conflict of Interest

The authors declare that there is no conflict of interest.

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