Theme: Strengthening vital statistics and cause-of-death data

Measurement of cause of death in Papua New Guinea populations using a locally developed verbal autopsy instrument: 1970-2001

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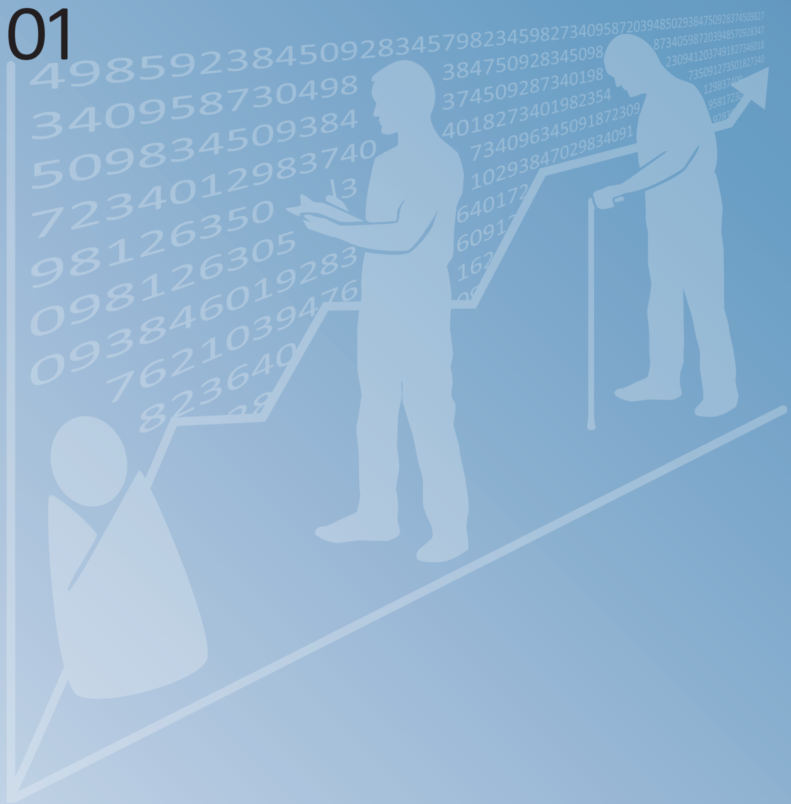

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Acronyms and abbreviations

ALRI	acute lower respiratory infection
CAL	chronic airflow limitation
CLD	chronic lung disease
COD	cause of death
COPD	chronic obstructive pulmonary disease
DHS	Demographic and Health Survey
DSS	Demographic Surveillance Site
IMR	infant mortality rate
LB	live births
LLC	lower limit of confidence
PNG	Papua New Guinea
PNGIMR	Papua New Guinea Institute of Medical Research
RTA	road traffic accidents
U5MR	under-five mortality rate
UCOD	underlying cause of death
ULC	upper limit of confidence
VA	verbal autopsy
VAI	verbal autopsy instrument
WHO	World Health Organization

Summary

Population data on cause of death (COD) in Papua New Guinea (PNG) since the Second World War has depended on small population studies established first by the Department of Health and later by the Papua New Guinea Institute of Medical Research (PNGIMR). In the 1970s a verbal autopsy instrument (VAI) was developed to measure causes of death in two sites in the PNG highlands with application to PNGIMR trials of pneumococcal polysaccharide vaccine in children and adults. This VAI was later used for studies of malaria in two lowland areas. The VAI was developed without reference to existing data and was used, virtually unchanged, on various field sites until 2001. Throughout the period of these studies, 85% of the national population lived in rural areas.

The VAI was initially designed to be used by field reporters with minimal schooling and had only 18 symptom questions. It also allowed for the recording of a brief open-ended narrative, the place of death, any treatment by health services, and the type of treatment. The disease classification was based on *Lay reporting of health information* (WHO 1978) and COD was entered into the international form of the death certificate. Verbal autopsies (VAs) were physician-coded with reference to diagnostic algorithms. For analysis purposes, we combined data for three different sites from hardcopy (held by author Riley), electronic records (held by author Lehmann) and hardcopy in the archives of PNGIMR. The sites were Tari in the Southern Highlands (1970–1995), Asaro in the Eastern Highlands (1979–1989) and Wosera, East Sepik (1996–2003). We also incorporated data from a published account of mortality in Madang (1982–1984), which used the same VAI. Wosera and Madang are both lowland sites.

In this working paper, we report details of 8489 deaths (6809 from Tari, 812 from Asaro, 461 from Wosera and 407 from Madang). Leading CODs were pneumonia (21.8%), chronic (non-tuberculous) lung disease (13.5%), diarrhoea/dysentery (8.3%), injury (7.3%), “other fevers” (7.3% %), and “other respiratory” (4.2%). Neonatal deaths (deaths in infants 0-28 days) constituted 5.9% of all deaths (excluding stillbirths); perinatal deaths (stillbirths and deaths 0-7 days) constituted 6.8% of all deaths (including stillbirths). Malaria and tuberculosis are both difficult to diagnose by VA. We argue that malaria is likely to have been responsible for 20% of child deaths in lowlands areas and that tuberculosis was probably responsible for 2.0% of deaths in the series as a whole. We compare these results with reports of deaths in health facilities in 1968 and 1998 and we refer to estimates of mortality levels based on demographic surveillance.

Although mortality declined markedly in PNG from the late 1940s, there is little evidence of change in the pattern of COD in these VA series up to the end of the century. These results are broadly consistent with reports from all hospitals in 1968 and from rural areas in 1998; the principal difference is greater emphasis in the population data on chronic lung disease and injuries, which is consistent with epidemiological studies. There is early evidence from urban health facilities in 1998 of an epidemiological transition, but that is not reflected in any of the rural data.

This short VA instrument was designed for a specific purpose in a particular environment. Considering its limitations, we consider it to have given a broad but remarkably accurate description of PNG rural mortality over a period of more than 30 years.

Introduction

Studies of COD in Papua New Guinea populations

Between 1947 and 1953, while investigating depopulation in New Ireland, the northernmost island province of Papua New Guinea (PNG), Scragg (1954) was able to assign a cause to 105 out of 188 deaths. This is the first study of cause of death (COD) in an open population that we can find in PNG. Later, between 1961 and 1968, as Director of Health, Scragg sponsored a series of demographic studies in coastal (New Ireland, Oro Bay, Trobriand Islands), coastal hinterland (Angugunak) and highland (Baiyer River) areas (Riley 2009). None referred to a standardised method of obtaining COD data from non-hospital deaths.

A Pneumonia Research Unit was established in Tari, Southern Highlands Province (now Hela Province) of PNG in 1970. A verbal autopsy instrument (VAI) was developed independently of developments elsewhere in 1971 for studies of mortality, firstly to determine the effects of pneumococcal polysaccharide vaccine on death from respiratory disease, and secondly to complement the earlier studies of mortality in small populations. The instrument was used continuously in Tari from 1970 to 1995, when the research unit was closed for reasons of security. The same instrument was used by Papua New Guinea Institute of Medical Research (PNGIMR) researchers from 1980 to 1989 in rural areas of the Asaro Valley and in the town of Goroka in the Eastern Highlands Province for a study of pneumococcal polysaccharide vaccine in children. The VAI was also used in studies of malaria in two lowland sites: Madang Province (1982–1984) and Wosera, East Sepik Province (1996–2003).

Although COD data derived from the use of this instrument have appeared in various publications (Appendix 1), results from its use have never been published as a single dataset, and the publications make little reference to the VAI as such. This material and the results from the earlier small population studies are the only sources of data available about COD in PNG populations before 2010. We aim here to assess the utility as well as evidence for the validity of the instrument and to review the distribution of, and trends in, the cause distribution of mortality between 1970 and 2001 in PNG as far as the limitations of these data will permit.

Verbal autopsies

A verbal autopsy (VA) is a questionnaire administered to the caregivers or family members of a recently deceased person (the decedent) to elicit signs and symptoms and their durations, together with other relevant information, in the period before death. VAs have been used to determine COD in situations where the majority of deaths occur without medical supervision. In particular, they have been used in demographic surveillance sites (DSS), which evolved from studies of mortality in small populations and in field trials aiming to determine the effect of public health interventions, such as vaccines, on mortality. More recently, VAs have been used, particularly in India and China, in sample vital registration systems.

High quality data about the frequency of different CODs in a population is fundamental to good public health practice. Such data are necessary to describe levels and trends of mortality as well as differences in sub-populations, for example, of different social classes or geographic regions. COD data facilitate policy development, the monitoring of public health programs and interventions, and resource allocation.

Few countries have data on mortality of sufficient quality to support policy development and implementation (Mathers et al. 2005). In the absence of comprehensive medical certification of COD, VAs are the only currently available means of obtaining quality population mortality data. Although their use dates back to the English Bills of Mortality in the seventeenth century, international interest has developed only over the last few decades (Soleman et al. 2006). Instruments in current use internationally, which include the World Health Organization (WHO) and Population Health Metrics Research Consortium (PHMRC) Verbal Autopsy Instruments (VAIs), belong to a family of instruments that evolved from work in Africa in the early 1990s (Chandramohan 2001). In this study, we examine results from, and the evidence for, the validity of a VAI developed independently in PNG in the early 1970s.

Their successful use in sample vital registration has led to the realisation that VAs could be used for civil registration of all deaths outside hospitals in countries where coverage by medical registration of deaths was at a low level. The principal obstacle has been the amount of time taken for the interview. The long forms of instruments in international use have taken up to an hour to administer. For routine use, it would be necessary to complete an interview in less than half an hour. This realisation has led to renewed interest in the PNG VAI, which was very short by current standards.

Papua New Guinea

New Guinea, the second largest island in the world after Greenland, lies to the north of Australia. The nation state of PNG occupies the eastern half of the island of New Guinea. It was administered by Australia until Independence in 1975. Four major regions can be defined: 1) an arc of islands to the north of the mainland, 2) the coast fringe of the mainland, 3) a coast hinterland consisting either of the flood plains of major rivers or of hills, 4) the central highlands with fertile valley floors lying at altitudes of between 1500 and 1600 metres.

In 1971, the population of PNG was over 2.4 million; by 2000 it was 5.2 million. In 1970, less than 10% of the population was living in urban areas; by 2000 this figure had increased to only a little more than 13%.

Less than 30% of PNG has potential for agricultural development (Eaton 1982). In 1971, the greater part of the country had population density of less than five persons per square kilometre. There were three areas of dense population: one included the Goroka area of the Eastern Highlands and the Mendi and Tari areas of the Southern Highlands; a second included the Wosera area of East Sepik Province; and a third involved the northern tip of the island of New Britain (Skeldon 1979).

A map of malaria endemicity, Figure 1 (Parkinson 1974), serves to indicate the principal geographic features of the country. Highlands areas, including their valley floors, were hypoendemic for malaria. Although most lowlands were hyperendemic, a small area around Wosera within the Sepik catchment to the north-east was classified as holoendemic. Endemicity was at variable levels in the arc of islands to the north of the mainland, and there was an area of hypo- to meso-endemicity along the Papuan coast in Central Province—the so-called Papuan dry belt. There was, however, considerable variation in endemicity from settlement to settlement within these broadly defined areas (Cattani 1992).

