

Neonatal tetanus incidence in China, 1996–2001, and risk factors for neonatal tetanus, Guangxi Province, China

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Background In China during 1995–1996 widespread tetanus toxoid (TT) mass vaccination of women of childbearing age in high-risk areas was conducted and neonatal tetanus (NT) surveillance was initiated as part of NT elimination efforts. Despite a subsequent decrease in the estimated rate of NT, the NT disease burden remains high in poorer areas of China.

Methods To describe the recent epidemiology of NT in China and estimate its risk, we analysed national surveillance data in China 1996–2001 and conducted a case-control study in one high-risk county (Bobai): 60 hospitalized cases were sex- and calendar-birth year matched to 60 controls from the same or neighbouring villages.

Results Reported national annual NT incidence decreased from 0.21/1000 live births (LB) in 1997 to 0.16/1000 LB in 2001. Case mothers were more likely to be aged >30 years (odds ratio [OR] = 6; 95% CI: 2.2, 20.2), unschooled (OR = 3.2; 95% CI: 1.1, 11.6), and with an annual income of <1000 yuan (\$125 USD) (OR = 6.0; 95% CI: 1.9, 25.6). Only 28% of control mothers and 12% of case mothers reported any TT vaccination. In multivariate analysis, relative to hospital delivery, cases had a 64-fold increased odds of home delivery by a family member or neighbour (95% CI: 8.4, 982.2), and a 13-fold increased odds of home delivery by a traditional birth attendant (95% CI: 1.6, 322.6).

Conclusions Improved access to clean deliveries in high-risk areas is critically needed in China. Nonetheless, targeted TT vaccination appears to have helped reduce NT incidence in China.

Keywords Neonatal tetanus, surveillance, case-control study, tetanus toxoid vaccination

Although neonatal tetanus (NT) incidence declined following implementation of NT elimination strategies, the burden remains high in poor underserved areas of China. NT is among the leading causes of death from vaccine preventable diseases among children worldwide, with an estimated 200 000 deaths in 2000.¹ The highest burden of the disease is in developing countries, particularly in areas where access to clean deliveries

and cord care is poor. In 1997, following initiation of NT surveillance, 4394 NT cases were reported from China, comprising approximately a quarter of all cases reported globally. Despite a decrease in the estimated rate of NT during the 1990s, the NT disease burden remains high in China,¹ particularly in poorer areas. In this report we present the background on NT elimination strategies in China, describe the recent epidemiology of NT in China, and present findings from a case-control study of NT in one high-risk province.

Background

In 1987, a retrospective survey conducted in 9 of 30 provinces in China found that the average NT incidence was 4.2 per 1000 live births (LB).² A survey conducted in the mid-1990s in 199 suspected high-risk counties identified an annual incidence of 1.1 per 1000 LB (range, 1–13 per 1000 LB).³ In 1996, the proportion

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of children born in hospitals in the poorest rural areas was only 23% (Ministry of Health, unpublished data). Before 1995, no systematic vaccination of pregnant women was conducted, and the main strategy for NT control was clean delivery. In 1995 an NT elimination plan for China was developed which included three primary strategies: (1) achieving high levels of protective tetanus toxoid (TT) coverage among pregnant and other childbearing-age women, focused particularly in areas considered at high-risk; (2) achieving high rates of clean deliveries; and (3) establishing effective surveillance to guide and monitor the impact of focused control efforts.

During 1995 and 1996 supplemental TT vaccination was conducted in 320 of 560 counties identified as high-risk, reaching an estimated 23 million women aged 18–35.¹ The reported coverage with two or more doses of TT (TT2+) reached in these 320 counties was 80%.³ To examine the impact of NT elimination strategies, surveillance data for 1996–2001 were analysed. To better understand the risk factors for NT in these high-risk areas, a case-control study was conducted in one county of one high-risk province in 1997.

Methods

Surveillance data analysis

NT has been included in the National Notifiable Disease Reporting System (NNDRS) since 1996. It is a passive reporting system which receives reports primarily from hospitals, although all health care providers, including midwives, are legally required to report NT cases. Cases are reported hierarchically from the village up through to the township, county, provincial, and then to the national level. Any counties with a case of NT are required to report (Table 1), therefore, reporting counties reflect those counties with at least one case of NT. Because NT tends to occur focally in poor underserved areas, we assumed that cases reported from these counties represented cases occurring nationally. We analysed all NT case reports received at the national level through this system and calculated national and provincial incidence rates per 1000 LB, using estimates of national and provincial LB from the national bureau of statistics.

