The epidemiology of tuberculosis in the rural Balimo region of Papua New Guinea

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Abstract

OBJECTIVE Papua New Guinea (PNG) has an emerging tuberculosis (TB) epidemic which has become a national public health priority. In Western Province, there are few data about TB outside Daru and the South Fly District. This study describes the epidemiology of TB diagnosed at Balimo District Hospital (BDH) in the Middle Fly District of Western Province, PNG.

METHODS All patients (n = 1614) diagnosed with TB at BDH from April 2013 to February 2017 were recorded. Incidence of reported new cases was calculated for the combined Balimo Urban and Gogodala Rural local level government areas. Analyses investigated patient demographic and clinical information, differences between pulmonary and extrapulmonary TB patients, and predictors of treatment failure.

RESULTS The average case notification rate (2014–2016) was 727 TB cases per 100 000 people per year. One-quarter of TB cases were in children, and 77.1% of all cases had an extrapulmonary TB diagnosis. There was a 1:1.1 ratio of female to male TB cases. When comparing pulmonary and extrapulmonary TB patients, extrapulmonary TB was more likely in those aged up to 14 years and over 54 years. Extrapulmonary TB was more likely in new patients, and pulmonary TB more likely in previously treated patients. Residence in rural regions was associated with treatment failure.

CONCLUSION There is a high burden of TB in the Balimo region, including a very high proportion of extrapulmonary TB. These factors emphasise the importance of BDH as the primary hospital for TB cases in the Balimo region and the Middle Fly District, and the need for resources and staff to manage both drug-susceptible and drug-resistant TB cases.

keywords pulmonary tuberculosis, extrapulmonary tuberculosis, epidemiology, Papua New Guinea, drug resistance

Introduction

Tuberculosis (TB) is an urgent health concern in Papua New Guinea (PNG). In 2016, incidence was estimated at 432 cases per 100 000 people per year, equating to almost 35 000 people diagnosed with TB each year [1]. The burden of TB cases resistant to standard treatment is also substantial, with drug resistance estimated to occur in 3.4% of new cases, and 26% of retreatment cases [1].

Western Province is the largest province in PNG by area. The province has three districts – North Fly, Middle Fly and South Fly (Figure 1). Middle Fly District, the most populous of the three, includes five local level government (LLG) areas. These are Balimo Urban, Gogodala Rural, Bamu Rural, Lake Murray Rural and Nomad Rural (Figure 1). Balimo District Hospital (BDH) primarily serves the Balimo Urban and Gogodala Rural LLGs, and to a lesser extent the Bamu Rural LLG. In this study, the area served by BDH is generally referred to as the Balimo region, while the term 'Gogodala region' refers to the combined Balimo Urban and Gogodala Rural LLGs only.

In Western Province, TB incidence has been estimated at 549 cases per 100 000 people per year, and drug resistance has been seen in 25% of Western Province-based TB patients presenting at Australian health clinics in the Torres Strait [2–4]. More recently, a multi-site study that included two sites in Western Province found MDR-TB in 34.2% of Daru Hospital TB cases [5]. Cases with rifampicin mono-resistance were also identified, including