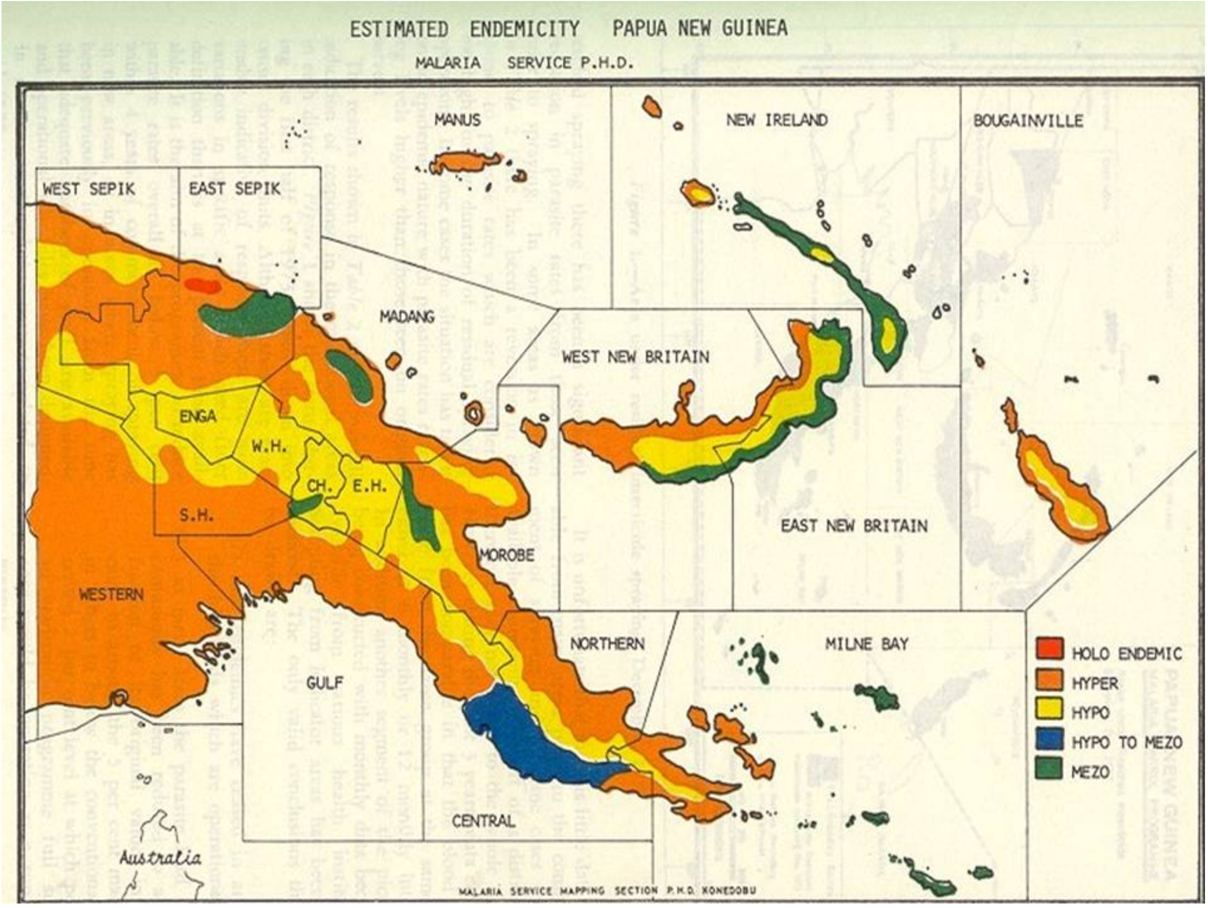
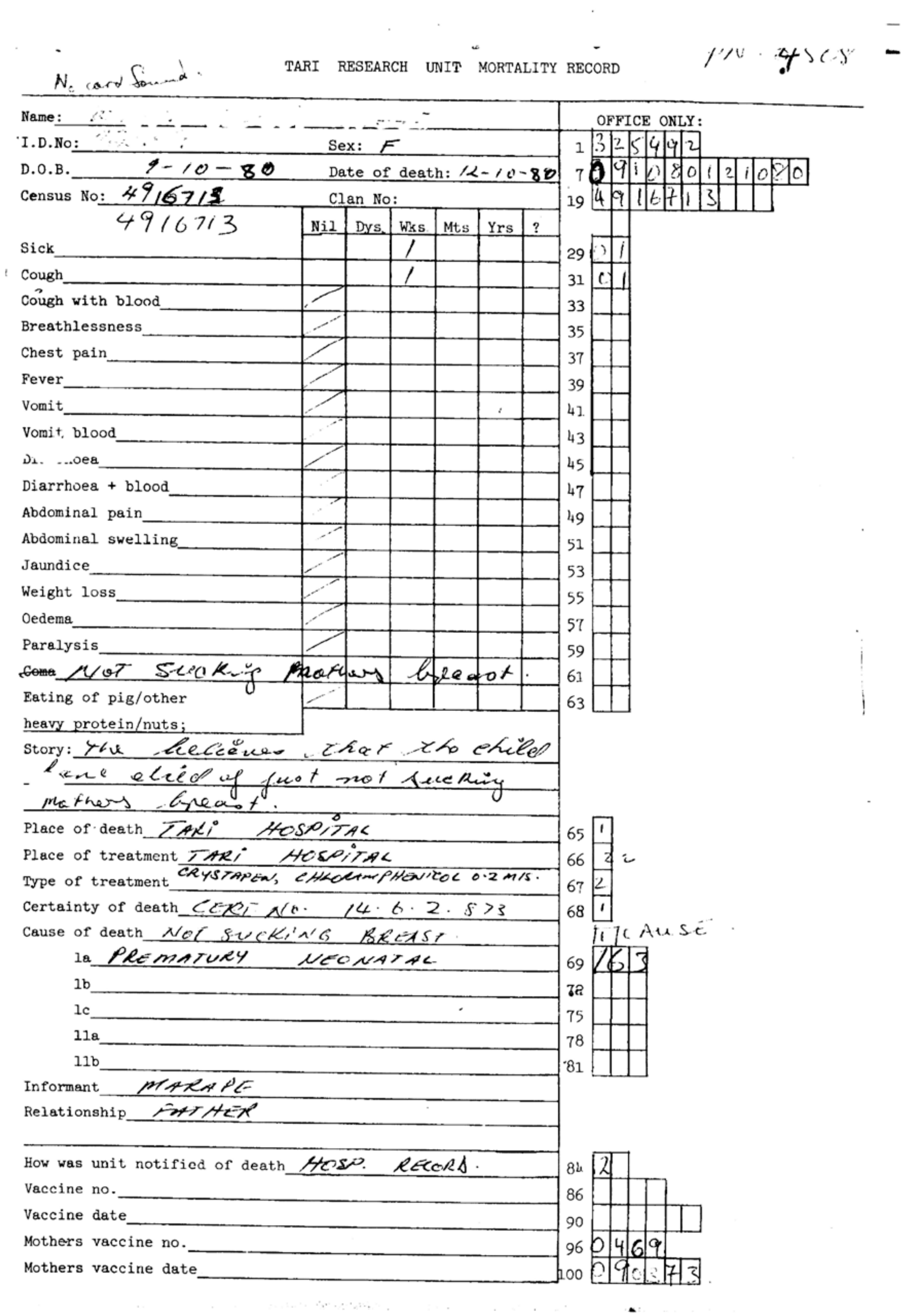


Figure 1 Malaria map of Papua New Guinea

Methods

Development of the verbal autopsy instrument

The VAI was designed by author Riley to be administered by field reporters without medical training and with primary schooling only. It was necessarily brief and at that time occupied a single foolscap page. After a mortality clerk had been informed of a death, and allowing for a period of mourning, a field reporter would visit the relatives of the decedent as soon as possible. The PNG VAI consisted of a series of closed questions about the presence or absence of symptoms and, if present, their duration. It also recorded a brief open-ended narrative, the place of death, any treatment by health services and the type of treatment. Certainty of the diagnosis of death was related to its source (e.g. medical officer, nurse, family). The list of symptom questions varied in minor detail at different times. The emphasis given to the brief open-ended narrative of the terminal illness, and its positioning within the framework of interview, varied at different times and on the various sites. Health workers or health service records provided additional information if the decedent had received treatment at a health institution. Figure 2 shows a de-identified mortality record from Tari in 1980. A neonate died with minimal symptoms; the family's comment that the infant had failed to suck at the breast was added; the child had been treated with penicillin and chloramphenicol; and reference to a hospital death certificate was copied into the VAI.



No card found.

TARI RESEARCH UNIT MORTALITY RECORD

Name:	OFFICE ONLY:
I.D.No: Sex: F	1 325492
D.O.B. 9-10-80 Date of death: 12-10-80	7 09108012 1080
Census No: 4916713 Clan No:	19 4916713
4916713	

	Nil	Dys	Wks	Mts	Yrs	?	
Sick			/				29 01
Cough			/				31 01
Cough with blood	/						33
Breathlessness	/						35
Chest pain	/						37
Fever	/						39
Vomit	/						41
Vomit blood	/						43
Diarrhoea	/						45
Diarrhoea + blood	/						47
Abdominal pain	/						49
Abdominal swelling	/						51
Jaundice	/						53
Weight loss	/						55
Oedema	/						57
Paralysis	/						59
~~Coma~~ Not sucking mothers breast.							61
Eating of pig/other heavy protein/nuts;	/						63

Story: The believes that the child have died of just not sucking mothers breast.

Place of death TARI HOSPITAL	65 1
Place of treatment TARI HOSPITAL	66 2
Type of treatment CRYSTAPEN, CHLORAMPHENICOL 0·2 MLS.	67 2
Certainty of death CERT NO. 14·6·2·573	68 1
Cause of death NOT SUCKING BREAST	CAUSE
1a PREMATURY NEONATAL	69 763
1b	72
1c	75
11a	78
11b	81
Informant MARAPE	
Relationship FATHER	
How was unit notified of death HOSP. RECORD.	84 2
Vaccine no.	86
Vaccine date	90
Mothers vaccine no.	96 0469
Mothers vaccine date	100 090373

Figure 2 Tari verbal autopsy record

Symptom questions were based on clinical experience of PNG disease patterns in the late 1960s and early 1970s. For example, pneumonia and chronic (non-tuberculous) lung disease were extremely common, but myocardial infarction and asthma occurred very rarely. Pigbel (*enteritis necroticans*) was a common cause of death in children in the highlands. Malaria, a leading cause of death in health facilities in PNG, has proven difficult to differentiate from other febrile conditions in field studies.

Cause-of-death classification and coding

COD coding and disease classification were based on *Lay reporting of health information* (WHO 1978), revised for use by local researchers as *Classification of symptom complexes for lay reporters* (Riley 1979/1989). Its symptom-based definitions took PNG disease patterns into account. If unable to report a specific COD, we assigned a symptom-based cause (Table 3). A death certificate was written in standard international format (WHO 1977).

We achieved consistency in diagnosis by using diagnostic algorithms based on clinical series and experience in PNG. These were increasingly formalised as the study progressed and, for example in the diagnosis of pneumonia in children, as standardised definitions evolved. As it happened, only a small number of physicians were involved in diagnosis over the 30-year period. Agreement between physician-coders was high when two investigators independently coded COD among children who had participated in pneumococcal vaccine trials.

Study sites

Tari

The Tari Basin is located in the Hela Province (then known as the Southern Highlands) and lies between altitudes of 1300 and 1800 metres above sea level; annual rainfall typically exceeds 2500 mm. Speakers of Huli, the local language, form the second largest language group in the country. Tari was subject to extraordinarily rapid social and economic change from 1970 through to 1995, when the research unit was closed for security reasons (Lehmann et al. 1997).

In 1970, almost the entire population was engaged in subsistence farming. First contact with the outside world had been in 1934. A government station, which included a health centre, was permanently established in 1952. By the late 1960s the health centre was classified as a hospital, with a medical officer in charge, and three mission health centres—focusing on maternal and child health services—and a network of aid posts had been established. The first high school was established in 1970.

During the 1970s, overland access had been extremely difficult and government and mission stations were supplied by air, but in 1980 a highway was opened connecting Tari to Mendi, the then capital of the province. Tari became a centre for oil and gas exploration from about this time. In 1987 there was a gold rush at Mt Kare to the north. Development of the Hides gas field in 1991 led to internal movement towards the site. Until this period, young men had been sequestered from society, traditionally in bachelors' initiation cults and later through out-migration to coastal plantations.

Their return in the 1980s to Tari and their subsequent engagement in the rapidly evolving economy contributed to social unrest (Lehmann et al. 1997). Major clan warfare broke out in 1986 and continued through 1988.

In 1971, Tari household surveillance for births and deaths had covered a population of about 11,000. By 1995, when the research unit was closed, the population under surveillance had been expanded to about 35,000 (Lehmann et al. 1997).

Asaro

Asaro was subject to steady social and economic development during the 1980s, due to the development of coffee as a cash crop and its proximity to the capital of Eastern Highlands Province, Goroka. The inhabited part of the Asaro Valley lies between 1500 and 1900 metres above sea level. The town of Goroka has an average annual rainfall of over 1700 mm. All villages in the study area were within 38 km or 1.5 hours drive of Goroka. The surveillance population for the Asaro site was based on a cluster sample comprising 85% rural and 15% urban communities. Sample size was based on requirements for a trial of pneumococcal polysaccharide vaccine in children.