Case-control study

Study area

Bobai county is in the southeast area of Guangxi Province (Figure 1). In 1997, 105 NT cases were reported from this

county, for a reported incidence of 4.9 per 1000 LB; one of the highest reported rates among all high-risk counties in China. In the same year, the estimated county population was 1 354 228 people distributed in 325 villages, with a birth rate of 15.9 per 1000 population. The farthest village is 113 km from the county capital where the main hospital is located. Although routine TT immunization has never been provided in the county, a mass TT campaign (two rounds) was performed in 1995, targeting all women aged 18–35. However, the estimated TT2+ coverage achieved was only about 10%. The reasons for such low coverage were related to insufficient social mobilization, difficult logistics, rumours that TT had anti-fertility properties, and poor management.

Bobai County is served by three tertiary care hospitals at the county level, in addition to one hospital in each of the 34 townships within the county. Of the 105 cases reported during 1997, 50 (47.6%) were reported from the county hospitals, and the remainder were reported from the township-level hospitals.

Case selection

Reporting cards and hospital records were reviewed for all 122 cases reported from Bobai county to the NNDRS from 1 January 1997 through 30 April 1998. In all, 120 cases (98.4%) met the WHO case definition for NT: (1) normal feeding and cry for the first 2 days of life; (2) onset of illness between 3 and 28 days of life; and (3) inability to suck (trismus), followed by stiffness (generalized muscle rigidity) and/or convulsions (muscle spasms).⁴ Of these, 60 (50%) who had sufficient and accurate locating information in the hospital records to find the case village were involved in the study. The 60 cases were distributed in a total of 45 villages. From 15–30 April 1998 interviewers visited the villages of these 60 cases, and interviews were completed for all 60 cases.

Control selection

One living infant born in the same village, in the same calendar year, and of the same sex as the case was selected as a control. If more than one infant was eligible, one was selected randomly. When an infant born in the same year from that village could not be identified, a control was selected from the nearest adjacent village ($n = 7$). However, if an infant born in the same year but of the opposite sex was identified in the same village ($n = 17$), then that infant was selected rather than choosing from the nearest adjacent village.

Cases and controls were selected and their parents interviewed during the same time period (April 1998). A

Table 1 Reported neonatal tetanus cases, deaths, and incidence, China, 1996–2001

Year	Province (n)		Counties (n)		Cases (n)	Incidence (Cases/1000 LB ^a)	Deaths (n)	Case fatality ratio (%)
	Total	Reporting	Reporting	%				
1996	30 ^b	27	627	24.2	3657	0.18	454	12.4
1997	31 ^b	28	904	35.1	4394	0.21	589	13.4
1998	31 ^b	29	894	34.9	3986	0.20	368	9.2
1999	31 ^b	30	915	31.6	3616	0.19	711	19.7
2000	31 ^b	30	821	28.4	3293	0.18	624	18.9
2001	31 ^b	30	N/A	–	2814	0.16	353	12.5

^a Live births.

^b Excluding Taiwan and Hong Kong.