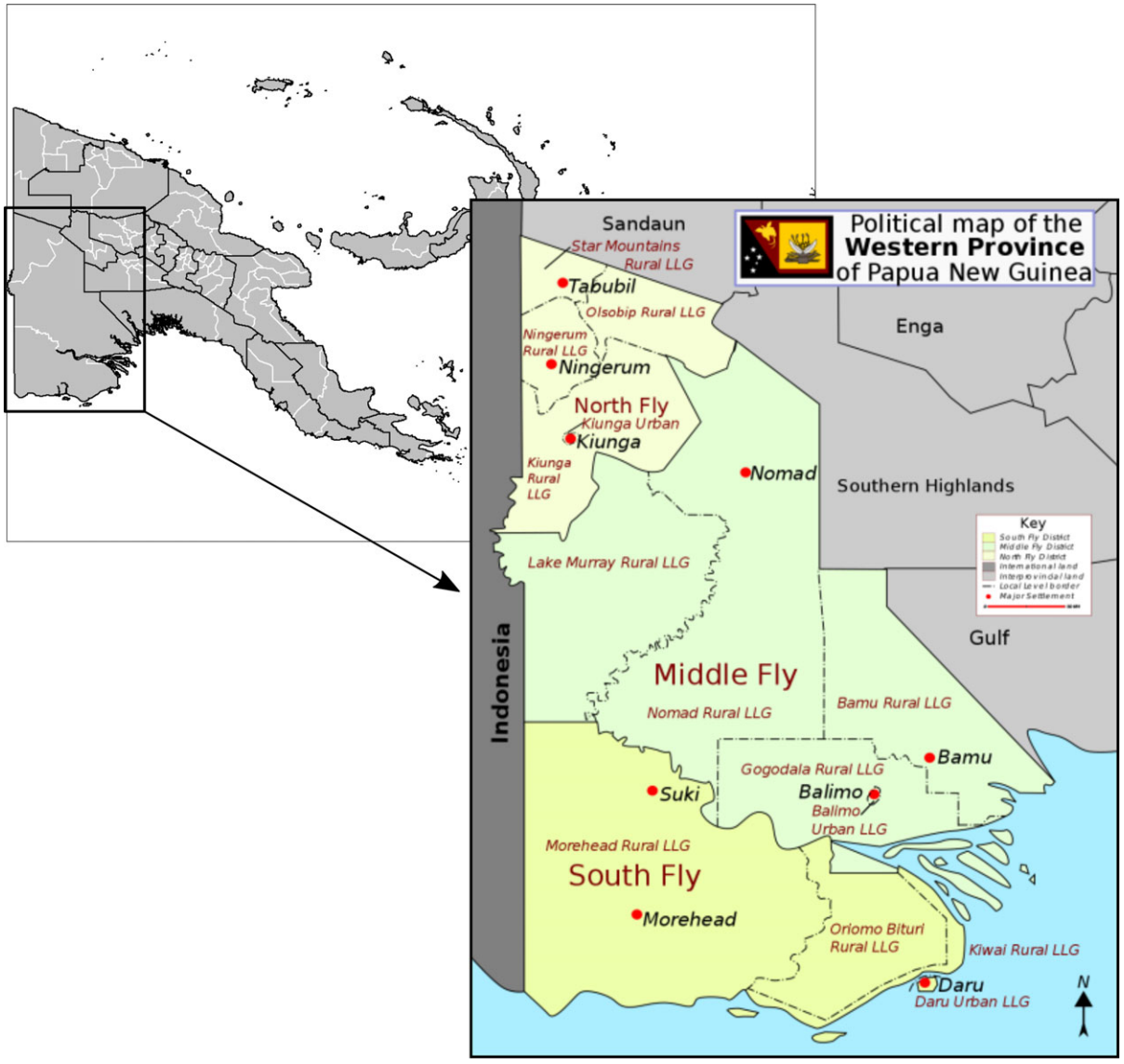

Figure 1 Western Province of Papua New Guinea (PNG), showing Balimo in the south-east of the Middle Fly District, and Daru on an island to the south of mainland PNG. (Image source: Wikimedia Commons).

7.3% of those from Daru, and 5.6% of those from Tabubil in the North Fly District [5] (Figure 1). However, data about the burden of TB in other areas of the province are scarce, particularly outside the South Fly District. Only one study examined TB in the province more broadly, an evaluation study which assessed the risks of TB across the province and concluded that the provincial burdens of TB and MDR-TB were much higher than official estimates, and that improvements within the TB control programme were essential to limit the spread of drug resistance [4].