In the rural area, people were primarily subsistence farmers, but they earned cash through smallholder production of coffee, employment on plantations and marketing of garden produce; their houses were made of wood and woven cane grass with thatched roofs. Houses in urban areas were built from permanent material; they usually had windows and a separate kitchen and bedroom. There were high-, medium-, and low-cost housing options. In the rural areas, people lived in hamlets grouped for administrative purposes into villages. Melanesian Pidgin was widely spoken throughout the valley and was the principal language of communication between health staff and local inhabitants. However, nearly all field workers spoke one of three local languages (Kakazo et al. 1999).

Goroka Hospital is the main hospital for the province. The study area was also served by a government health centre and two health sub-centres. Thirteen aid posts existed in the area at the start of the study. One health sub-centre was destroyed during inter-clan fighting in 1989, and three aid posts had closed down before the study was completed. Since road access to Goroka was relatively good in the monitored area, many people bypassed their local aid posts and sought treatment either at the more distant health centres or at the Goroka Hospital (Kakazo et al. 1999).

At the beginning of the study in 1980, the population under surveillance was 7000; by 1989 it had reached 8840 (Kakazo et al. 1999).

Wosera

Wosera is located in the Maprik district of East Sepik Province. Demographic surveillance was established in 1990 as part of the Malaria Vaccine Epidemiology and Evaluation Project. The site was selected because of its “high malarial endemicity, high mortality and morbidity rates, relatively poor nutritional status and low socioeconomic development… [It had] a large and accessible population with good internal communications, a good infrastructure of services and high population density” (Alpers et al. 1992, p. 287). The site is situated at 50–100 m above sea level on an alluvial plain that lies between mountains to the north and the flood plain of the Sepik River in the south. It covers an area 12 km x 16 km.

According to the 1979 national census, the population of the Wosera area was 22,314. The study population consisted of just over 4000 people in 10 villages selected to include a range of malaria endemicities. Maternal nutrition was poor and anaemia common. Malnutrition was common in children aged < 10 and was related to chronic deficit in energy and protein. A typical house consisted of a timber frame covered with a roof of sago-palm leaves. Mean annual rainfall was 1850 mm (Alpers et al. 1992; Genton et al. 1995a).

Madang

The study area lay within a 22 km radius of Madang, the provincial capital. This was described as an advantaged rural population with good access to the town and was made up of 72 villages of between 30 and 700 inhabitants with a total population of 16,500 (Moir et al. 1989). Average annual rainfall in Madang is over 3000 mm.

Health services available to those in the study area were 12 aid posts, two health centres and a hospital in Madang. Mobile maternal and child health teams visited rural populations. The people were primarily subsistence farmers who had supplementary cash income. Malaria was hyperendemic. The area had a tropical wet climate with an annual rainfall of 3500 mm (Moir et al. 1989).

Population surveillance

In each site, households were placed under regular surveillance for morbid events and for deaths and pregnancy outcomes. Field reporters were recruited from the surveillance population and were responsible for monitoring between 700 and 1400 people. Reporters aimed to visit each person listed in their books at least once every four weeks. For most of the period described here, surveillance was supplemented with annual censuses of study populations.

Data sources and data quality

The VA records were stored at different PNGIMR sites and in some cases were very difficult to locate. All Asaro records and Tari records from 1977 onwards had been kept in archives at the PNGIMR library in Goroka and were reconciled with electronic records held by author Lehmann. Earlier records from Tari from 1970 to 1974 were retrieved from a logbook held by author Riley. The Wosera VA forms included in this investigation were found at the Wosera PNGIMR office. VAs conducted in Wosera on deaths that occurred between 1991 and 1994 could not be retrieved and were not included (Genton et al. 1995b). We extracted the Madang data from the publication by Moir et al. (1989).

Although standards were generally high and consistent, the quality of the data compiled here does vary by site and over time. The VA instrument and methods of application were developed in Tari during the 1970s and 1980s. We encountered minor variations in the symptom list and the positioning of the open-ended narrative. Members of the same team were involved in applying the instrument in Asaro through the 1980s and acted as advisors for studies in Madang and Wosera. Nevertheless, variability in the quality and nature of supervision, the level of skill and training of reporters, and in the quality of health services information was only to be expected over a 30-year period across the four different sites. There was no single body overseeing the application of the instrument in both the highland and the lowland field sites.

Data management and data analysis

Data from VA forms were entered and stored into an Access database. Data were entered once and checked by a second clerk for errors. Data cleaning was conducted using Microsoft Excel and Stata software. All statistical analyses were conducted using Stata12 (StataCorp 2013). Frequencies and cross-tabulations were used to explore CODs in the three different sites by age and sex. Analyses were based only on the underlying cause of death (UCOD). Patterns of COD over time were inspected, and level of health care and certainty of diagnosis were examined.

Results

In this section we describe the distribution of deaths in terms of symptom complexes. We then describe the distribution of deaths under symptom complex headings, either as specific causes where descriptions of those deaths have met predetermined criteria or, where this is not possible, we continue to use symptoms to describe the patterns of death.

Number of cases

A total of 8489 deaths, including 234 stillbirths, were analysed across the four sites (Table 1). The majority of deaths were from Tari (80.2%) and occurred between 1970 and 1995 (Tari data for 1975 and 1976 had been lost). Asaro deaths, which make up 9.6% of all deaths, were collected over a ten-year period between 1979 and 1989. Wosera deaths make up 5.4% of deaths presented here and cover the years 1996 to 2001. We were unable to locate Wosera data for 1998 and do not know why it was not available. Wherever feasible, we have also incorporated data taken from a published account of Madang deaths for the years 1982 to 1984 (Moir et al. 1989): these deaths make up the final 4.8% of all deaths in the series.

Table 1 Number of deaths by year of death and site

Year of death	Asaro	Tari	Wosera	Madang	Total[1]
1970	0	111	0		111
1971	0	176	0		176
1972	0	149	0		149
1973	0	206	0		206
1974	0	87	0		87
1977	0	280	0		280
1978	0	347	0		347
1979	23	384	0		407
1980	76	627	0		703
1981	64	329	0		393
1982	80	298	0		378
1983	76	311	0	407	387
1984	58	336	0		394
1985	87	393	0		480
1986	90	291	0		381
1987	70	324	0		394
1988	88	275	0		363
1989	100	378	0		478
1990	0	301	0		301
1991	0	263	0		263
1992	0	311	0		311
1993	0	293	0		293
1994	0	286	0		286
1995	0	53	0		53
1996	0	0	113		113
1997	0	0	141		141
1999	0	0	89		89
2000	0	0	87		87
2001	0	0	31		31
Total	**812**	**6809**	**461**	**407**	**8489**
Percentage of total	**9.6**	**80.2**	**5.4**	**4.8**	**100**

[1]Includes 234 stillbirths

Specific versus symptom diagnosis by certainty of diagnosis

A death was assigned a specific diagnosis (e.g. pneumonia) in 68.8% of cases and a symptom-based diagnosis (e.g. cough) in 31.2% of cases (Table 2). The greater the certainty of the diagnosis (i.e. whether the diagnosis was assigned by a health professional or whether it was based on family history alone), the more likely it was that a specific diagnosis would be assigned: 89.9% of decedents who had been seen by a medical officer were assigned a specific diagnosis, whereas in cases where there had been no contact with health services and the COD was based solely on symptom history, only 64.5% of decedents were assigned a specific diagnosis. Table 2 excludes Madang deaths and stillbirths.

Table 2 Certainty of diagnosis by specificity of diagnosis (Madang not included)

Certainty of diagnosis	Specific diagnosis		Symptom diagnosis		Total
	n	%	n	%	n
Medical officer	957	89.9	108	10.1	1065

Nurse	274	81.5	62	18.5	336
Aid post orderly	146	81.1	34	18.9	180
No record of health facility attended	3,776	64.5	2,078	35.5	5854
Missing	246	59.6	167	40.4	413
Total	5,399	68.8	2,449	31.2	7848

Cause of death by symptom group

Table 3 includes Madang deaths. It is based on the *Classification of symptom complexes for lay reporting in Papua New Guinea* (Riley 1979/1989) and shows the number and percentage of cases assigned a specific cause (e.g. malaria) and those with a symptom diagnosis only (e.g. fever with coma) by symptom group. The table shows that overall, 65.0% of cases were assigned a specific cause and 35.0% a symptom-based cause. A group of ill-defined conditions and unknown causes (13.3% of all cases) were included in the latter group. Among the leading causes of death, it was most difficult to assign a specific diagnosis to chronic abdominal conditions (8.0%), to a small group of miscellaneous causes (16.7%), and to febrile conditions (28.8%). For all other groups more than half the cases were assigned a specific diagnosis. Low numbers of deaths and a requirement for high specificity under the headings of neoplasms, neurological manifestations, and cardiovascular diseases reflect dependence on professional diagnosis. In the neurological category, hemiplegia and paraplegia were considered specific diagnoses. In the cardiovascular category, heart failure was considered a non-specific diagnosis.

Table 3 Cause of death by symptom group by specificity of diagnosis

Symptom group	Specific diagnosis		Symptom diagnosis or undefined		Total
	N	%	N	%	N
Acute respiratory infections	1818	86.8%	276	13.2%	2094
Chronic respiratory diseases	1218	94.1%	76	5.9%	1294
Acute abdominal conditions	862	81.1%	201	18.9%	1063
Febrile conditions	237	28.8%	587	71.2%	824
Injuries	602	100.0%		0.0%	602
Conditions specific to the neonatal period[1]	163	51.6%	153	48.4%	316
Chronic abdominal conditions	20	8.0%	229	92.0%	249
General problems[2]	141	56.6%	108	43.4%	249
Neoplasms	136	100.0%		0.0%	136
Neurological manifestations	83	75.5%	27	24.5%	110
Miscellaneous causes[3]	18	18.8%	78	81.3%	96
Maternal problems	42	72.4%	16	27.6%	58
Cardiovascular diseases	22	55.0%	18	45.0%	40
Other and unknown[4]			1124	100.0%	1124
Total	5362	65.0%	2893	35.0%	8255

[1] Stillbirths excluded
[2] Anaemia, jaundice, malnutrition, oedema
[3] Urogenital, eye, other head and neck, congenital after the first month of life, other specified conditions
[4] Senility, sudden death, unknown

Distribution of deaths by symptom group

Table 4, also based on the *Classification of symptom complexes for lay reporting in Papua New Guinea* (Riley 1979/1989), shows the distribution of deaths by site. Because the series is dominated by Tari deaths, we have shown the percentages by symptom group both for the series as a whole and as the average percentage of deaths across the four sites. Thus, febrile conditions were responsible for 10.0% of deaths in the series as a whole but, on average, 13.3% of deaths across sites because of the greater frequency of these conditions in lowland areas. On the other hand, acute respiratory infections were more frequent in the highlands (25.4% of deaths overall, 20.3%% on average) while chronic respiratory deaths were relatively evenly distributed across the sites. Injuries were more common in the highlands (7.3% overall and 6.2% on average).

Table 4 Causes of death categorised by symptom group by site

Symptom complexes	Tari		Asaro		Madang		Wosera		Total		Average % across sites
	1970–1995		1979–1989		1982–1982		1996–2001		1970–2001		
	n	%	n	%	n	%	n	%	n	%	
Acute respiratory infections	1778	26.8	190	24.5	70	17.2	56	12.7	2094	25.4	20.3
Chronic respiratory diseases	1034	15.6	110	14.2	77	18.9	73	16.5	1294	15.7	16.3
Acute abdominal conditions	908	13.7	91	11.8	35	8.6	29	6.6	1063	12.9	10.2
Febrile conditions	600	9.0	81	10.5	73	17.9	70	15.8	824	10.0	13.3
Injuries	503	7.6	58	7.5	23	5.7	18	4.1	602	7.3	6.2
Conditions specific to the neonatal period[1]	213	3.2	36	4.7	27	6.6	40	9.0	316	3.8	5.9
Chronic abdominal conditions	189	2.8	39	5.0	0	0	21	4.8	249	3.0	3.2
General problems[2]	186	2.8	26	3.4	4	1.0	33	7.5	249	3.0	3.7
Neoplasms	60	0.9	34	4.4	26	6.4	16	3.6	136	1.6	3.8
Neurological manifestations	85	1.3	11	1.4	2	0.5	12	2.7	110	1.3	1.5
Miscellaneous causes[3]	73	1.1	13	1.7	5	1.2	5	1.1	96	1.2	1.3
Maternal deaths	38	0.6	6	0.8	6	1.5	8	1.8	58	0.7	1.2
Cardiovascular diseases	29	0.4	6	0.8	5	1.2	0	0	40	0.5	0.6
Other and unknown[4]	936	14.1	73	9.4	54	13.3	61	13.8	1124	13.6	12.7
Total	**6632**	**100**	**774**	**100**	**407**	**100**	**442**	**100**	**8255**	**100**	**100**

[1] Stillbirths not included (Tari = 177, Asaro = 38, Wosera =19)
[2] Anaemia, jaundice, malnutrition, oedema
[3] Urogenital, eye, other head and neck, congenital after the first month of life, other specified conditions
[4] Senility, sudden death, unknown

Deaths are evenly distributed between the sexes overall: 49.0% females, 51.0% males (Table 5). There are more deaths among males than females for cardiovascular diseases (62.9%), injuries (59.2%), neurological manifestations (59.3%) and miscellaneous causes (57.1%) and more deaths among females than males for general problems (55.5%).