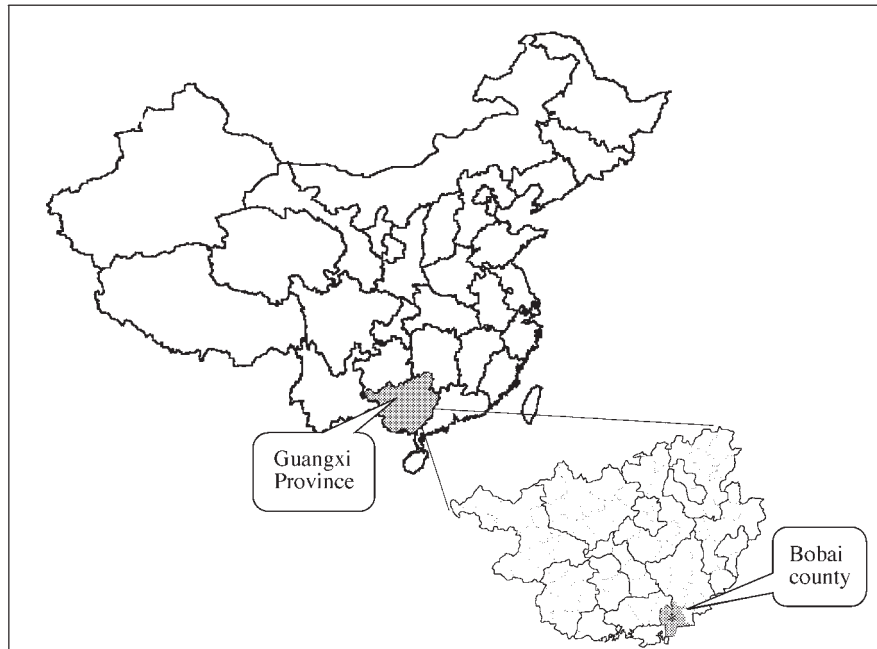


Figure 1 Map of study area

detailed questionnaire was administered to the parents of cases and controls to collect information on parental demographics, birthing practices, as well as parental knowledge, attitudes, and practices regarding NT. Because women were not provided with their own TT immunization record, TT immunization history collected was based on the mother's recall.

Data analysis

All univariate analyses were performed in Epi Info.⁵ All variables with a significant matched odds ratio (OR) in univariate analysis were further considered for inclusion in a multivariate model; this set of variables was examined for intra-correlation and confounding. All multivariate modelling was performed using conditional logistic regression in SAS,⁶ using as sets each case and his/her age- and sex-matched control (although 17 cases were matched on age only).

Because sex was significantly associated with NT, but was incompletely matched for during the design, this variable was included in all multivariate models. Three categories were created with respect to birthplace and birth attendants: (1) birth at hospital, (2) birth at home delivered by traditional birth attendant (TBA), and (3) birth at home delivered by family member, relatives, or neighbours. Thus, a single variable incorporating birthplace and birth attendant was included as a categorical variable in the multivariate model. To ascertain any independent effect of age, income, birth order, and the remaining variables after controlling for place of delivery, forward selection was performed.

Results

Surveillance data analysis

The national annual incidence of reported NT was 0.18/1000 LB ($n = 3657$ case) in China in 1996. After an initial increase to

0.21/1000LB in 1997, incidence decreased between 1997 and 2001 from 0.21/1000 LB ($n = 4394$ cases) to 0.16/1000 LB ($n = 2814$ cases) (Table 1). The sensitivity of the surveillance system increased following its implementation: the number and proportion of counties reporting at least one case increased from 627 (24.2%) in 1996 to 904 (35.1%) in 1997 and 894 (34.9%) in 1998. Following this initial increase, the proportion of counties reporting at least one case decreased from 1999 to 2000, concurrent with the decline in incidence. The reported case fatality ratios (CFR) ranged from 9.2% to 19.7% during the 6 years 1996–2001. The overall male:female sex ratio of reported cases was 3.4:1, excluding the 755 (9.4%) cases for which sex was unknown. The reported NT annual average incidence (1996–2001) rates in Guangxi (1.03 per 1000 LB), Guangdong (0.93 per 1000 LB), Hainan (0.52 per 1000 LB), and Guizhou (0.59 per 1000 LB) provinces exceeded that of all other provinces in China (Figure 2).

Case-control study

Information was collected on 60 cases and 60 age-matched controls, 53 (88%) of whom lived in the same village as their matched cases. The remaining seven controls were selected from the nearest adjacent village to their matched case. These adjacent villages had similar socioeconomic and cultural characteristics as the case village. Seventeen cases were matched on birth year only (the control was of a different sex). The mean age of the 60 cases at onset of NT was 6.6 days (range 3–12 days). Cases and controls did not differ significantly with respect to age at the time of investigation. The median age of cases at the time of investigation for this study was 9.0 months (range 0–28 months). The median age of controls at the time of investigation was 10.7 months (range 1–27.3 months). Overall, 93% of cases were male.