A small number of health facilities across Western Province are able to provide TB diagnosis and treatment. However, the lack of roads and cost of travel makes access difficult [6]. Furthermore, TB patients with evidence of drug resistance, based on a lack of response to first-line treatment, or persistent positive smear microscopy results, must travel to the provincial capital on the island of Daru to access second-line treatment. Thus, Daru risks becoming a bottleneck for severe TB cases, with high numbers of drug-resistant cases concentrated on a small and densely populated island that has already

suffered from other health crises, including cholera [7, 8].

The known high rate of DR-TB cases in Daru, combined with the lack of research describing TB across the province more broadly, means there is an urgent need for epidemiological data describing TB patients from other areas of Western Province. This study describes the epidemiology of TB in the patient cohort of BDH located in the Middle Fly District of Western Province, PNG (Figure 1).

Methods

Balimo, located on the Aramia River floodplain in the Middle Fly District of Western Province, is a town of approximately 4400 people, and the urban centre of the Gogodala Rural LLG area [9]. Numerous small villages in the Gogodala Rural LLG area have a combined population of approximately 33 000 people [9]. There are very few roads outside of Balimo town, and travel is predominantly by foot, boat or canoe.

BDH is the primary health facility in Middle Fly District capable of diagnosing TB and initiating treatment. As a district hospital, BDH is classified as a level four facility, based on the National Health Service Standards [10]. These are a comprehensive set of standards that define objectives relevant to patient care, leadership and management, human resources management, information systems, the environment and improving performance [11]. A number of smaller health facilities in the region, including seven in the Gogodala Rural LLG and five in the Bamu Rural LLG, are able to commence patients on TB treatment. However, these facilities can only diagnose TB clinically, and sputum or other clinical specimens should be sent to Balimo for laboratory confirmation. At BDH, TB diagnoses are primarily passive, based on symptomatic patients seeking care at the hospital through self-referral, or onwards referral from health workers at a peripheral health centre or aid post.

BDH has not had the services of a resident medical officer since the 1990s. The only method available to confirm TB diagnoses is Ziehl-Neelsen (ZN)-stained smear microscopy, and X-ray was not available at the time of this study. As such, the majority of TB patients recorded in this study have received clinical diagnoses led by resident health extension officers (HEOs) trained in the management of drug-susceptible TB cases, and without laboratory confirmation of infection. In this region, the criteria for TB diagnoses and treatment outcomes are based on the PNG National Tuberculosis Management Protocol and the WHO definitions [12, 13]. Based on these definitions, all people given TB treatment are recorded as a TB case [12]. This occurs regardless of laboratory confirmation of infection, or whether the diagnosis is pulmonary or extrapulmonary TB. A pulmonary TB diagnosis may be indicated by symptoms such as prolonged cough (more than 2–3 weeks), fever, weight loss and night sweats; or in extrapulmonary TB by signs and symptoms including lymphadenitis, loss of function in the lower limbs, headache or mental confusion, as per the PNG National Tuberculosis Management Protocol [12].

Standardised TB treatment in the region is available only for drug-susceptible TB cases. Six months of treatment is provided using fixed dose combinations. Treatment is comprised of a 2-month intensive phase with rifampicin, isoniazid, ethambutol and pyrazinamide; followed by a 4-month continuation phase with rifampicin and isoniazid only [14]. Drug resistance is the presence of resistance to any of the anti-TB drugs. In Balimo medications for drug-resistant TB are not available, and patients who may have drug resistance must travel to Daru for diagnosis and treatment.

Treatment outcomes are defined in Table 1, based on the PNG National Tuberculosis Management Protocol [12]. Furthermore, in this study, binary categorisation of treatment success or treatment failure groups has been used (Table 1).