Table 5 Cause of death categorised as symptom groups by sex (Madang not included)

	Females		Males		Total
	n	%	n	%	n
Acute respiratory infections	1065	52.6	959	47.4	2024
Chronic respiratory diseases	583	47.9	634	52.1	1217
Acute abdominal conditions	452	44.0	576	56.0	1028
Febrile conditions	380	50.6	371	49.4	751
Injuries	236	40.8	343	59.2	579
Conditions specific to the neonatal period[1]	142	50.7	138	49.3	280
Chronic abdominal conditions	116	46.6	133	53.4	249
General problems[2]	136	55.5	109	44.5	245
Neoplasms	48	43.6	62	56.4	110
Neurological manifestations	44	40.7	64	59.3	108
Miscellaneous causes[3]	39	42.9	52	57.1	91
Maternal problems	52	100.0	0	0.0	52
Cardiovascular diseases	13	37.1	22	62.9	35
Other and unknown[4]	539	50.4	531	49.6	1070
Total	**3845**	**49.0**	**3994**	**51.0**	**7839**

[1] Stillbirths and neonates of unknown sex not included (9)
[2] Anaemia, jaundice, malnutrition, oedema
[3] Urogenital, eye, other head and neck, congenital after the first month of life, other specified conditions
[4] Senility, sudden death, unknown

Table 6 shows deaths in four age groups. The leading CODs in infants and children aged from one month to 12 years were acute respiratory infections (41.4%) and acute abdominal conditions (23.8%); in adults aged 13–39 years, leading CODs were injuries (30.3%), febrile conditions (11.1%) and acute respiratory infections (10.7%); and in adults 40 years of age and older, leading CODs were chronic respiratory diseases (26.8%) and acute respiratory infections (21.3%).

Table 6 Cause of death categorised by symptom group by age group

	Neonates		Children one month to 12 years		13–39 years		≥40 years		Total
	n	%	n	%	n	%	n	%	n
Acute respiratory infections	85	11.7	943	41.4	104	10.7	962	21.3	2094
Chronic respiratory diseases	0	0	24	1.1	60	6.2	1210	26.8	1294
Acute abdominal conditions	11	1.5	542	23.8	94	9.7	416	9.2	1063
Febrile conditions	25	3.5	376	16.5	108	11.1	315	7	824
Injuries	13	1.8	105	4.6	294	30.3	190	4.2	602
Conditions specific to the neonatal period[1]	550	76	0	0	0	0	0	0	550
Chronic abdominal conditions	2	0.3	10	0.4	43	4.4	194	4.3	249
General problems[2]	4	0.6	118	5.2	20	2.1	107	2.4	249
Neoplasms	0	0	5	0.2	44	4.5	87	1.9	136
Neurological manifestations	3	0.4	20	0.9	32	3.3	55	1.2	110
Miscellaneous causes[3]	1	0.1	32	1.4	23	2.4	40	0.9	96
Maternal problems	0	0	0	0	45	4.6	13	0.3	58
Cardiovascular diseases	1	0.1	12	0.5	11	1.1	16	0.4	40
Other and unknown[4]	29	4	89	3.9	92	9.5	914	20.2	1124
Total	**724**	**100**	**2276**	**99.9**	**970**	**99.9**	**4519**	**100.1**	**8489**

[1] Stillbirths included

[2] Anaemia, jaundice, malnutrition, oedema

[3] Urogenital, eye, other head and neck, congenital after the first month of life, other specified conditions

[4] Senility, sudden death, unknown

Specific diseases as causes of death

Table 7 shows leading CODs by field site as specific diseases. The list has been structured to be as consistent as possible with Department of Health reports for health facilities (see Table 13). It includes also a symptom-based category “Other fevers” (see below).

Table 7 Leading causes of death by site

Causes of death	Tari		Asaro		Madang		Wosera		Total		Average % across sites
	1970–1995		1979–1989		1982–1984		1996–2001		1970–2001		
	n	%	n	%	N	%	N	%	n	%	
Pneumonia	1533	22.0	158	20.0	67	16.5	43	9.5	1801	21.8	17.0
Chronic lung disease	909	13.7	77	9.9	72	17.7	59	13.3	1117	13.5	13.7
Diarrhoea/dysentery	581	8.6	59	7.6	24	5.7	23	5.2	687	8.3	6.8
Other fevers	445	5.4	46	7.9	47	10.1	65	12.2	603	7.3	8.9
Injury	503	7.4	58	7.5	23	4.9	18	3.8	602	7.3	5.9
Other respiratory diseases	296	4.6	36	5.9	0	0.0	17	3.8	349	4.2	3.6
Neonatal[1,2]	213	5.6	36	5.4	27	6.6	40	11.3	316	3.8	7.2
Cancer	60	0.9	34	4.4	26	6.4	16	3.6	136	1.6	3.8

Measles	90	1.4	26	3.4	7	1.7	0	0.0	123	1.5	1.6
Pigbel	114	1.7	6	0.8	0	0.2	0	0.0	120	1.5	0.7
Malnutrition	81	1.2	16	2.1	1	0.2	12	2.7	110	1.3	1.6
Tuberculosis	44	0.7	16	2.1	5	1.2	10	2.3	75	0.9	1.6
Meningitis	42	0.6	3	0.4	12	2.9	1	0.2	58	0.7	1.0
Maternal causes	38	0.6	6	0.8	6	1.5	8	1.8	58	0.7	1.2
Malaria	23	0.3	6	0.8	7	1.7	4	0.7	40	0.5	0.9
Heart disease	29	0.4	6	0.8	5	1.2	0	0.0	40	0.5	0.6
Anaemia	24	0.3	1	0.1	3	0.5	3	0.7	31	0.4	0.4
Pertussis	11	0.2	3	0.4	3	0.7	0	0.0	17	0.2	0.3
Other and unknown	1596	24.3	181	19.8	72	20.1	123	28.7	1972	23.9	23.2
Total	**6632**	100.0	**774**	100	**407**	100.0	**442**	100.0	**8255**	100.0	100.0

[1] Neonatal here refers to infants aged 0–28 days
[2] Stillbirths not included

Respiratory diseases

Respiratory diseases dominate the COD pattern. We defined acute respiratory conditions as cases with respiratory symptoms of less than four weeks duration, and chronic respiratory diseases as having a duration of four weeks or more.

Table 4 showed that acute respiratory infections were responsible for 25.4% of all deaths and chronic respiratory diseases for 15.7%. We defined adult pneumonia in terms of cough, breathlessness, fever and pleuritic chest pain that interfered with breathing; and child pneumonia in terms of cough and breathing difficulty. We assigned 86.0% of acute respiratory conditions to pneumonia, and 0.8% to pertussis; only 13.7% were classified as symptomatic.

We divided chronic respiratory diseases into those with a history of 1–5 months cough and breathlessness, and those with a history of ≥ 6 months cough and breathlessness. Those with specific symptoms of loss of weight, recurrent fever, blood in the sputum, or a family history of tuberculosis were classified as tuberculosis; those with a history of 1–5 months cough and breathlessness but without the specific symptoms were classified as suspect tuberculosis. Chronic (non-tuberculous) lung disease (CLD), a PNG variant of chronic obstructive pulmonary disease (COPD), was defined in terms of cough, nearly always productive, and breathlessness of ≥ 6 months. We assigned 86.3% of chronic respiratory deaths to CLD, 5.8% to tuberculosis as defined above, and 2.0% to asthma; 5.9% were classified as symptomatic.

Febrile conditions

The category of febrile conditions, which includes many different infections, constituted 10.0% of all deaths and was characterised by a high percentage of symptom diagnoses. Proportionally, febrile conditions were twice as common in Wosera and Madang, the two lowland sites, as they were in Tari and Asaro, the two highlands sites (Table 8). Non-specific fevers were responsible for 60.2% of cases and fever with coma for a further 11.0%; the remainder comprised measles (14.9%), meningitis (7.0%), malaria (4.9%), skin infections (1.5%) and typhoid (0.5%). The category "Other fevers" in Tables 7 and 8 includes non-specific fevers, fever with coma, and fever with skin infection.

Malaria is notoriously difficult to analyse in field studies. In Table 8, we show malaria deaths and deaths from "Other fevers" as a percentage of deaths from all causes by age group in the highlands and the lowlands sites. We have excluded neonates, who are unlikely to suffer from malaria, from the table. The percentage difference between highlands and lowlands from febrile conditions in all ages ≥ 29 days is due to large differences in child but not adult deaths.

Table 8 Percentage of deaths with fever (excluding measles) or malaria as underlying cause of febrile condition by age in highlands and lowlands field sites

	29 days – 9 years			≥ 10 years			All ages ≥ 29 days		
	Other fevers	Malaria	Total	Other fevers	Malaria	Total	Other fevers	Malaria	Total
Highlands	7.9%	0.5%	8.4%	7.1%	0.4%	7.5%	7.5%	0.4%	7.9%
Lowlands	26.2%	4.5%	30.7%	8.2%	0.2%	6.2%	14.1%	1.3%	15.4%

Figure 3 shows the annual percentage of all deaths due to measles in children aged 29 days to 9 years in the highlands sites of Tari and Asaro. It shows an epidemic of measles in Asaro which occurred in 1982 as well as a major epidemic that lasted from 1985 to 1989. It also shows a series of epidemic peaks in Tari: in 1980, 1982, 1984, 1987 and 1990. The 1982 and 1985–1989 epidemics appear to have coincided in the two sites, suggesting that they were highlands wide. Proportional mortality from measles was higher in Asaro and was responsible for over 30% of deaths in this age group in 1987.

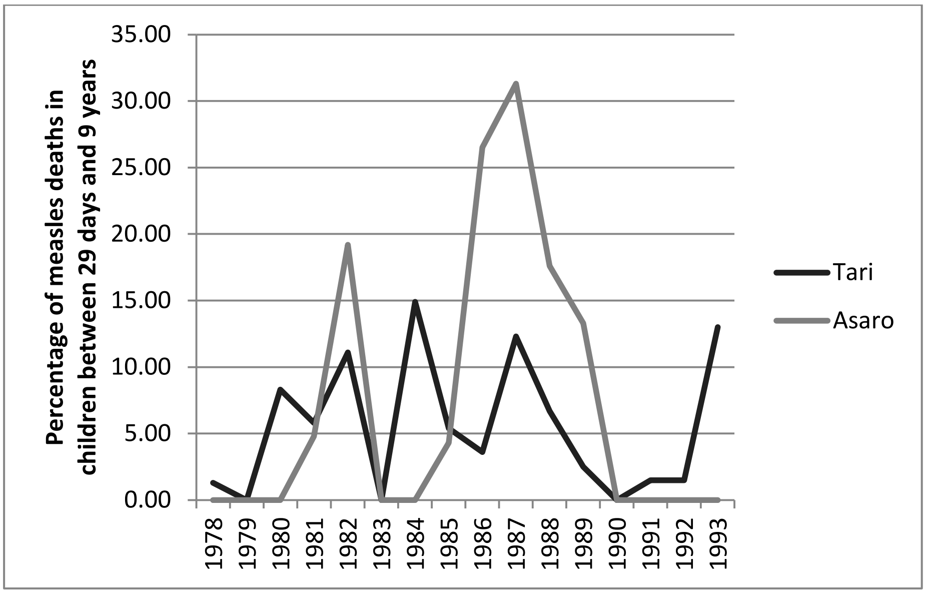


Figure 3 Percentage of all deaths in children aged 29 days to 9 years due to measles in Tari and Asaro by year

Acute abdominal conditions

This group is divided into infectious and non-infectious causes: diarrhoeal diseases (diarrhoea and dysentery) accounted for 64.6% of these deaths and pigbel (*enteritis necroticans*) for a further 11.3%. Pigbel was defined in terms of bloody diarrhoea, severe abdominal pain, the vomiting of foul material, abdominal distension and a history of eating pig, other animal protein or nuts. Figure 4 shows the percentage of all deaths caused by pigbel and from diarrhoeal diseases in Tari and Asaro between 1970 and 1995. Both conditions declined as a percentage of all deaths over the period of study. The remaining 23.9% of acute abdominal deaths were non-infectious; they included abdominal pain with or without swelling (8.1% of all acute abdominal deaths), haematemesis and melaena (5.2%) and other undefined conditions (10.8%).