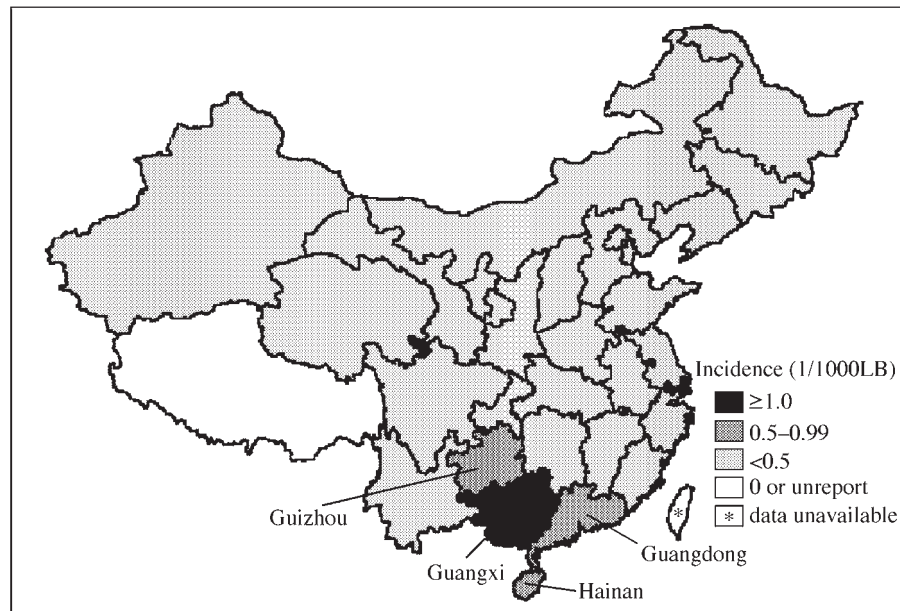


Figure 2 Neonatal tetanus average incidence by province, 1996–2001

Table 2 Odds ratios (OR) for selected demographic and birth characteristics; parental knowledge and attitudes, and neonatal tetanus (NT), Bobai, China, 1 January 1997–30 April 1998

Factor	No. (%) exposed		Matched OR ^a	95% CI
	Case = 60	Control = 60		
Demographic and birth characteristics				
Infant				
Male gender	56 (93.3)	43 (71.7)		
Second or higher birth order	49 (81.7)	29 (48.3)	3.9	1.7, 9.6
Infant born at home	56 (93.3)	31 (51.7)	26.0	4.9, 538.8
Maternal				
Maternal age ≥ 30 years	31 (51.7)	11 (18.3)	6.0	2.2, 20.2
Maternal education level (No schooling/completed primary school)	18 (30.0)	9 (15.0)	3.2	1.1, 11.6
Annual income <1000 Yuan (RMB/per capita/per year)	35 (58.3)	20 (33.3)	6.0	1.9, 25.6
Mother previously experienced neonatal death of liveborn infant	15 (25.0)	0 (0.0)	–	–
Mother previously received tetanus toxoid	7 (11.7)	17 (28.3)	0.2	0.03, 0.7
Parental knowledge and attitudes regarding NT				
Parents have heard of NT	28 (46.7)	37 (61.7)	0.5	0.2, 1.1
Parents know that NT can be prevented	7 (11.7)	23 (38.3)	0.2	0.06, 0.6
Parents know how NT is caused	8 (28.6)	18 (48.6)	0.5	0.06, 2.8
Parents recognize symptoms	17 (60.7)	22 (59.5)	1.0	0.2, 4.4
Parents think hospital delivery is better	57 (95.0)	55 (91.7)	1.7	0.4, 8.5

^a Incomplete matching on village and sex: 7 controls were of the same birth year and sex but from a different village, and 17 were from the same village and of the same birth year, but of a different sex.

Univariate analysis

Cases were 26 times more likely to have been born at home, compared with controls ($P < 0.05$) (Table 2). Among infants born at home, case infants had a 6.5-fold increased odds of having been delivered by someone other than a TBA (family

members, neighbours, relatives) compared with control infants. Among those born at home, use of a clean cord-cutting instrument and a clean umbilical stump dressing were significantly protective, even after adjusting for birth attendant (TBA versus other) (Table 3). A clean cord-cutting tool was

Table 3 Unmatched univariate analysis among cases and controls delivered at home, Bobai County, China, 1 January 1997–30 April 1998

Factor	No. (%) exposed		Unmatched OR ^a	95% CI
	Case = 56	Control = 31		
Delivered by family member versus TBA ^b	45 (80.4)	12 (38.7)	6.5	2.2, 19.6
Clean cord-cutting instruments used	27 (48.2)	26 (83.9)	0.18 (0.3 ^c)	0.06, 0.5
Clean cord dress material used	10 (17.9)	16 (51.6)	0.12 (0.3 ^c)	0.02, 0.5