Patient data were primarily obtained from the TB patient register (hereafter called the TB register) held at BDH, including demographic, clinical and laboratory details of all patients diagnosed with TB and commenced on treatment at the hospital during the period 26 April

Table 1 Definitions used for treatment outcomes, based on the Papua New Guinea National Tuberculosis Management Protocol [12]

Group (this study)	Treatment outcome	Definition
Treatment success	Cured	Initially sputum smear-positive, but smear-negative in last month of treatment, and on at least one previous follow-up occasion
	Treatment complete	Completed treatment, but not classified as cure or treatment failure
Treatment failure	Treatment failure	Smear-positive at 5 months or later, or at 2 months if initially smear-negative
	Died	Death for any reason during treatment
	Default	Treatment interruption for two or more consecutive months

2013–25 February 2017. All pages of the register books available at the time of two study visits (April 2016 and February 2017) were transcribed into the TB study spreadsheet in Microsoft Excel. At the second study visit, the TB register was studied again, to update treatment outcomes added since the first visit.

In addition to the TB register, data were obtained from a secondary source – the BDH TB laboratory database. The BDH TB laboratory database is a register of all clinical samples investigated for TB at BDH using ZN-stained smear microscopy, and the results of these investigations.

The TB register records were matched with patients recorded in the BDH laboratory database, based on name and demographic data, and any additional demographic or laboratory data were added to the TB study spreadsheet. For minor discrepancies (e.g. similar but not exact age), the TB register was assumed to be correct for demographic information. However, the majority of patients (1294/1614, 80.2%) could not be matched to the laboratory database due to both a high proportion of clinical diagnoses and small overlap of the data sources.

In this region, people are often uncertain of their age, and there was evident bias towards reporting of even-numbered ages. For this reason, age range categories were used, and where multiple different ages were recorded (e.g. in the TB register and the laboratory database) people were placed in the age category that matched the average of the reported ages.

Statistical analyses were undertaken for 1518 of the 1614 patients recorded in the TB patient register. The 96 excluded patients were diagnosed through non-routine active case detection activities in the Bamu region and were thus not considered to be representative of the usual patient cohort seen at BDH.

Incidence of reported cases was estimated for the Gogodala region only, which consists of Balimo Urban LLG and Gogodala Rural LLG. Incidence was based on case numbers for new patients commenced on treatment in all full months and years of the study period. The total population for the two Gogodala LLG regions was used as the denominator, based on 2011 census data [9]. The most recent estimate of population growth in the province (2.5% per annum for the 2000–2011 period) was used to estimate population for all years subsequent to 2011 [15]. The monthly trend of reported TB cases was based on the month of treatment commencement.

Demographic and clinical categories were tabulated. Chi-square analyses were used to assess differences between patient groups based on TB presentation (pulmonary or extrapulmonary TB, with concurrent or unknown presentations excluded).

Predictors of treatment failure outcomes were analysed using univariate and multivariate logistic regression, based on binary categorisation of treatment success (cured and treatment complete outcomes) or treatment failure (treatment default, death and treatment failure outcomes). Excluded patients included those with a 'transfer out' status (n = 127) or unknown outcome (n = 293); as well as those patients commenced on treatment in the last six full months of the study period (August 2016–February 2017) (n = 368), as insufficient time had elapsed for these patients to have a treatment outcome recorded. All variables included in the univariate model were also included in the multivariate model.

Tabulations, charts and statistical analyses were performed using Stata/IC, version 14. Confidence intervals were calculated using the AusVet 'Confidence limits for a proportion' calculator [16]. Specific and direct standardised incidence rates were calculated using the Epi_Tools spreadsheet [17]. The pie chart and line graph were created using GraphPad Prism 7.

The study was approved by the James Cook University Human Research Ethics Committee under approval number H6432. The Middle Fly District Health Service and the Evangelical Church of PNG Health Service gave permission and support for the project. The PNG Medical Research Advisory Committee approved the study under MRAC No. 17.02.

Results

TB case numbers and the incidence of reported cases for patients commenced on treatment across the study period are shown in Figure 2. The average yearly reported incidence for the three complete years of the study period was 727 cases per 100 000 people per year (Table 2).