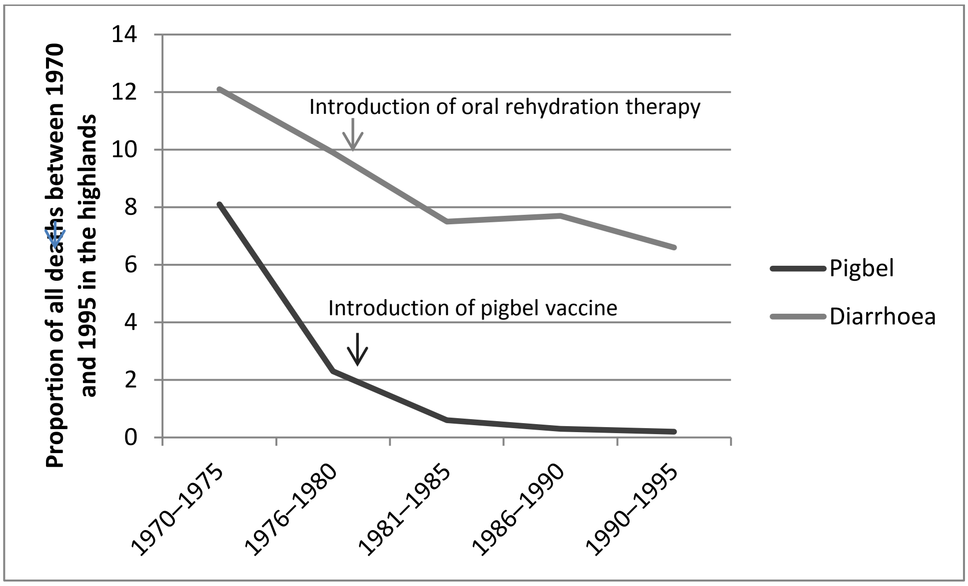


Figure 4 Diarrhoeal diseases and pigbel as a percentages of all deaths in Tari and Asaro 1970–1995

Newborn conditions

We have defined neonatal deaths as all deaths occurring from 0 to 28 days; this relates directly to the causes of neonatal mortality (deaths in the first month of life). In the tables, we have included a symptom group *Conditions specific to the neonatal period*; this corresponds to ICD10 Chapter XVI *Certain conditions originating in the perinatal period*. Perinatal mortality includes both stillbirths and deaths in the first week of life; these are regarded as having a common set of causes relating to congenital conditions and to complications of pregnancy and child birth. We have defined deaths in the neonatal period from causes such as pneumonia as *Conditions not specific to the first month of life*.

Neonatal deaths constituted 5.9% of all deaths (excluding stillbirths); perinatal deaths constituted 6.8% of all deaths (including stillbirths).

Table 9 shows that death occurred in the early neonatal period (0–7 days) in 69.8% of neonatal deaths and in the late neonatal period in 30.2%. Conditions specific to the neonatal period accounted for 64.5% of neonatal and conditions not specific to this period for 35.5%. Specific conditions included low birth weight (22.4% of neonatal deaths), birth injury (4.1%), congenital conditions (3.9%) and a large group of miscellaneous conditions (34.1%). Pneumonia, meningitis, and sepsis accounted for 23.7% of neonatal deaths and a group of miscellaneous causes not specific to the neonatal period for 11.8%.

Neonatal tetanus was responsible for three deaths. Thirteen deaths were ascribed to injuries: falls (2), drowning (1), accident (5), intentional (5); they represent 2.8% of neonatal deaths and were distributed between early and late neonatal periods proportionally to other causes of death. Stillbirths are not included in Table 9.

Table 9 Leading causes of death for early and late neonatal deaths

	0–7 days		8–28 days		Total	
	n	%	n	%	n	%
Low birth weight	98	28.7	12	8.1	110	22.4
Birth injury	20	5.8	0	0.0	20	4.1
Congenital abnormalities	14	4.1	5	3.4	19	3.9
Other causes specific to the neonatal period	139	40.6	28	18.9	167	34.1
Infections : Pneumonia/meningitis/sepsis	37	10.8	79	53.4	116	23.7
Other causes not specific to neonatal period	34	9.9	24	16.2	58	11.8
Total	**342**	**100.0**	**148**	**100.0**	**490**	100.0

Stillbirths not included

External causes of injury

The pattern of death from injury varied between highlands and lowlands. Injuries were responsible for 7.4% of all deaths in the two highlands sites of Tari and Asaro and 4.4% in the two lowlands sites of Wosera and Madang (Table 7). Table 10 shows that the difference is due to high proportionate mortality from intentional causes (suicide, homicide and other forms of violence) in the highlands (4.0% of all deaths) and much lower mortality from these causes on the coast (0.9% of all deaths).

Table 10 External causes of death from injury by field site

	Tari		Asaro		Madang		Wosera		Total	
	n	%	n	%	n	%	n	%	n	%
Road traffic accidents	40	8.0	11	19.0	7	35.0	0	0.0	58	9.6
Poison	20	4.0	3	5.2	0	0.0	4	22.2	27	4.5
Falls	20	4.0	5	8.6	0	0.0	5	27.8	30	5.0
Fires	46	9.1	5	8.6	0	0.0	1	5.6	52	8.6
Drowning	63	12.5	5	8.6	0	0.0	1	5.6	69	11.5
Other accidents	45	8.9	3	5.2	13	56.5	2	11.1	63	10.5
Suicide	76	15.1	3	5.2	3	15.0	0	0.0	82	13.6
Homicide	181	36.0	22	37.9	0	0.0	4	22.2	207	34.4
Other violence	12	2.4	1	1.7	0	0.0	1	5.6	14	2.3
Total	**503**	100.0	**58**	100.0	**23**	100.0	**18**	100.0	**602**	100.0

Table 11 and Figure 5, which exclude Madang, shows numbers of deaths from accidental and intentional injury from 0 years, 1–4 years and then by 10-year age groups. The frequency of death from accidental injury is highest in children aged from one to 14 years; it declines slowly through the 55–64 year age group and then falls sharply. The frequency of intentional injury rises steeply to a peak in the 25–34 year age group and then declines.

The frequency of different CODs from accidental injury also varies by age. Drowning and poisoning were commonest in persons 1–24 years of age. Road traffic accident deaths were commonest in persons 25–44 years of age. Death from fire was commonest in persons 55–64 years and falls in persons 65–74 years (Table 11).

Road traffic accidents were not particularly prominent (9.7% of all injury deaths), although the percentage of all deaths caused by road accidents increases between 1970 and 1995 in the highlands (Figure 6).

Homicides were responsible for 34.4% of all injury deaths and suicide for 13.6% (Table 10); Homicide was the leading COD from injury in persons aged 15–64. Figure 7 illustrates trends in deaths from intentional injury for males and females in the highland sites of Tari and Asaro. Homicides were the leading COD from injury in males, and suicides were the leading COD from injury in females. Homicides in males rose sharply from the 1976–1980 period through to the 1991–1995 period; the trend in females was similar but less marked. Deaths from suicides in females fell in the period 1970–1975 but rose parallel to deaths from homicide in the period 1981–1985. It is notable that overall mortality from intentional injury was higher in females than in males for most of the period under study.

Table 11 External causes of death from injury by age group excluding Madang

	Age groups										
	0	**1–4**	**5–14**	**15–24**	**25–34**	**35–44**	**45–54**	**55–64**	**65–74**	**75+**	**Total**
Transport	2	2	2	6	23	10	3	3	0	0	51
Poison	0	7	9	4	2	2	2	1	0	0	27
Falls	3	3	1	3	1	3	4	4	8	0	30
Fire	3	4	9	2	3	2	5	16	7	1	52
Drowning	2	20	16	11	7	4	4	4	1	0	69
Other accidents	8	7	8	5	4	6	5	4	3	0	50
Suicide	0	0	3	29	20	14	9	3	1	0	79
Homicide	6	5	8	32	52	39	39	20	6	0	207
Other violence	2	3	1	2	1	0	0	2	3	0	14
All injuries	26	51	57	94	113	80	71	57	29	1	579
As a percentage of all deaths in this age group	1.5%	5.7%	16.7%	37.5%	35.4%	15.6%	6.3%	3.3%	3.4%	0.4%	7.2%

