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Effect of birthweight on pneumonia-specific and total mortality among infants in the highlands of Papua New Guinea

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SUMMARY

A cohort of 1711 children born in Tari, Southern Highlands Province, Papua New Guinea was followed to determine the effect of birthweight on total and cause-specific mortality at varying ages during infancy. Mean birthweight was 3.04 kg, males were significantly heavier than females and first offspring significantly lighter than other offspring. Children weighing ≤2.5 kg at birth accounted for 15% of all births and 32% of all deaths and were 2.7 times more likely to die in infancy than heavier children. Infant mortality was negatively associated with birthweight ($p<0.001$). Mortality was very high among children with birthweight ≤2 kg and was lowest in the 3.1-3.5 kg birthweight category. Pneumonia mortality declined with increasing birthweight in the 1-5 month age group, but in the 6-11 month age group the risk of death from pneumonia was the same among children with birthweight >3.5 kg as those with birthweight ≤2.5 kg. While control of infectious diseases will have a marked impact on infant mortality in the short term, longer-term interventions aimed at improving socioeconomic status are needed to improve nutritional status of both adults and children (including birthweight) and hence sustain the lower mortality levels achieved in young children.

Introduction

Birthweight has been shown to be an important determinant of infant mortality in both developed and developing countries (1-10). Low birthweight is particularly associated with a high risk of neonatal death, but is also associated with an increased risk of death in the postneonatal period (1,4,6,7,9-12) and its effect on mortality may even extend beyond the age of one year (13). Recent data suggest that cardiovascular disease in adulthood may be associated with low birthweight (14).

A limited number of studies have examined the effect of birthweight on cause-specific mortality in developing countries or among deprived communities in developed countries (6). In Brazil children weighing <2.5 kg at birth are 2.5 times more likely to die of diarrhoea and 7 times more likely to die of respiratory infections in the first year of life than heavier newborns (3). Although low birthweight is associated with increased risk of death in the postneonatal period, the effects of social and environmental factors are also very potent at this age: Native American children weighing ≥2.5 kg at birth are 4 times more likely to die in the postneonatal period than white American children with normal birthweight and 6 times more likely to die from infections (11); and postneonatal mortality among Australian Aboriginal children weighing 2.5 kg or more at birth is 3 times as high as among white Australian children with normal birthweight (10).

There have been a number of studies of birthweight in various populations in Papua New Guinea (PNG) over the past 40 years, predominantly among urban and semiurban populations (15-20), but a limited number have been carried out in rural areas (16,21-23) (Table 1). In general, birthweights have been higher in the highlands than in other parts of the country.

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To date no studies have been carried out in PNG to determine the association between birthweight and mortality. The present study was therefore initiated in Tari, Southern Highlands Province to determine (i) the importance of low birthweight as a risk factor for death at varying times during the first year of life, (ii) the effect of birthweight on cause-specific mortality, (iii) whether 2.5 kg would be an appropriate cut-off point for health workers to identify a group of children in the highlands requiring special attention, and (iv) whether interventions to reduce the number of children born with a low birthweight could reduce infant mortality.

The Huli people inhabit the Tari Basin and live in scattered homesteads between 1500 and 1800 metres above sea level. The staff of three health subcentres and a district hospital serviced the people under regular demographic surveillance in Tari. Antenatal care is provided at Tari Hospital and to a limited extent at monthly mobile maternal and child health (MCH) clinics. Traditional birthing practices among the Huli have been described elsewhere (24,25). In the hospital and health subcentres, births are generally supervised by nurses who also record data in birth registers; doctors are only involved in complicated deliveries at Tari Hospital.

Materials and methods

The demographic base

Monthly demographic surveillance by Huli lay reporters was continuous in Tari between 1971 and 1995, at which time approximately 33 000 people were under regular surveillance. Pregnancies, births, deaths, migrations, marriages and divorces were reported and data entered on computer monthly. The crude birth and death rates in Tari from 1977 to 1983 were 35 and 15/1000/annum, respectively (26). Neonatal and postneonatal mortality rates were 19 and 55/1000 livebirths, respectively, between 1980 and 1983 (26). Pneumonia accounted for 50% of infant deaths, and neonatal and gastrointestinal causes a further 21% and 8% of infant deaths, respectively (26,27); malaria, which causes morbidity in the lower lying areas, was not identified as a cause of death in infants.