^a Odds ratio.^b Traditional birth attendant.^c Adjusted OR (stratified by birth attendant).**Table 4** Odds ratios (OR) for final logistic regression model, neonatal tetanus case-control study, Bobai County, China, 1 January 1997–30 April 1998

Factor	Matched OR	95% CI
Delivered by TBA versus hospital birth	13.1	1.6, 322.6
Delivered by family number or others versus hospital birth	63.9	8.4, 982.2
Second or higher birth order (Yes/no)	7.4	1.7, 57.1

^a Traditional birth attendant.

defined as one which had been at least washed with water prior to use, and clean umbilical stump dressing material (generally cotton cloth) was defined as one that had been washed and dried before use.

Case mothers had a significant sixfold increased odds of being aged >30 years, a threefold increased odds of having received no schooling, and a sixfold increased odds of having an annual income of <1000 yuan (RMB) (Table 2). Case mothers were also nearly four times more likely to have a second born or higher birth order index infant child. None of the control mothers reported neonatal death among any previous live-born children, compared with 25% of case mothers ($P < 0.05$). (Table 2). Only 28% of control mothers and 12% of case mothers reported having received any doses of TT. Nonetheless, having a history of receiving one or more doses of TT was significantly protective for NT (Table 2). Parental belief that NT could be prevented had a significant protective association, although general knowledge about NT (e.g. symptoms, how it is acquired) was not significantly associated with NT (Table 2).

Multivariate analysis

Maternal age, education, family income, birth order, prior TT vaccination, and parental knowledge of prevention of NT were all significantly associated with NT, with one another, and with place of delivery. Place of delivery was determined to be the variable most directly related to risk, and was included in all models along with infant sex. Second-born children are more likely to be born to older women; in turn, women aged >30 years are likely to be less educated than younger women, due to the initiation of socioeconomic reforms including better educational opportunities, in 1978. Therefore, age of the mother was selected as an indicator for education and a better indicator of risk.

After controlling for sex of infant, cases had a 64-fold increased odds of having been delivered at home by a family member, relative, or neighbour, and a 13-fold increased odds of having been delivered by a TBA. Second-born or higher birth

order children still had a sevenfold greater odds of NT even after controlling for these factors (Table 4). None of the remaining factors remained significant after inclusion of these variables in the model.

Discussion

Surveillance data analysis

This paper presents the first 6-year national analysis of NT surveillance data in China (1996–2001) since the disease became reportable. Although reporting sensitivity increased following implementation of the surveillance system, as demonstrated by an initial increase in the number and proportion of counties reporting, the incidence decreased during this same period. This decline suggests that NT elimination strategies were effective, particularly targeted TT vaccination among women whose infants are at high-risk for NT. Because we could not estimate more precisely the interventions and incidence at the county level, we may be underestimating the impact of these interventions.

CFR for NT identified in our analysis were lower than expected based on previous studies in China. One community-based study conducted in Hezheng county, Gansu province, China in 1994 found a CFR of 91%.⁷ Another study conducted at a provincial-level paediatric hospital in Beijing found a CFR of 30%.⁸ The low reported CFR may be due in part to a hospitalization bias: the most severe cases with the highest risk of death are least likely to be admitted to a hospital in time to be saved. In addition, those severe cases which are admitted may be discharged prior to death when it appears death is imminent. In such instances, the case may be reported but not the death. The reported overall NT CFR of 14.2% observed for cases from the national surveillance system, together with the high male:female sex ratio, suggests substantial under-reporting of NT cases and deaths, with a predominance of reporting from hospitals, and the need to further strengthen NT surveillance.

Case-control study

We found that home delivery attended by family members or relatives placed infants at extremely high risk: such deliveries were associated with an independent 64-fold increased odds of NT compared with hospital delivery. Home delivery by a TBA greatly reduced the risk of NT, but was nonetheless associated with a 13-fold increased odds of NT relative to hospital delivery. These findings are consistent with those from other case-control studies conducted in China^{9,10} and elsewhere.^{11–14} Although TBA training was not investigated in this study, these results suggest that the safety of delivery practices by TBA may need

strengthening. In addition, parents should be made aware of the decreased risk of delivery by a TBA compared with relatives or neighbours when the delivery has to be conducted at home. Unsterile practices such as application of dirt or other traditional substances to the umbilical stump may increase the risk of NT,^{11–17} even if the delivery was clean. Thus, proper cord care following delivery is important even for infants born in hospitals. Detailed data on type of materials applied to the umbilical stump were not collected in this study. Future studies should consider examining in more detail umbilical stump care practices by both parents and TBA following delivery.