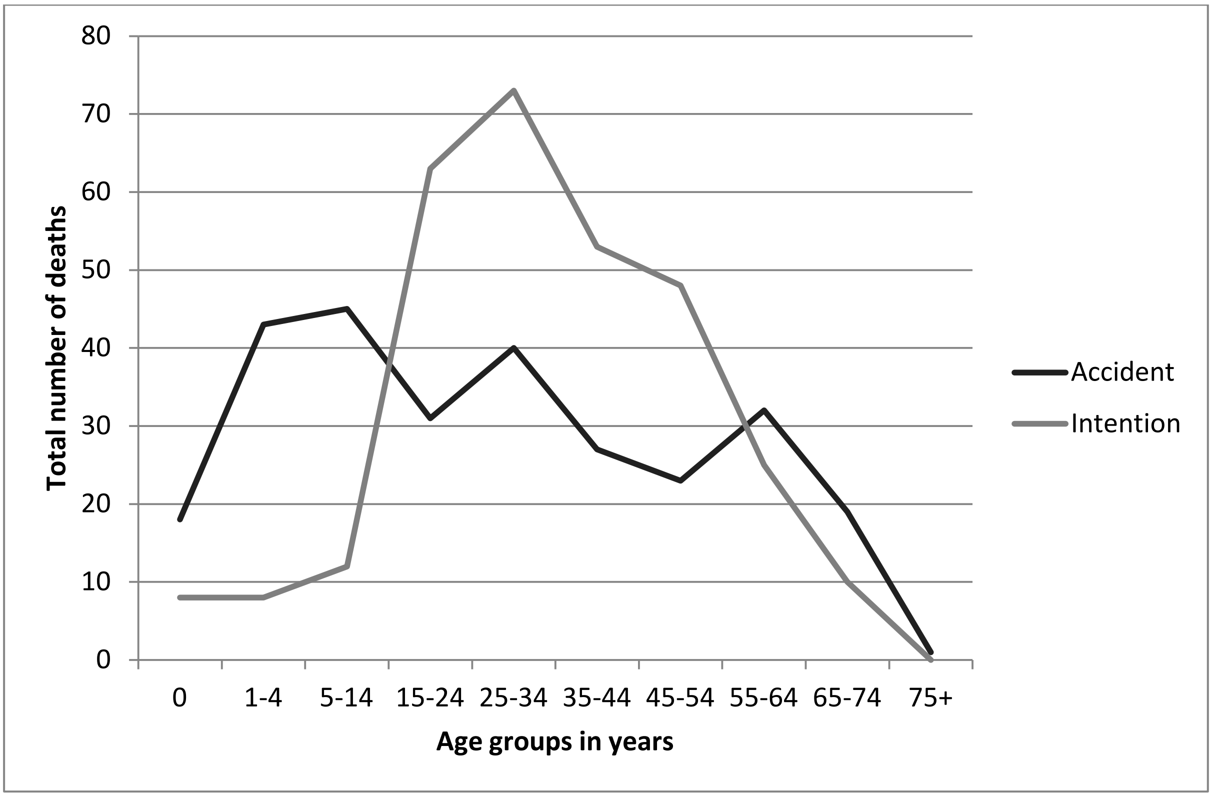


Figure 5 Numbers of deaths from accidental and intentional injury by age group

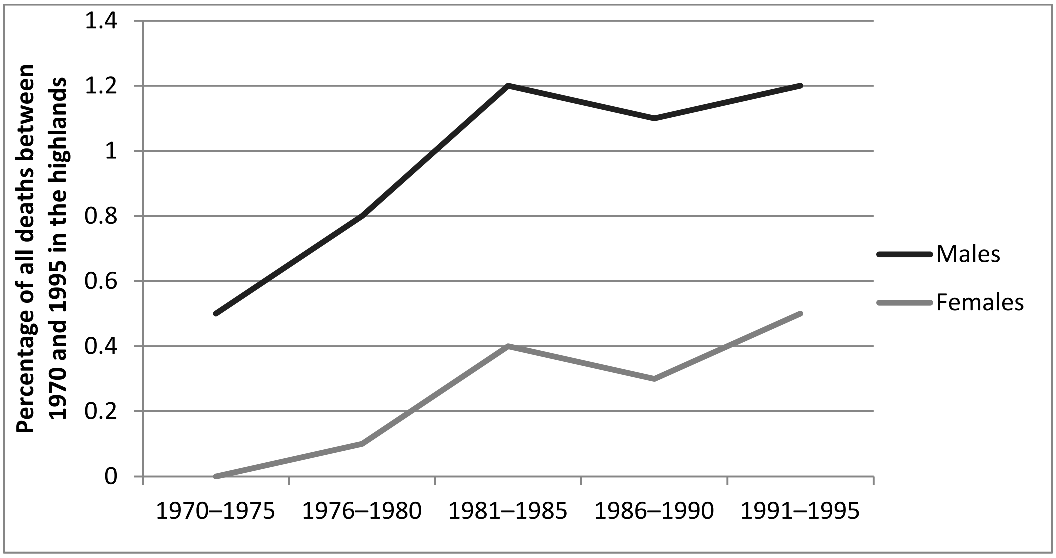


Figure 6 Road traffic accident as a percentage of all deaths from unintentional injuries in Tari and Asaro 1970–1995 by sex

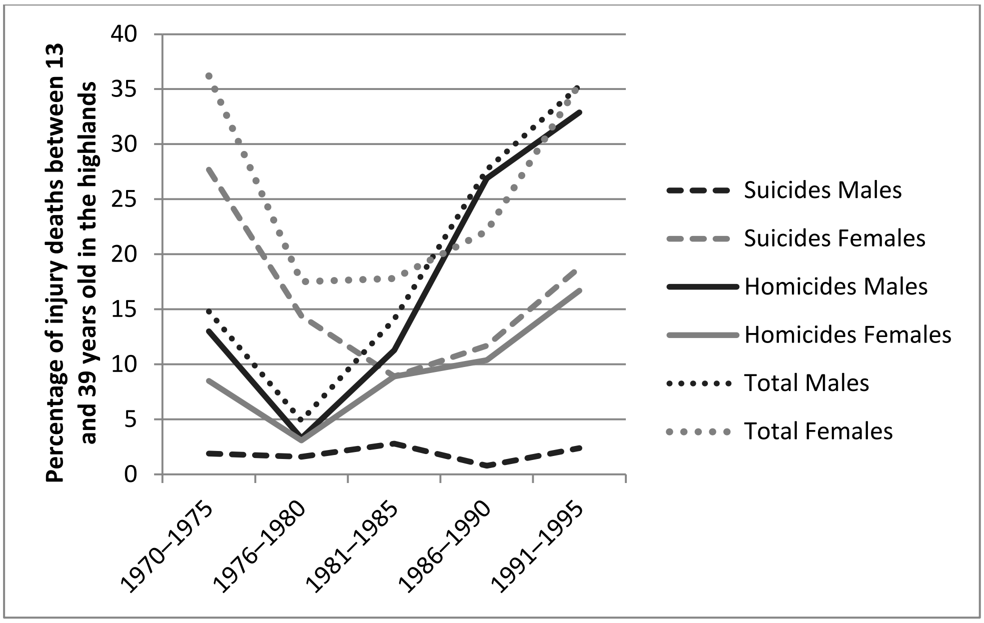


Figure 7 Deaths from homicide and suicide as a percentage of all injury deaths in persons aged from 13 to 39 years in Tari and Asaro by sex

General problems

Malnutrition, including kwashiorkor, was responsible for 44.2% of deaths in this group. Oedema was associated with a further 33.3% of deaths, with 60.2% of these being in females. Pallor (anaemia) was associated with 12.4% of deaths and jaundice with 10.0%.

Chronic abdominal conditions

Chronic abdominal swelling was associated with 53.8% of these deaths and chronic pain with swelling with a further 9.6%. Cirrhosis was diagnosed in 8.0% of chronic abdominal deaths. The remainder (28.5%) were not further classified.

Neoplasms

Cancers were reported more commonly in males (56.4%) than in females (43.6%). Leading sites in men were liver (hepatoma) (20.9%) and head and neck, which were principally oral (19.4%). Leading sites in women were the genitalia (33.3%), breasts (16.7%), head and neck (10.4%) and liver (10.4%).

Neurological manifestations

Neurological manifestations of disease causing death were epilepsy (29.1%), coma (18.2%), psychosis (16.4%), paraplegia (13.6%), hemiplegia (9.1%), tetanus (7.3%) and other paralyses (6.4%).

Maternal deaths

There were 58 maternal deaths in the series, accounting for 0.7% of all deaths: 10.3% occurred during pregnancy, 37.9% during labour, 17.2% during the puerperium and 6.9% were due to abortion. The remainder (27.6%) were not assigned to any particular stage of pregnancy.

Miscellaneous causes

Leading causes in this group of 91 deaths were urogenital conditions (40.7%), other conditions affecting head and neck (20.9%), congenital conditions outside the neonatal period (17.6%), and conditions affecting the eye (7.7%). The group included two deaths from diabetes (classified as urogenital symptomatically).

Cardiovascular diseases

Congenital heart disease was responsible for 45.0% of deaths in this small group of 40 deaths. Ischaemic heart disease accounted for only four deaths (10.0%).

Other and unknown conditions

These included sudden deaths (7.2%) and unknown causes (89.9%).

Levels of mortality

Table 12 shows published vital rates for Tari, Asaro, Madang and Wosera for relevant periods. The rate of natural increase was the same in the two highlands populations of Tari and Asaro (2.2%) and a little higher in Madang (2.8%). The infant mortality rate ranged from 121/1000 live births (LB) in Wosera to 45.9/1000 LB in Madang. The under-five mortality rate (U5MR) decreased by almost one-third in Tari from 125/1000 LB in 1979 to about 81/1000 LB in 1993. Maternal mortality was less in Tari (2.8/1000 LB) and Asaro (3.0/1000 LB) than in Madang (4.1/1000 LB).

Table 12 Published vital rates from surveillance sites in Tari, Asaro, Madang and Wosera

	Tari[1]	Asaro[2]	Madang[3]	Wosera[4]
	1979–1993	1980–1989	1982–1983	1991–1994
Crude birth rate(/1000 population)	35.2	31.9	36.7	
Crude death rate (/1000 population)	12.8	10.1	8.7	14.3
Stillbirth rate (/1000 livebirths)	14.1	18.8		
Infant mortality rate (/1000 livebirths)	77.5	59.7	45.9	121
Neonatal mortality rate (/1000 livebirths)	20.7	21.3	22.0	
Under-five mortality rate (/1000 livebirths)	104.7	91.2		
Maternal mortality rate (/1000 livebirths)	2.8	3	4.1	
Rate of natural increase (%)	2.2	2.2	2.8	

[1] Calculated as an average of rates for three-year periods from 1979 to 1993 (Lehmann et al. 1997)
[2] Coakley et al. (1993) and Kakazo et al. (1999)
[3] Moir et al. (1989)
[4] Genton et al. (1995a, 1995b)

Discussion

In this section, we first discuss the distribution of deaths by cause in relationship to the extensive published literature on the diseases of PNG. We attempt to assess the accuracy and the utility of the instrument and ask how representative the data from these small population studies are in relationship to mortality patterns in PNG generally.

Disease patterns and trends in PNG

Respiratory diseases

The outstanding characteristic of the cause structure of mortality in PNG is the high percentage of deaths due to respiratory diseases. As long ago as the 1880s, successive administrations expressed concern about high mortality from pneumonia (Spencer 1999). Population-based surveys in five different provinces in the 1960s all showed pneumonia to be the leading COD (Riley 2010). A high incidence of pneumonia in adults was initially associated with migration from semi-isolated communities and subsequent contact with new and virulent serotypes of pneumococcus. High incidence in infancy is associated with unusually early acquisition of bacterial pathogens within days of birth when the immune system is immature (Gratten et al. 1986); malnutrition, poor standards of personal hygiene and high levels of domestic smoke pollution are also contributing factors (Riley 2010).

CLD was the leading COD in adults over the age of 40 (23.6%) in these series. Its high prevalence in PNG rural communities was investigated independently by Woolcock and by Anderson in the 1960s and 1970s (Anderson & Woolcock 1992). It is characterised by chronic productive cough and chronic airflow limitation (CAL) and is associated with marked reduction in vital capacity associated with pulmonary fibrosis and dense pleural adhesions. Cor pulmonale is a common complication seen in hospital practice. CLD differs from chronic obstructive pulmonary disease (COPD) as commonly described, because of the extent of pulmonary fibrosis in CLD and the lack of a demonstrated aetiological association between CLD and tobacco smoke. Prevalence in the 1960s and 1970s was similar in the highlands and in lowlands areas, which led to doubts about the importance of domestic wood smoke pollution as an aetiological factor. It has also been suggested that the high prevalence of acute lower respiratory infections (ALRI) in infancy may predispose to CAL in later life. It appears to be inevitable that as commercial tobaccos replace native, home-cured tobaccos, the western form of the disease will be superimposed upon the older form. Surveys in Tari in 1971 and again in 1973/74 showed a prevalence of 22.5% of CLD in persons 50 years and older, with little difference in prevalence between the sexes; diagnosis was based on the presence of loose cough and a peak expiratory flow rate less than 80% of the predicted value (Riley 1979).

Little or no asthma was seen in clinical practice or in respiratory surveys in PNG until the early 1970s, when the disease was described in high prevalence (7.3%) in the South Fore population of the Eastern Highlands; surveys in 1982 and 1983 showed a prevalence of only 0.2% in the Asaro Valley (Anderson & Woolcock 1992). Asthma accounted, on average, for only 0.3% of all deaths in these VA series.

Tuberculosis was introduced into PNG in the late nineteenth century. It spread from urban areas and coastal mission stations, and did not reach the highlands until the early 1950s (Wigley 1975). Tuberculosis accounted, on average, for only 0.9% of all deaths in these VA series. If we argued that tuberculosis was under-diagnosed in these series because i) many cases would have had a cough that lasted 6 months or greater; ii) the natural history of the disease is that mortality is highest in young adults; and iii) 91 deaths classified as CLD in persons aged 15–44 years should be reclassified as tuberculosis, the effect would be to more than double the total number of deaths in these series from 75 to 166, and hence give an estimate of 2.0% of all deaths being due to tuberculosis. We would regard this as an upper limit although it should be borne in mind that the series is heavily weighted by low prevalence areas for tuberculosis.

Febrile conditions

In a review of Goroka Hospital records, Mgone et al. (2000) describe measles outbreaks in the Eastern Highlands in 1982, 1986 and 1988–1989. Their data conform broadly with the population data shown in Figure 3 although the duration of the epidemic in the Asaro population from 1985 to 1989 appears to have been longer than the hospital data suggest. This was part of a larger pattern of measles outbreaks occurring every three to four years in the Eastern Highlands between 1980 and 2000. Measles immunisation was introduced to PNG in 1982.

Malaria transmission is stable in Madang and Wosera and unstable in Tari and Asaro. In areas of stable transmission, it is expected that malaria deaths will either be in children < 10 years of age or in pregnant women. In unstable areas, death can occur at any age.