The distributions of patient demographic and clinical data are shown in Table 3. Of note is the large proportion of cases in children (25.0%), and that 77.1% of all cases had a diagnosis of extrapulmonary TB. The site of extrapulmonary infection was reported for 275 TB patients. The distribution of sites is shown in Figure 3, with the majority localised to the glands or lymph nodes (n = 108, 37.6%, 95% CI 32.2–43.4); or the spine (n = 88, 30.7%, 95% CI 25.6–36.2).

The 2014–2016 average specific and direct standardised rates per 100 000 people per year for sex are shown in Table 3, according to the national population proportion for PNG from the 2011 census [18]. Based on the standard population proportion, the number of cases in females was smaller than the reported incidence based on their proportion of the population, while the number of

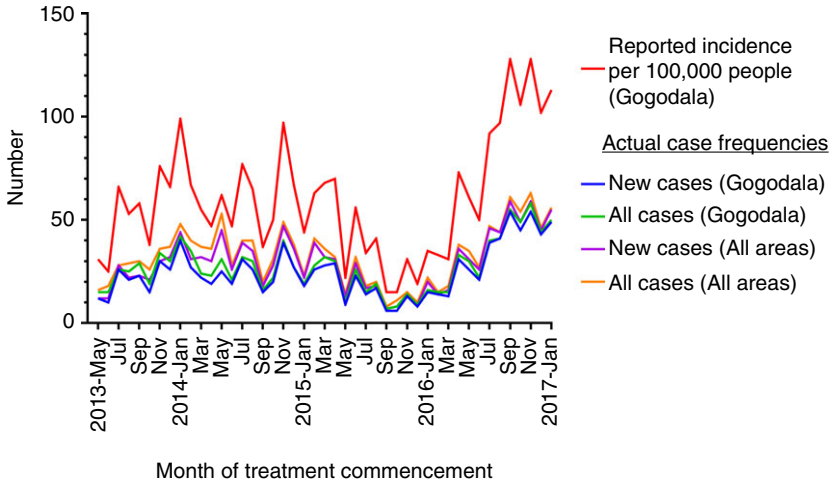

Figure 2 Case frequencies and incidence of reported new cases (per 100 000 people) per month for tuberculosis (TB) across the study period. Cases in the Gogodala region include the Balimo Urban and Gogodala Rural local level government (LLG) areas only.

Table 2 Case numbers and incidence of reported cases (per 100 000 people) per year for new tuberculosis (TB) patients in the Gogodala region

Year	*n*	Calculated population	Reported incidence (per 100 000)
2014	310	40 305	769
2015	197	41 313	477
2016	396	42 346	935
2014–2016	903		727 (Average)

cases in males was higher than the reported incidence based on their proportion of the population.

Pre-treatment ZN smear microscopy results were recorded for 359 of the 1518 TB patients (23.6%, 95% CI 21.6–25.9), including 101/1171 (8.6%, 95% CI 7.2–10.4) patients diagnosed with extrapulmonary TB, 250/321 (77.9%, 95% CI 73.0–82.1) with pulmonary TB, 4/6 (66.7%, 95% CI 30.0–90.3) with concurrent infection and 4/20 (20.0%, 95% CI 8.1–41.6) with unknown infection. Although the majority of smear results were obtained from sputum samples, a small proportion of extrapulmonary smear results were from other clinical specimens (e.g. discharge). For pulmonary TB patients, 65.7% (n = 211) were smear-positive, and 12.1% (n = 39) were smear-negative; no smear result was recorded for the remaining pulmonary TB patients. The microscopy results for each of the patient groups are shown in Table 4. Where more than one smear result was recorded, the highest smear grade is shown here.

Analysis of pulmonary and extrapulmonary TB patient groups

The analysis comparing pulmonary and extrapulmonary patient groups is shown in Table 5. There was a greater proportion of extrapulmonary TB cases in the 0–14 years group (X^2 = 117.45, P < 0.01) and those aged 55 and over (X^2 = 11.45, P < 0.01); and a greater proportion of pulmonary cases in the 15–54 years age groups compared to both the 0–14 years and 55+ years age groups (Table 5). New patients were more likely to be diagnosed with extrapulmonary than pulmonary TB when compared to previously treated patients (X^2 = 6.15, P = 0.01).