The birth cohort

All children born between 1979 and 1983 to mothers under demographic surveillance at the time of delivery were identified on the demographic database, which provided information on sex, birth order, date of birth, date of exit from the study, names of parents, place of residence and, in the event of death, date of death. The cohort was followed for at least 12 months. Birthweights (recorded to the nearest 100 g) were obtained from birth registers kept at the health facilities.

Determination of cause of death

Cause of death was determined by verbal autopsy, supplemented by any information available from health services, as described previously (27). For half the deaths in this study, cause of death was assigned by a doctor,

TABLE 1

SUMMARY OF BIRTHWEIGHT DATA COLLECTED IN RURAL AREAS OF PAPUA NEW GUINEA

Author	Region	Date	Number	Mean (g)	SD (g)	%<2.5 kg
Wark and Malcolm (16)	Lowland	1962-1967	63	2400	500	?
McKay (21)	Highland	1957-1958	207	2835	?	?
Heywood (22)	Highland	1957-1977	4103	2910	414	15
	Lowland	1954-1981	5632	2818	489	36-19
Lourie (20)	Island	1936-1978	769	2964	?	16
Garner (23)	Lowland	1988	121	2540	358	40

health extension officer or senior nurse who cared for the child during the terminal illness. Data were analyzed with respect to the underlying cause of death only. Pneumonia was recorded as the cause of death if there was a history of cough and breathlessness with or without fever for less than three weeks. This symptom complex may not be highly specific for pneumonia (i.e. cases of septicaemia, malaria and meningitis may be included in this group) but it is very sensitive and has been used successfully in two trials of pneumococcal polysaccharide vaccines in children (28,29).

Statistical analysis

Multiple births, stillbirths and adopted children were excluded from the study (49 in all). Age at death was considered in three categories: <1 month, 1-5 months and 6-11 months. The number of livebirths was the denominator for all three age groups. In view of the nurses' digit preference for the nearest 0.5 kg, birthweights in kilograms were combined as follows for grouped analysis: ≤2.0, 2.1-2.5, 2.6-3.0, ... 4.1+. All children weighing more than 3.5 kg were grouped

TABLE 2

DESCRIPTION OF THE BIRTH COHORT

		Number	Birthweight (kg) Mean	SD
	Male	845	3.07*	0.48
	Female	866	3.00*	0.46
	Total	1711	3.04	0.47
Birth Order				
	1st	376	2.89	0.46
	2nd	326	3.01	0.41
	3rd	286	3.09	0.49
	4th	247	3.06	0.45
	5th	216	3.17	0.50
	6th	151	3.09	0.46
	7th+	109	3.11	0.46
Prevalence of low birthweight (≤2.5 kg)				
	Male	13.1%		
	Female	16.2%		
	Total	14.7%		
Infant deaths		**Number**	**Mortality rate/1000 livebirths/year**	
	Male	43	51	
	Female	61	70	
	Total	104	61	
Age at death (months)		**Number**	**Mortality rate /1000 livebirths/month**	
	<1	19	11.1	
	1-5	50	5.8	
	6-11	35	3.4	

* p<0.01 between males and females

together for survival analysis since there were few births and no deaths among those weighing more than 4.0 kg.

Cox's proportional hazard model was used to determine the effect of birthweight on mortality; sex and birth order were included as covariates (30,31). Risk is expressed as a hazard function. The effect of birthweight on mortality was examined as a continuous variable which provided an overall indication of hazard (risk) for a 1.0 kg reduction in birthweight. Since the effect of birthweight on mortality was unlikely to be uniform, and to determine the hazard ratios for different birthweight categories, birthweight was also examined as a discrete variable, grouped in 0.5 kg categories. Hazard ratios were determined in relation to the birthweight group with the lowest risk of death and separately for age groups <1, 1-5 and 6-11 months. In order to test whether the hazard ratios for the different age groups were significantly different, interaction terms between birthweight and age group were fitted using the time-dependent covariates option of the EGRET package (32). Where appropriate, the t-test or analysis of variance was used for comparison between groups of interest (30).