In this rural area of China first-born children generally receive more attention than second or subsequent children, including a greater likelihood of hospital delivery; in addition, firstborns may be more likely to be brought to a hospital when ill. Also, multiparous women may have a shorter labour, allowing them less time to get to a hospital for delivery. These factors could explain the association of birth order with NT even after controlling for birthplace. This finding is consistent with NT surveillance data from the Americas, showing that 78% of identified NT cases occurred in women with at least two prior pregnancies.¹⁸ Overall the risk factors for NT identified in this case-control study are similar to those identified in several epidemiological studies in Latin America: multiparous, unvaccinated, poor women with little or no formal education who deliver at home are at greatest risk of having a child with NT.^{19–21}

The male predominance among NT cases has been observed previously, in both hospital-based^{11,15,22} and community-based studies,^{12,16,23} and some authors^{24,25} have suggested that males are more sensitive to the tetanus toxin than females. Nevertheless, the predominance of male cases in China might also reflect an increased likelihood of ill boys being hospitalized in the study area. One study conducted in China verified that female children were less likely to be brought to see a doctor when ill than male children and more than half of female children did not receive any health services from illness onset to the 24 hours prior to death.²⁶ The predominance of male NT cases in China might also be related to the demographic shift towards male births. The true sex ratio of NT cases in China in the absence of a hospitalization bias is difficult to ascertain.

Access to clean deliveries, including proper post-delivery umbilical stump care is one of the WHO/UNICEF recommended strategies for maternal and neonatal tetanus elimination. However, until these can be achieved, TT immunization of pregnant and other childbearing age women is the primary strategy for achieving maternal and neonatal tetanus elimination, particularly in rural areas where access to clean deliveries is low. Previous serosurveys from China, conducted prior to the initiation of routine TT immunization, have documented a low seroprevalence of anti-TT antibodies among women of childbearing age.^{9,10,27} In a tetanus antibody serosurvey conducted among mothers and their newborn babies in Southern Fujian, China,⁹ only 23.8% and 20.6% of women and their babies respectively had protective levels of tetanus antitoxoid antibodies prior to routine TT vaccination. After five doses of TT, 100% of mothers and 93.9% of newborns in the same population had protective levels in a follow-up serosurvey. Among 8882 newborns followed whose mothers were fully vaccinated with TT, no NT cases occurred. In contrast, among 4835 newborns whose mothers did not receive vaccination, the incidence of NT cases was 5.3 per 1000 LB.⁹ TT immunization is a strategy critical to rapidly achieving and maintaining NT elimination in China. Our findings reinforce the current strategy for vaccinating high-risk areas or population groups. Continued surveillance and evaluation are needed to determine the impact of these strategies.

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KEY MESSAGES

- Reported national neonatal tetanus (NT) incidence in China decreased from 0.21/1000 live births (LB) in 1997 to 0.16/1000 LB in 2001.
- The observed decline in NT incidence suggests the effectiveness of mass tetanus toxoid (TT) vaccination campaigns targeted at women of childbearing age in high-risk areas during 1995–1996, with coverage of 80% achieved.
- The case-control study confirmed findings from other countries worldwide that multiparous, unvaccinated, poor women with little or no formal education who deliver at home are at highest risk of having a child with NT.

References

- 1 World Health Organization. Progress towards the global elimination of neonatal tetanus, 1990–1998. *Weekly Epidemiol Rec* 1999;**74**:73–80.
- 2 Su WN, Ze WY. Retrospective survey on the morbidity of neonatal tetanus in some areas. *Chin J Epidemiol* 1987;**8**:129–32.
- 3 Chai F, Zhang RZ. Progress towards the elimination of neonatal tetanus in China (Review). *Chin J Epidemiol* 2000;**21**:58.
- 4 World Health Organization. *WHO Recommended Standards for Surveillance of Selected Vaccine-Preventable Diseases*. WHO/EPI/GEN/ 98.01 REV.2, Geneva, 1999. Available from: <http://www.who.int/vaccines-documents/>