Analysis of treatment outcomes

Of the 1150 patients who had completed the 6-month treatment period, outcomes were known for 857 (Table 6). A complete summary of all registered patients and treatment outcomes is shown in Figure 4.

The logistic regression results for the analysis of treatment outcomes are shown in Table 7. In the univariate analysis, residence in the Bamu Rural LLG was a predictor of treatment failure (OR = 3.00, P = 0.01), while in the multivariate analysis, residence in either the Gogodala Rural LLG or Bamu Rural LLG was a predictor of treatment failure (Gogodala Rural, OR = 2.49, P = 0.02; Bamu Rural, OR = 4.11, P < 0.01).

Co-infection of HIV and TB

Of the 1614 patients recorded in the TB register, 74 (4.6%, 95% CI 3.7–5.7) had a HIV test outcome

Table 3 Patient demographic and clinical data for sex, age category, local level government (LLG) area, tuberculosis (TB) type and patient status

Variable	Frequency	% (95% CI)	Specific and direct standardised incidence rates per 100 000 (2014–2016 average)
Sex			
Female	722	47.6 (45.1–50.1)	709 (specific)
Male	793	52.2 (49.7–54.7)	742 (specific)
Unknown	3	0.2 (0.1–0.6)	726 (standardised)
Age category			
0–14 years	379	25.0 (22.9–27.2)	
15–24 years	254	16.7 (14.9–18.7)	
25–34 years	259	17.1 (15.3–19.0)	
35–44 years	211	13.9 (12.3–15.7)	
45–54 years	192	12.6 (11.1–14.4)	
55–64 years	138	9.1 (7.7–10.6)	
65+ years	31	2.0 (1.4–2.9)	
Unknown	54	3.6 (2.7–4.6)	
LLG area			
Balimo Urban	252	16.6 (14.8–18.6)	
Gogodala Rural	1010	66.5 (64.1–68.9)	
Bamu Rural	199	13.1 (11.5–14.9)	
Kiwai Rural	6	0.4 (0.2–0.9)	
Morehead Rural	4	0.3 (0.1–0.7)	
Nomad Rural	1	0.1 (0.1–0.4)	
Unknown	46	3.0 (2.3–4.0)	
TB type			
Pulmonary	321	21.1 (19.2–23.3)	
Extrapulmonary	1171	77.1 (75.0–79.2)	
Both	6	0.4 (0.2–0.9)	
Unknown	20	1.3 (0.9–2.0)	
Patient status			
New	1375	90.6 (89.0–91.9)	
Treatment after relapse	26	1.7 (1.2–2.5)	
Treatment after failure	11	0.7 (0.4–1.3)	
Treatment after default	77	5.1 (4.1–6.3)	
Transfer in	6	0.4 (0.2–0.9)	
Other	2	0.1 (0.0–0.5)	
Unknown	21	1.4 (0.9–2.1)	

CI, confidence interval; LLG, local level government; TB, tuberculosis.

recorded. Of these, four were positive (5.4%, 95% CI 2.1–13.1), one had no result recorded and the remainder were negative.

Discussion

This study describes the high burden of TB in the Balimo region of PNG and highlights a very high proportion of clinically diagnosed extrapulmonary TB patients. In PNG TB may be diagnosed clinically based on the PNG National Tuberculosis Management Protocol and the WHO definitions [12, 13]. Misdiagnosis due to limited access to laboratory confirmation is possible, and indeed, it is a feature of TB epidemics in these resource-limited settings. Therefore, this study also highlights the need to increase the capacity of laboratory and medical imaging-based diagnostics to aid in the accuracy of diagnosis, which will lead to more directed and evidence-based therapeutic interventions.