Results

The birth cohort consisted of 1711 singleton livebirths (845 males, 866 females), born between 1979 and 1983 under the supervision of nurses or doctors – approximately half of all births in the area under demographic surveillance. The mean birthweight was 3.04 kg, females were significantly lighter than males ($p<0.01$) and firstborn children significantly lighter than other children ($p<0.0001$) (Table 2). The prevalence of low birthweight (≤2.5 kg) was 15% and mortality declined with increasing age during the first year of life (Table 2). Pneumonia was the most important cause of death after the first month of life (Table 3); in view of the small numbers of deaths from other causes, the effect of birthweight was examined only with respect to total and pneumonia-specific mortality.

Birthweight had a very significant effect on infant mortality (Table 4), similar in males and females (Figure 1). The hazard ratio of infant death for a 1 kg reduction in birthweight was 2.47 (95%CI 1.62-3.76; likelihood ratio statistic = 17.7, 1df, $p<0.001$). Children weighing ≤2.5 kg at birth accounted for 32% of infant deaths compared to 14% of survivors

TABLE 3

CAUSE OF DEATH BY AGE AMONG 1711 SINGLETON LIVEBIRTHS

Cause	**Age at death**			**Total**
	0-28 days	**1-5 months**	**6-11 months**	
Pneumonia	5	32	20	57
Neonatal causes*	10	2	-	12
Diarrhoea/dysentery	-	1	5	6
Measles	-	-	5	5
Other**	3	11	5	19
Unknown	1	4	-	5
Total	19	50	35	104

* includes birth injury, prematurity, congenital abnormality and undetermined causes

** includes febrile illness (9), abdominal illness other than diarrhoea/dysentery (1), acute lower respiratory disease not fully specified (4), malnutrition (1), trauma (2) and other (2)

TABLE 4

MORTALITY RATE PER 1000 LIVEBIRTHS BY BIRTHWEIGHT AND AGE AMONG 1711 SINGLETON LIVEBIRTHS

Birthweight kg	Number of births	Age at death 0-28 days rate	(n)*	1-5 months rate	(n)	6-11 months rate	(n)	Total deaths rate	(n)
≤2.0	35	114	(4)	86	(3)	86	(3)	286	(10)
2.1-2.5	216	14	(3)	46	(10)	46	(10)	106	(23)
2.6-3.0	745	9	(7)	34	(25)	8	(6)	51	(38)
3.1-3.5	527	6	(3)	21	(11)	13	(7)	40	(21)
3.6-4.0	162	12	(2)	6	(1)	56	(9)	74	(12)
4.1+	26	0	(0)	0	(0)	0	(0)	0	(0)
Total	1711	11	(19)	29	(50)	20	(35)	61	(104)