In Madang, Moir et al. (1989) attributed 5.4% of all deaths in children under age 10 to malaria, with a possible range of 4–17% in children under 10. The lower end of the range reflected levels of proven parasitaemia and the upper end reflected the total number of deaths from febrile conditions. Based on clinical studies, Genton et al. (1995b), working in Wosera, attributed death to malaria when a history was obtained of an illness of sudden onset, characterised by high fever without gastro-intestinal or respiratory symptoms. They reached a very similar conclusion and attributed 4.9% of deaths to malaria, with a range of 4.9–16.3% once clinical data were taken into account.

Lehmann et al. (1997) showed that at lower altitudes in Tari, febrile conditions were proportionally 1.5 times more frequent as a COD than at higher altitude areas of the study site and attributed the difference to malaria. We show in Table 8 that confirmed malaria was nine times more frequent in children in the two lowlands sites than in the highlands (which could be a consequence of the focus on the diagnosis of malaria of the two lowlands studies). However, a higher percentage of all deaths in children were from “Other fevers” in the lowlands (26.2%) than was the case in the highlands (7.9%). On average, there were 22.3% more deaths in children from all fevers including malaria on the coast than was the case in the highlands.

Taking the published work and the results in Table 8 into account, it seems reasonable to assume that 20% of deaths in children aged from 29 days to 10 years in the lowlands sites were from malaria. This would imply that 5.3% of all deaths in all age groups on the two lowlands sites were from malaria. An estimated upper limit of malaria mortality in the lowlands from malaria can be obtained by subtracting all febrile deaths in the highlands from all febrile deaths in the lowlands: 7.5%. It is not possible to make similar adjustments to the highlands data, so we are left with an estimate of 0.4% of all deaths in the highlands being due to malaria.

In a clinical series in Madang, 30% of children who died from malaria suffered respiratory distress caused either by metabolic acidosis or by pneumonia (Allen et al. 1996). Attribution of such deaths to ALRI would lead to further underestimation of mortality from malaria.

The clinician confronted by a febrile, comatose patient in PNG needs to consider diagnoses of malaria, bacterial meningitis, typhoid fever and viral encephalitis and must, at the very least, be able to examine cerebro-spinal fluid for pus cells and a blood slide for malaria parasites to make a preliminary differentiation. Only 91 deaths (1.1%) in the VA series were identified as being associated with fever and coma. This allows very few deaths to be distributed among these four diseases and, in contradistinction to hospital practice, gives no indication of the importance of non-malarial causes of fever with coma at the population level.

Passey (1995) described the re-emergence of typhoid fever in PNG after it having been absent from the record for many decades. The first indication was an outbreak reported in 1977 in a high school near Goroka. Although disease appeared with increasing frequency in hospital practice in Goroka and Port Moresby in the early 1980s, antibody levels were low in highlands communities as late as 1987; by 1992, there was evidence of increased transmission that was person-to-person and not waterborne. Richens (1995) developed clinical criteria for health centres based on a duration of fever greater than two weeks, alteration of bowel habit, an altered state of consciousness, and the absence of the pallor or jaundice that is typical of malaria. It was not possible to incorporate these criteria into diagnostic algorithms for VAs. The VA series identified only seven deaths from typhoid (1% of all deaths from febrile conditions).

Acute abdominal conditions

The disease pigbel is a consequence of a patchy necrosis of small intestine caused by the production of the β toxin of *Clostridium perfringens* type C growing in the gut lumen (Lawrence 1992). Growth follows a high protein meal. Digestive enzymes normally inactivate the β toxin, but a trypsin inhibitor in sweet potato, the dietary staple, renders individuals susceptible. Low protein diets also lower trypsin levels. Natural antibody to the toxin increases with age. High levels of environmental contamination with the organism are found in endemic areas. Immunisation with β toxoid is effective and has been included in immunisation programs in the highlands since 1980. In these VA series pigbel was common in Tari, where it was responsible for 7.3% of deaths in children aged 1–4 years, 11.3% of deaths in children aged 5–9 years and 6.5% of deaths in persons aged 10–19 years. In these series, 99 of the 120 cases identified (82.5%) were during the first ten years of the study, from 1970 to 1980, which supports evidence based on hospital admissions that the immunisation program was indeed effective (Lawrence et al. 1990). Reasons for clustering of pigbel cases in time and place are not fully understood (Duke et al. 2002). Following withdrawal of the vaccine from production in 1995, the disease persisted in some areas of the highlands but did not reappear in others where it had been endemic. Figure 4 does suggest that although the introduction of the vaccine to Asaro and Tari in 1980/81 almost certainly contributed to a decline in mortality from pigbel, it did not initiate the decline.

Newborn conditions

Duke et al. (2002) audited child deaths in the Goroka Hospital over a two-year period between 1998 and 2000: 126 of these deaths were in neonates. They did not restrict the analysis to UCOD but included the main conditions contributing to death. (This is consistent with the perinatal form of the international death certificate.) On average, each neonatal death was associated with 1.9 conditions. Leading causes were very low birth weight of < 1.8 kg (50.8%), septicaemia (42.9%), birth asphyxia (23.8%); congenital syphilis (13.5%), multiple congenital defects (8.7%), necrotising enterocolitis (7.9%) and congenital heart disease (7.1%). Village birth and low birth weight were predictors of death from gram negative sepsis. This is broadly comparable with the VA series, although congenital syphilis was not diagnosed at all and the disease classification had no category for birth asphyxia.

The number of deaths from injury was unexpected. At least five could be classified as infanticide, possibly of a second twin.

In a seminal article, Schofield et al. (1961) reported on the effectiveness of maternal immunisation on mortality from neonatal tetanus in the Maprik area including Wosera. VAs with stringent criteria indicated a mortality rate of 61/1000 LB. That we only identified three deaths from neonatal tetanus in the VA series as a whole is a tribute to the effectiveness of maternal immunisation and supervised delivery of infants.

Lehmann et al. (1997) estimated the neonatal mortality rate in Asaro to range from 5/1000 LB in Goroka town to 52/1000 LB in Asaro, more than one hour's drive from the hospital. The mean neonatal mortality rate in Tari was 21.8/1000 LB. These data emphasise the effect of maternal access to services, including supervised deliveries, upon neonatal mortality and the importance of categorising neonatal mortality in terms of access in population studies.

External causes of deaths from injury

High levels of intentional injury reported from Tari and Asaro, the two highlands sites, would appear to be an accurate reflection of mortality patterns in the highlands during the period of these studies. The background is of escalating warfare over land and resources between traditional enemies, which began in the years just before Independence in 1975 and has continued well beyond the end of the century. In 1979, the government declared the first in a series of states of emergency, in an attempt to deal with a deteriorating law and order situation in the five highlands provinces (May 2006). Firearms were introduced into warfare in Enga Province to the north of Tari in 1990, which resulted in total numbers of deaths much greater than those reported here (Wiessner & Pupu 2012). The situation in Tari was exacerbated by growing realisation of the resource wealth of the area. It was the deteriorating law and order situation that forced the closure of the research unit in 1995.

The pattern of injury in this study reflects that seen in Mendi, Southern Highlands Province in 1993. Injuries were the third leading cause for hospital admission, after antenatal cases and pneumonia. Domestic accidents (25%), tribal fights (25%) and assault (31%) were the commonest causes of injury; road traffic accidents accounted for only 14% of trauma admissions (Matthew et al. 1996). Such data reflect high rates of conflict and high levels of tolerance for violence, both between clans and within households generally in the PNG highlands (Kopi et al. 2010). In the national capital, Port Moresby, assault and road traffic accidents were leading causes for admission to the surgical wards (Watters et al. 1996). Watters and Dyke (1996) estimated the road toll at 250–300 deaths per year, with a rate of 71 deaths/10,000 registered vehicles, which was over 20 times higher than in New Zealand.

The importance of the VA study lies in its giving a clear indication of the distribution of deaths from injury by external causes in the general population. Interpretation needs to be tempered by an understanding of the likely variation of causes in different parts of the country. Intentional injuries were very much more frequent in the highlands than on the coast.

Neoplasms

The distribution of neoplasms in these series is broadly consistent with a report by Martin et al. (1992), which summarised cancer registrations from 1958 to 1988. The authors point out that the pattern of the more common malignant lesions is unique and not shared by any other developing country, even among the Pacific nations. The commonest cancers in men in order of frequency were oral cancer, non-melanotic skin cancer, hepatoma and non-Hodgkins lymphoma. The commonest cancers in women were cervix, breast, mouth and non-melanotic skin cancers. The non-melanotic skin cancers complicated chronic tropical ulcers and had their lowest incidence in the highlands region; they were declining in incidence generally.

The VA instrument did not detect cases of lymphoma. It should be noted that viruses cause both hepatoma and cervical cancer, the commonest site for female genital cancer, and both of these can be prevented with vaccines. Thomas and MacLennan (1992) demonstrated an association between the chewing of betel nut, tobacco smoke and the application of slaked lime to the mouth with oral cancer, the predominant form of head and neck cancer in PNG. Lung cancer was uncommon in the VA series and does not appear to be associated with smoking of home-cured tobacco in PNG (Crouch-Chivers 2010).

An emphasis on specificity of diagnosis led to neoplasms accounting for a low percentage of all deaths in Tari in particular (0.9%). Their frequency in the other sites ranged from 3.6% in Wosera to 6.4% in Madang (Table 4).

Chronic abdominal conditions

Interest in liver disease as a generic problem in PNG appears to have waned after the discovery of hepatitis B virus and demonstration of its association with cirrhosis and hepatoma (Nishioka et al. 1975). In the 1960s, cirrhosis—associated with massive ascites, with reversed albumin/globulin ratios and with generalised oedema but lacking other classical signs of hepatic failure—was a common problem in hospitalised adults in the highlands (Ian Riley, personal observation). Vines (1967, pp. 173–199), in his sample survey of morbidity in three regions of PNG, showed hepatomegaly to be widespread and reported prevalence associated with malaria in lowlands areas but with a prevalence of 10–20% in adults in the highlands that could not be explained by malaria.

Consumption of alcohol was not a factor. Vines (1967, p. 238) also demonstrated low levels of serum albumin in the general population (average 3.0 grams/100 ml in the highlands) and high levels of serum globulin (average 4.3 grams/100 ml). Blackburn and Ma (1972) reported the widespread occurrence of portal tract inflammation and fibrosis in apparently healthy persons but no evidence of progression to cirrhosis. Marsden and Connor (1968) reported an association between portal fibrosis, portal hypertension and splenomegaly in PNG. It has since been shown that sinusoidal portal hypertension is a necessary factor in the development of hepatic ascites (Morali et al. 1992; Ginés et al. 1997).

In these VA series, 1.7% of all deaths were associated with chronic abdominal swelling without associated pain and a further 1% with oedema (classified under the heading 'General problems'). A small percentage of deaths in this series were identified as being caused by cirrhosis (0.2%) or hepatoma (0.3%), with a further 0.3% being associated with jaundice. The aetiology of the first group of deaths associated with chronic abdominal swelling is obscure but is consistent with a high prevalence of hepatitis virus infections associated with low protein diets and possibly with aflatoxins. The second group is most probably caused by hepatitis B and other viruses, with an increasing contribution from alcohol. The total percentage of deaths caused by liver disease most probably lies in a range of 0.8–2.8% of all deaths.

Maternal deaths

Mola and Aitken (1985) thought that the maternal mortality in PNG at that time ranged from 2/1000 LB in urban areas to 20/1000 LB in rural areas lacking accessible services, and the national average to be about 8/1000 LB. This would place the observed rates in Tari (2.8/1000 LB), Asaro (3.0/1000 LB) and Madang (4.1/1000 LB) at the bottom of the range for rural areas. Against this, it must be questioned whether there was under-enumeration of pregnancy by male reporters.

Non-communicable diseases

The VA series provide little evidence for an epidemiological transition. Only 10 deaths could be ascribed to stroke (hemiplegia), four to ischaemic heart disease and two to diabetes, equivalent to 0.2% of all deaths.

Accuracy of the instrument

An estimate of accuracy can be based on i) the internal consistency of the dataset, described above, ii) more specifically from trials of vaccines against acute respiratory infections, and iii) in a comparison with COD data in health facility reports.

Validity of acute respiratory diagnoses

Although all four field sites collected mortality data for all causes of death, the two highlands sites of Tari and Asaro were concerned to use pneumonia deaths, and the two lowlands sites of Madang and Wosera malaria deaths, in epidemiological studies.