There are a number of limitations that may have influenced patient data analysis. Patient data are recorded in handwritten registers by a number of different health workers. Data entry mistakes may occur, and some patient data may go unrecorded. Record-keeping in this resource-limited region is undoubtedly difficult, especially given the lack of digital records. There are also inherent challenges resulting from the use of records in separate

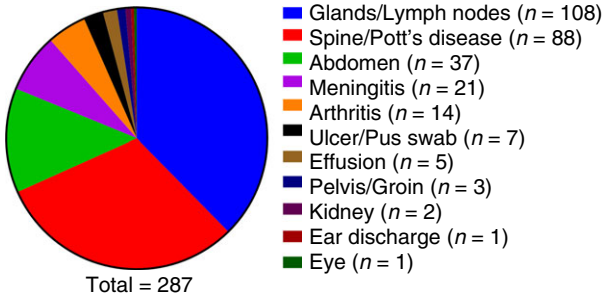

Figure 3 Distribution of extrapulmonary tuberculosis (TB) site of infection. The site was known for 275 TB patients, with a total of 287 sites recorded as some patients had more than one site recorded.

patient and laboratory registers, particularly in locating and updating historical records. Despite this, the TB register was assumed to be correct in the classification of patients, even if it was unclear how those decisions were reached, and given that the TB register represents the official TB record. For example, if a patient was classified as cured, but only one negative smear was recorded in the register, the cured classification was still used in this study. Furthermore, any missing treatment commencement dates were assumed to be the same as the patient registration date. As already noted, there are inherent problems with some data, including age inaccuracies. These problems are unavoidable in a data set such as this, but are mentioned here due to the need to interpret the results with caution. Given the challenges of travel throughout the South Fly and Middle Fly Districts of the province, it is possible that some Gogodala- and Bamu-LLG area patients present directly at Daru or other peripheral health facilities instead of at Balimo. Thus, the TB data presented here are not intended to be an exhaustive record of TB patients for the Balimo region, but a description of the TB cases presenting at BDH, the only hospital in the Middle Fly District.

The overall incidence of reported new cases for TB in the Balimo Urban and Gogodala Rural LLG areas, estimated here to range from 477 to 935 cases per 100 000 people per year, is substantially higher than the PNG-wide WHO estimates. In 2016, 27 294 new TB cases were notified in a population of 8.1 million people, equating to 337 case notifications per 100 000 people per year [19]. By further comparison, the Western Pacific Region reported 1 305 408 new cases in a population of 1.9 billion people, equating to 69 case notifications per 100 000 people per year [19].

The extremely high number of TB diagnoses emphasises the heavy burden of disease that TB causes in this region. Our estimate for the Balimo region is higher than the previous Western Province region incidence estimate of 549 cases per 100 000 people per year [4]. The South Fly District and the provincial capital of Daru have previously been noted for having a high burden of TB, and particularly DR-TB [2–5, 20–22]. A heavy burden of TB cases in the North Fly District has previously been observed, while more recent research described 18 cases of TB from Tabubil, with one of these identified as rifampicin resistant [4, 5]. The data from the North Fly District, in combination with the Middle Fly District data described in our study, highlight the broad reach of TB across Western Province. Well-resourced health services across all three districts are essential to respond to TB across the province, and until that time, the burden on the urban capital Daru will continue.

In this study of the Balimo region, extrapulmonary TB accounted for more than 75% of TB diagnoses. Globally, extrapulmonary TB usually accounts for about 15% of TB cases, although in the WHO Western Pacific Region, extrapulmonary TB cases are reported to be as low as 8% [1]. The most recent nation-wide data for TB in PNG reported that 43% of cases were extrapulmonary;

Table 4 Pre-treatment Ziehl-Neelsen (ZN) smear microscopy results for patients diagnosed with tuberculosis (TB) at Balimo District Hospital (BDH), based on the highest smear grade recorded for each patient