*number of deaths in parenthesis

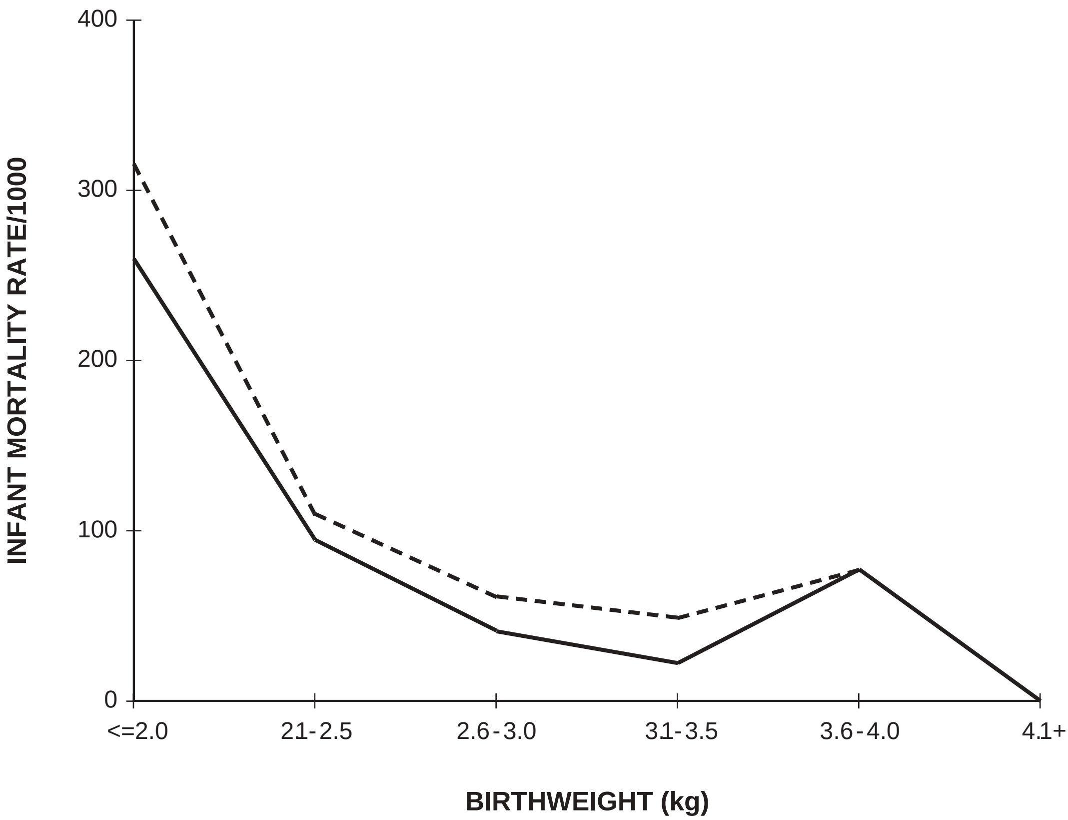

Figure 1. Infant mortality rate/1000 livebirths according to birthweight in males (solid line) and females (dashed line).

and they were 2.7 times more likely to die before their first birthday than heavier children. Birthweight also had a significant effect on pneumonia mortality in the first year of life. The hazard ratio for pneumonia mortality throughout the first year of life for a 1 kg reduction in birthweight was 2.10 (95%CI 1.19-3.73, p=0.01).

There was a marked variation in the effect of birthweight on mortality at different ages during the first year of life (likelihood ratio statistic = 21.11, 8df, p=0.007) (Table 5): for total mortality, reduction in birthweight led to a significant increase in hazard ratio in children <1 month and 1-5 months of age but this was not the case during the second six months of life because both those weighing 2.5 kg or less and those weighing more than 3.5 kg were at increased risk of dying compared to children weighing 2.6-3.5 kg at birth (Table 4). The effect of a 1 kg reduction in birthweight on pneumonia mortality was significant only for children 1-5 months of age, though it should be noted that there were only 5 deaths attributed to pneumonia in the first month of life. Figure 2 shows the hazard ratios for pneumonia mortality with respect to the optimum birthweight group of 3.1-3.5 kg in children aged 1-5 and 6-11 months. While there was a markedly linear negative relationship between birthweight and pneumonia mortality in the 1-5 month age group, the risk of death from pneumonia in children aged 6-11 months was as great among those weighing >3.5 kg as among those ≤2.5 kg at birth.

Discussion

The present study is among the very few from rural areas in developing countries in which the effect of birthweight on pneumonia-specific as well as overall mortality is reported throughout the first year of life. It is also the first report of the relationship between birthweight and infant mortality in PNG. Birthweight has a strong and significant effect on infant mortality but its effect is clearer during the first 6 months of life. Although low birthweight remains a risk factor for mortality in the second 6 months of life the picture is complicated by the fact that high birthweight is also an important risk factor for mortality - in this age range the relationship between mortality and birthweight is 'U' shaped. This pattern has been well documented in studies of neonatal mortality (33), and Kliewer and Stanley (10) have reported levelling off or increased risk of death

TABLE 5

EFFECT OF BIRTHWEIGHT ON TOTAL AND PNEUMONIA-SPECIFIC MORTALITY

	Age (months)		
	<1	1-5	6-11
All mortality, effect of a 1 kg reduction in birthweight			
Hazard ratio	4.02	2.74	1.62
95% CI	(1.57-10.28)	(1.48-5.00)	(0.79-3.34)
p	0.005	0.001	0.19
Pneumonia mortality, effect of a 1 kg reduction in birthweight			
Hazard ratio	1.20	2.81	1.52
95% CI	(0.18-7.99)	(1.32-5.99)	(0.58-4.01)
p	0.85	0.008	0.39

at higher birthweight during the postneonatal period. Genetic factors are likely to operate in determining this susceptibility at higher birthweights but no clear explanation has yet been established. Susceptibility to infections and other environmental hazards (particularly those associated with low socioeconomic status) may be masked by breastfeeding and maternal proximity during the first six months of life and may only become apparent thereafter.