- ⁵ Dean AG, Dean JA, Coulombier D *et al.* *Epi Info, Version 6: A Word Processing, Database, and Statistics Program for Public Health on UBM-compatible Mirocomputers*. Centers for Disease Control and Prevention, Atlanta, GA, USA, 1996.
- ⁶ Stokes ME, Davis CS, Koch GG. *Categorical Data Analysis Using the SAS System*. Cary, NC: SAS Institute Inc. 1995.
- ⁷ Qi HY, Bian ZB. Epidemic investigation of neonatal tetanus in Hezheng County. *Dis Surveill* 1996;**11**:295.
- ⁸ He JP, Wu HS. Clinic observation on 53 neonatal tetanus cases. *Chin J Vaccine Immunization* 1997;**3**:222.
- ⁹ Li L, Liu WH, Liao SH. Research on factors affecting neonatal tetanus and its prevention through immunization. *Chin J Epidemiol* 1996;**17**:83–86.
- ¹⁰ He H. A study on risk factors and control of neonatal tetanus during 1975–1990 in Yichang City. *Chin J Epidemiol* 1993;**14**:160–62.
- ¹¹ Traverso HP, Kamil S, Rahim H, Samadi AR, Boring JR, Bennett JV. A reassessment of risk factors for neonatal tetanus. *Bull World Health Organ* 1991;**69**:573–79.
- ¹² Hlady WG, Bennett JV, Samadi AR *et al.* Neonatal tetanus in rural Bangladesh: risk factors and protective efficacy. *Am J Public Health* 1992;**82**:1365–69.
- ¹³ Parashar, UD, Bennett JV, Boring JR, Hlady WG. Topical antimicrobials applied to the umbilical cord stump: a new intervention against neonatal tetanus. *Int J Epidemiol* 1998;**27**:904–08.
- ¹⁴ Baltaza JC, Sarol JN Jr. Prenatal tetanus immunization and other practices associated with neonatal tetanus. *Southeast Asian J Trop Med Public Health* 1994;**25**:132–38.
- ¹⁵ Bennett JV, Azhar N, Rahim F *et al.* Further observations on ghee as a risk factor for neonatal tetanus. *Int J Epidemiol* 1995;**24**:643–47.
- ¹⁶ Traverso HP, Bennett JV, Khan AJ *et al.* Ghee application to the umbilical cord: a risk factor for neonatal tetanus. *Lancet* 1989;**i**:486–88.
- ¹⁷ Leroy O, Garenne M. Risk Factors of Neonatal Tetanus in Senegal. *Int J Epidemiol* 1991;**20**:521–26.
- ¹⁸ Pan American Health Organization. Neonatal tetanus control, defining high risk areas: the experience in the Americas. *EPI Newsletter* 1990;**XII**(4).
- ¹⁹ Tapia CR, Sepulveda-Amor HJ, Salvatierra IB *et al.* [Factors related to mortality in neonatal tetanus in the rural area of Jalisco], *Salud Publica de Mexico* 1991;**33**:207–13.
- ²⁰ Pan American Health Organization. Neonatal tetanus in Venezuela, 1970–1991. *EPI Newsletter* 1993;**XV**(1).
- ²¹ Cardenas Ayala VM, Nunez UM, Brogan D *et al.* Neonatal tetanus mortality in Veracruz, Mexico 1989. *Bull PAHO* 1995;**29**:116–28.
- ²² Simental PS, Parra MM, Valdez JM *et al.* Neonatal tetanus experience at the National Institute of Pediatrics in Mexico City. *Pediatr Infect Dis J* 1993;**12**:722–25.
- ²³ Wassilak SG, Orenstein WA, Sutter RW. Tetanus. In: Plotkin SA, Orenstein WE (eds). *Vaccines. 3rd Edn*. Philadelphia: Saunders, 1997, pp. 1–12.
- ²⁴ Bytchenko B. Geographical distribution of tetanus in the world, 1951–60. A review of the problem. *Bull World Health Organ* 1966;**34**:71–104.
- ²⁵ Ebisawa I. Mortality and sex difference of tetanus in Japan. *Japan J Exp Med* 1971;**41**:21–29.
- ²⁶ Jiang F. The health status and problems of female children in poor areas in China. *Chinese Health Care for Mothers and Children* 1997;**12**:183.
- ²⁷ Ze WY. A serological survey of the tetanus antibody of the normal population in China. *Chin J Epidemiol* 1987;**8**:133–35.