Clinical definitions for pneumonia in adults were based on a clinical series of cases of pneumonia in Lae, PNG (Douglas & Riley 1970). Clinical definitions of ALRI in children were initially based on a clinical series in Tari (Riley 1979) but also reflected participation in the development of the WHO global program for the Control of Acute Respiratory Infections (Riley 2010). In the course of the evolution of that program, clinically diagnosed ALRIs were re-classified as pneumonia, and the revised definitions later incorporated into the program for the Integrated Management of Childhood Illnesses (WHO 2001). Polyvalent pneumococcal polysaccharide vaccines were evaluated in separate field trials in adults and children, both of which used VA-assigned death from pneumonia to evaluate the vaccine. The vaccines were shown to cause statistically significant reductions in pneumonia-specific and all-causes mortality (Riley et al. 1977; Riley et al. 1986). This demonstrates specificity of the diagnosis of pneumonia (dependent on pneumococcus being the causative agent in a majority of deaths).

Sensitivity of diagnosis is reflected in the classification by symptom group. As pneumonias were responsible for 20.9% of all deaths and acute respiratory infections for 25.4% of all deaths, then the upper limit for the percentage of all deaths caused by pneumonia can be estimated to be 25.4%.

Health facility data

Table 13 compares leading CODs in the VA series with leading CODs in PNG hospitals in 1968 (Department of Public Health 1974) and with rural health facilities and major hospitals (urban) in 1998 (National Department of Health 2009). The high proportion of deaths due to pneumonia in the VA series is reflected in the 1968 report and in 1998 rural, but not 1998 urban, facilities. This last may be a consequence of a changing pattern of disease and a consequent decline in the incidence of severe lobar pneumonia in urban adults (Kevau & Saweri 2010). High mortality from CLD found in the VA data is not reflected in the hospital statistics at all. One reason for this is likely to be low attendance at a health facility when CLD was the cause of a terminal illness (Riley 1979). A second reason is that health facilities in PNG do not report the UCOD on death certificates, instead reporting deaths in terms of the principal reason for admission. Thus, a death from cor pulmonale, most commonly a consequence of CLD, will be reported as a death from other heart diseases. The hospital series suggest declining mortality for diarrhoeal diseases, which is consistent with the VA data (Figure 4). Pigbel is more prominent in the VA series, which is possibly a consequence of the uneven geographic distribution of the disease in the highlands. The VA series report higher mortality from measles than do the health facilities, but this is consistent with the measles data from Goroka Hospital reported by Mgone et al. (2000).

Table 13 Comparison of leading causes of death from the verbal autopsy series across all sites with deaths from Papua New Guinea hospitals in 1968 and rural facilities and major hospitals (urban) in 1998

	Hospitals 1968	Verbal Autopsies 1970–2001	1998 rural facilities	Major hospitals 1998
Pneumonia	17.3	**21.8**	21.4	11.9
Chronic lung disease	3	**13.5**		

Diarrhoea/dysentery	11.6	**8.3**	3.6	1.6
Injury	4.2	**7.3**	2	3.2
Perinatal deaths[1]	8.7	**6.8**	7.4	10.2
Other respiratory diseases		**4.2**	4.2	4.3
Cancer	3.6	**1.6**		5.6
Pigbel		**1.5**	0.1	
Measles		**1.5**	0.9	
Malnutrition	3.2	**1.3**	1	1.4
Tuberculosis	3.8	**0.9**	4.9	9
Meningitis	4.3	**0.7**	6.7	5.4
Maternal death	1.8	**0.7**		2.8
Malaria	4.5	**0.5**	9.7	8.4
Heart disease	3.4	**0.5**		11.1
Typhoid		**0.5**	3.8	2.9
Anaemia	1.9	**0.4**	3.7	2.3
Pertussis	0.9	**0.2**	0.4	
Other conditions	27.8	**29.7**	30.2	19.9
Total deaths	2843	**8489**	4866	3421

[1] Stillbirths + deaths in the first week of life
Source: Department of Public Health (1974) and National Department of Health (2009)

A number of conditions are much less prominent in the VA series than in the hospital and health facility reports, and this may well represent under-diagnosis of specific causes. Such conditions include cancer, malaria, tuberculosis, meningitis, heart disease, anaemia and typhoid fever. Difficulties with assigning a specific COD to febrile conditions have already been mentioned. In 1998, 20.2% of deaths in rural facilities were due to meningitis, malaria, and typhoid fever. Septicaemia, regarded as an ill-defined COD, would have accounted for still more deaths in rural facilities (and may appear in the VA series under the heading of skin infections). As febrile conditions were responsible for only 9.7% of VA deaths, we assume that the difference between observed percentage of deaths in health facilities and in VAs reflects a real difference. Furthermore, deaths from malaria, meningitis and typhoid fever are all likely to be associated with coma. Fever with coma was recorded for only 1.1% of all deaths in the VA series. Tuberculosis was quite probably under-diagnosed in the VA series (see above). Medical diagnosis was a general requirement for cancer and heart disease deaths in the VA series, and this requirement most probably led to under-diagnosis.

The instrument was not designed with maternal or neonatal deaths in mind. For these causes, not only would the questionnaire need to be reviewed but also the diagnostic categories.

How representative can this sample be of all deaths in PNG over this period?

The only data available that could possibly answer this question are in a review of under-five mortality rates (U5MRs) in PNG based on the 1996 Demographic and Health Survey and the 2000 National Census (Tran et al. 2011; Bauze et al. 2012). These data were disaggregated to district level (86 districts) which revealed large differences among and within provinces.

In 1985, which is a mid-point for the VA series, the national U5MR was said to be 85.5/1000 LB: in rural areas it was 91.8/1000 LB and in urban areas it was 37.7/1000 LB. Over the period 1985–1999, the U5MR was said to range from 26.2 deaths/1000 LB in Kundiawa-Gembogl district in Chimbu province to 236.0 deaths/1000 LB in Menyama district in Morobe province.

Such wide differences make sampling within PNG extremely complex. Table 14 compares estimated U5MRs from this analysis with observed U5MRs in the VA series.

Table 14 Under-five mortality analysis for Papua New Guinea vs. observed data

Rank in 86 PNG districts	District	Study site	U5MR[1] DHS[2] REVIEW: 1985 estimates			U5MR VA series	IMR[3] VA series	Ratio IMR/U5MR in VA series
				LLC[4]	ULC[4]			
4	Eastern Highlands: Goroka	Asaro	32.2	17.5	58.8	91.2	59.7	0.65
6	Eastern Highlands: Daulo		34.3	19.4	60.3			
16	Southern Highlands: Tari-Pori	Tari	51.0	25.8	99.2	104.7	77.5	0.74
30	Madang: Madang	Madang	61.2	25.0	142.4	65.6	45.9	0.7
68	East Sepik: Maprik	Wosera	123.7	56.4	250.2	172.9	121.0	0.7

[1] U5MR – Under-five mortality rate
[2] DHS – Demographic and Health Survey
[3] IMR – Infant mortality rate
[4] LLC/ULC – Lower limit of confidence / Upper limit of confidence
Source: Tran et al. 2011

The table shows that the observed U5MR for Madang and Wosera fall well within limits of confidence for the district estimates but that Asaro and Tari do not. We are unable to reconcile these data. The quality and duration of surveillance in Tari and Asaro make ageing errors improbable. Under-enumeration, not over-enumeration, of events is the usual problem with field data. We think it unlikely that Asaro (Goroka and Daulo districts) and Tari (Tari-Pori) were among the top-ranked districts in the country for low U5MR. The observed data would rank Asaro and Tari at between 52 and 61 of the 86 districts tabulated in Tran et al. (2011).

On this basis, in terms of their U5MR ranks we would regard the four study sites to be representative of mid-range PNG districts but not of the extremes of the range. The series are biased by heavy dependence on highlands mortality, but the data from Madang and Wosera do provide and do allow for correction. In general terms, the VA data are reasonably homogeneous.

Conclusions

PNG has depended heavily on reports of deaths in hospitals to describe the national cause distribution of mortality. However, hospital deaths are a biased sample of all deaths, with greater representation of deaths in the young, the educated, the comparatively wealthy, and in those living close to hospitals and other facilities.

How much do the verbal autopsies reviewed here add to understanding of the pattern of mortality in PNG during the period under study? First, they provide strong evidence of underestimation of mortality from CLD and from injury in hospital data. Second, they provide evidence for a decline in mortality from diarrhoea, dysentery and pigbel. Third, although they do not discriminate well between leading CODs from febrile conditions (malaria, meningitis, typhoid and encephalitis), they suggest that the percentage of such deaths from febrile conditions in the general population is less than was occurring according to the hospital data.

The VAs confirm the significance of pneumonia as the leading COD in PNG and of measles as a leading COD in highlands children before 2000. Because of reliance on health professionals for diagnosis, this VA series is likely to have underestimated mortality from cancer. The series provided no evidence for an increase in non-communicable diseases such as diabetes, ischaemic heart disease and stroke.

After the end of the Second World War, the PNG population entered a sustained period of mortality decline: crude mortality fell from 30–35 deaths/1000 population in 1946 to about 12/1000 in 2000; infant mortality fell from about 240/1000 LB in 1946 to about 60/1000 LB in 2000 (Riley & Lehmann 1992; Riley 2009). Riley and Lehmann (1992) argued that declining mortality had taken place without the investments in education, housing, sanitation and water supplies that would have eliminated underlying causes of disease. In other words, although mortality declined during the period of this study, the relative importance of the difference CODs had varied little since 1946. This review verifies that argument.

In the absence of comprehensive medical certification and registration of all deaths, it is extraordinarily difficult to describe mortality patterns in PNG because of the large differentials between geographic areas. At one extreme, remote districts are likely to have a mortality pattern reminiscent of the immediate post-war period. Urban and peri-urban areas are likely be experiencing increasing mortality from tuberculosis and AIDS at the same time that mortality from non-communicable diseases is also on the increase. Differentials between highlands and lowlands with respect to tuberculosis, malaria and injuries are likely to persist.

Future measurement of COD in PNG populations needs to take data from multiple sources into account. Sample vital registration in DSSs has the advantage of providing population mortality. The disadvantages relate to problems of sampling and the logistic requirements of maintaining regular surveillance (preferably four-monthly household visits) under difficult conditions. Although hospital and health facility deaths are a biased sample of all deaths, they have the advantage of providing coverage down to district level. Standards of diagnosis in and of reporting from health facilities need to be addressed. Sample surveys such as DHS should provide useful correction to other data from other sources, particularly with respect to mortality levels, and should be designed with this in mind. Issues appear to relate to quality of sampling and to performance in the field.

The outstanding advantage of the PNG VAI has been that it is brief, with only 18 symptom questions, and that interviewers with little education could apply it to non-literate populations. Interviewers needed to be carefully supervised and there needed to be linkage with health services data, but these remarks apply to all VAs. Considering its limitations, we consider this short VA instrument to have given a broad but remarkably accurate description of PNG population mortality over a period of more than 30 years. It was designed for a specific purpose in a particular environment. It has so happened that it has described a pattern of mortality preceding the epidemiological transition. With increased incidence and prevalence of non-communicable disease, it needs to be replaced by a new instrument, standardised internationally, which can be computer analysed and is less dependent on physician coding.

Appendix 1: Publications referencing the use of this verbal autopsy instrument (in date order)

Riley, I, Tarr, P, Andrews, M, Pfeiffer, M, Howard, R, Challands, P & Jennison, G 1977, 'Immunisation with a polyvalent pneumococcal vaccine: reduction of adult respiratory mortality in a New Guinea Highlands community', *The Lancet*, vol 1, iss. 8026, pp. 1338–41.

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Smith, D 1981, 'Suicide in remote preliterate society in the highlands of Papua New Guinea', *Papua New Guinea Medical Journal*, vol. 23, iss. 4, pp. 242–246.

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Riley, I, Alpers, M, Gratten, H, Lehmann, D, Marshall TF DeC & Smith, D 1986, 'Pneumococcal vaccine prevents death from acute lower respiratory infections in Papua New Guinean children', *The Lancet*, vol. 328, iss. 8512, pp. 877–81.

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Moir, JS, Garner, PA, Heywood, PF & Alpers, MP 1989, 'Mortality in a rural area of Madang Province, Papua New Guinea', *Annals of Tropical Medicine and Parasitology*, vol. 83, iss. 3, pp. 305–319.

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