We do not know whether there has been any change in mean birthweight in Tari over the past decade, though there has been a decline in postneonatal mortality in recent years. However, the postneonatal : neonatal mortality ratio has remained high and pneumonia is still the cause of almost half of the infant deaths (J. Vail, D. Lehmann et al., unpublished data). It is unlikely that the actual relationship between birthweight and mortality has changed since this study took place.

Our results suggest that in the more deprived areas of the highlands it would be appropriate for health workers to use a birthweight of ≤2.5 kg to identify children at risk of death since this cut-off would identify 32% of infants dying but only 14% of survivors to the age of one year. In this study birthweights were available only for offspring of mothers delivering at a health institution – approximately half of all births – raising the question of whether the children in this study

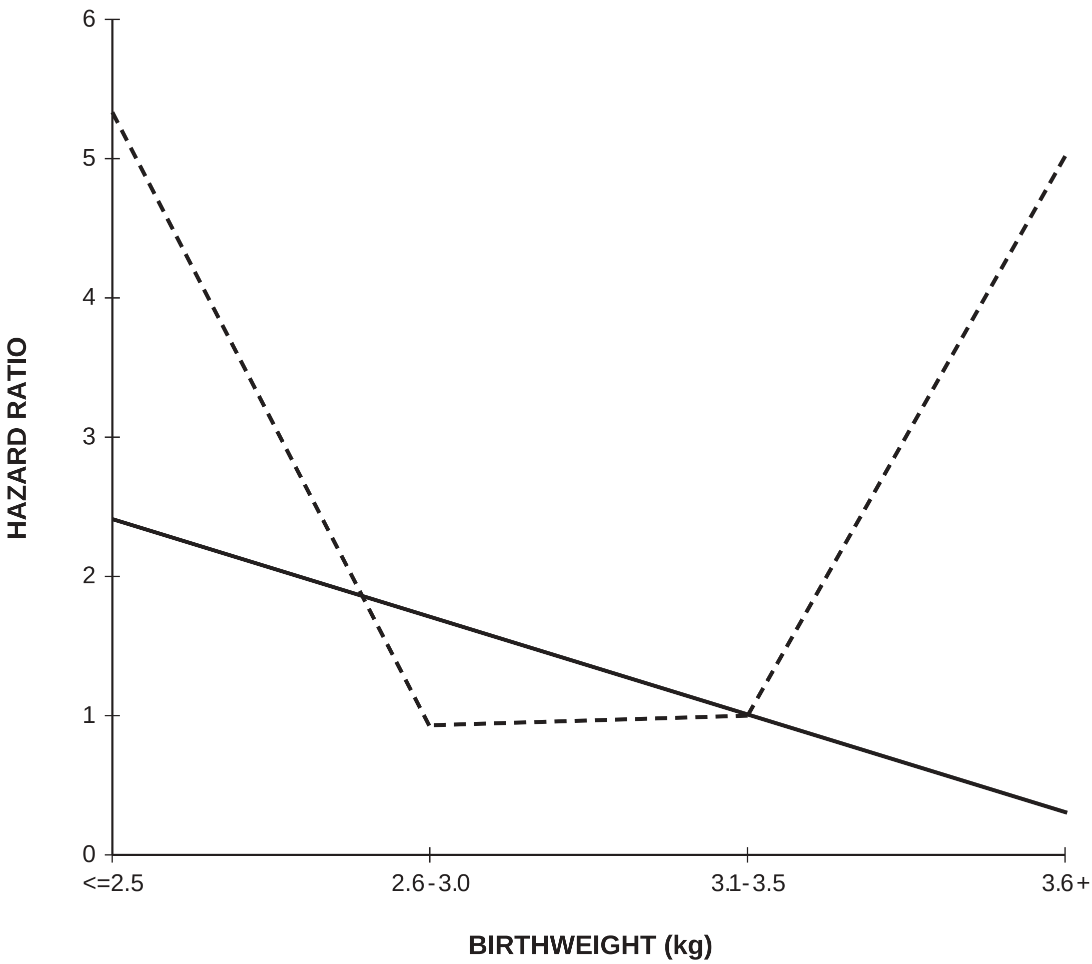

Figure 2. Hazard ratio for pneumonia mortality at varying birthweight (with respect to birthweight 3.1-3.5 kg) in children aged 1-5 months (solid line) and 6-11 months (dashed line).

were different from those who were not delivered under medical supervision. Over the period of this study, the mortality rate during the first month of life in the monitored population as a whole was 18/1000 livebirths (26) compared to 11/1000 for the children included in this study. Thus mortality under 1 month of age must have been higher among children of mothers who delivered at home. The risk of death associated with low birthweight in this age group is probably also an underestimate of the actual risk in the wider community. Mothers should be encouraged to deliver in a health institution and improved antenatal care is required in rural areas to identify high-risk mothers and babies.

In general, the results reported here are consistent with those obtained by other investigators (2,3,5,6,34). The effect of low birthweight on infant mortality appears to be dependent on (a) the infant mortality rate, (b) the postneonatal : neonatal mortality ratio, (c) the causes of death in infancy, and (d) the proportion of low birthweight babies who are either preterm or small-for-gestational-age. In developed countries, infant mortality is low, the postneonatal : neonatal mortality ratio low, deaths in infancy are primarily from perinatal causes and preterm infants account for a large proportion of low birthweight infants (7). In this situation, with a low baseline mortality and a high relative risk of low birthweight with respect to mortality, birthweight is an important determinant of infant mortality, particularly during the neonatal period, and therefore interventions aimed at reducing the number of low birthweight babies should have a significant impact on mortality.

In Tari the infant mortality rate is in the middle of the range, the postneonatal : neonatal mortality ratio is relatively high and pneumonia is the most important cause of death throughout the postneonatal period. There is no information on whether the low birthweight is predominantly due to preterm delivery or fetal growth retardation. However, data from a lowland area of PNG (23) and other countries (5) suggest that low birthweight in developing countries is generally due to intrauterine growth retardation. We have found a strong and significant effect of low birthweight on mortality. Nevertheless, because infectious disease is the predominant cause of death, control of infectious disease is seen as the desired type of intervention since it will have a greater impact on infant mortality than interventions aimed at reducing the number of low birthweight babies. There is no doubt that in the short term this will be true and in fact increased utilization of health services for treatment of pneumonia has probably contributed to the decline in postneonatal mortality in Tari. However, in the absence of longer-term measures to change the level of risk factors such as low birthweight, maintenance of the lower level of mortality will be dependent on maintaining a high input into the health system. It is important that longer-term interventions to reduce risk factors are not accorded a low priority just because they are long-term and, often, more complicated. In developing countries such interventions might include malaria prophylaxis, calorie supplementation in pregnancy, delayed child-bearing in adolescents and better maternal education, as well as interventions to improve nutritional status, especially in girls, socioeconomic status, sanitation and water supplies (5).

Interventions to improve the height and weight of adult females, including their growth during childhood, may be the most effective way to increase birthweight (35); moreover, interventions which successfully increased birthweight without increasing the growth of women would lead to an increase in problems from cephalopelvic disproportion (36). There is clear evidence from Simbu Province of an upward secular trend in birthweight and maternal stature and a significant reduction in infant mortality over a 25-year period (37). Between the mid-1950s and the early 1970s mean birthweight increased by approximately 200 g. This was accompanied by increases in maternal weight and height. Later work by Groos and Hide (38) found that birthweights had remained stable during the first half of the 1980s and that the stature and weight of adult females had continued to increase. Over this same period there had been significant decreases in infant mortality rates at a time when there was significant economic development and social change: the provision of basic health and education services, significant investment in infrastructure such as roads, and the introduction of coffee as a cash crop.

In lowland areas of PNG the prevalence of low birthweight is generally higher than in highland areas (Table 1) (16,20,22,23). Malaria is endemic in these areas and is a significant cause of reduced birthweight (22,39) as well as a significant contributor to both morbidity and mortality in infants. Low birthweight in lowland areas is likely to be a more important contributor to infant mortality than in the Tari Basin and this study should be replicated in a lowland area to assist in developing health policies and programs in PNG.

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