	Extrapulmonary, *n* (%)	Pulmonary, *n* (%)	Concurrent, *n* (%)	Unknown, *n* (%)
3+	4 (0.3)	100 (31.2)	0 (0)	1 (5.0)
2+	2 (0.2)	58 (18.1)	1 (16.7)	0 (0)
1+	4 (0.3)	32 (10.0)	0 (0)	1 (5.0)
Scanty	0 (0)	19 (5.9)	0 (0)	0 (0)
Positive*	0 (0)	2 (0.6)	0 (0)	0 (0)
NAFB	91 (7.8)	39 (12.1)	3 (50.0)	2 (10.0)
Unsatisfactory	1 (0.1)	0 (0)	0 (0)	0 (0)
Unknown	1 (0.1)	0 (0)	0 (0)	0 (0)
No smear	1068 (91.2)	71 (22.1)	2 (33.3)	16 (80.0)
Total	1171 (100.0)	321 (100.0)	6 (100.0)	20 (100.0)

*Grade unknown; NAFB: no acid-fast bacilli.

Table 5 Chi-square analysis comparing pulmonary and extrapulmonary tuberculosis (TB) patient groups by sex, age, incoming patient status, local level government (LLG) area and treatment outcome

		TB type	
Variable	Frequency	Pulmonary	Extrapulmonary
Sex	*n*	Freq (%)	Freq (%)
Female	706	141 (20.0)	565 (80.0)
Male	783	180 (23.0)	603 (77.0)
Total	1489	321	1168
Pearson X^2 = 2.00, df = 1, P = 0.16			
Age category	*n*	Freq (%)	Freq (%)
0–14 years	376	11 (2.9)	365 (97.1)
15–54 years	905	278 (30.7)	627 (69.3)
Total	1281	289	992
Pearson X^2 = 117.45, df = 1, P < 0.01			
15–54 years	905	278 (30.7)	627 (69.3)
55+ years	168	30 (17.9)	138 (82.1)
Total	1073	308	765
Pearson X^2 = 11.45, df = 1, P < 0.01			
Patient status	*n*	Freq (%)	Freq (%)
New	1363	283 (20.8)	1080 (79.2)
Previously treated	114	35 (30.7)	79 (69.3)
Total	1477	318	1159
Pearson X^2 = 6.15, df = 1, P = 0.01			
Treatment outcome	*n*	Freq (%)	Freq (%)
Treatment success	605	169 (27.9)	436 (72.1)
Treatment failure	119	25 (21.0)	94 (79.0)
Total	724	194	530
Pearson X^2 = 2.43, df = 1, P = 0.12			
LLG area	*n*	Freq (%)	Freq (%)
Balimo Urban	249	43 (17.3)	206 (82.7)
Gogodala Rural	995	223 (22.4)	772 (77.6)
Bamu Rural	192	45 (23.4)	147 (76.6)
Total	1436	311	1125
Pearson X^2 = 3.52, df = 2, P = 0.17			

LLG, local level government; TB, tuberculosis.

Table 6 Tuberculosis (TB) treatment outcomes for all patients who had completed the 6-month treatment period, and where the treatment outcome was known

Treatment outcome	*n*	% (95% CI)
Cured	90	10.5 (8.6–12.7)
Treatment complete	521	60.8 (57.5–64.0)
Default	47	5.5 (4.1–7.2)
Treatment failure	5	0.6 (0.3–1.4)
Died	67	7.8 (6.2–9.8)
Transfer out	127	14.8 (12.6–17.4)
Total	857	100.0

while a study investigating presumptive TB in children hospitalised at Modilon in Madang Province found extrapulmonary TB to be the final diagnosis in 52.3% of paediatric TB cases [1, 23]. One study from PNG has commented on the prevalence of extrapulmonary TB in the country, noting that both under-diagnosis and over-diagnosis are possible outcomes in settings where diagnoses are predominantly symptom based [24]. The large proportion of extrapulmonary TB diagnoses in the Balimo region requires further investigation.

The 1:1.1 ratio of female to male TB cases identified in this study differs from the PNG national, South-East Asia and Western Pacific Region ratios, which in 2016 had estimated female:male incidence ratios of 1:1.7, 1:1.9 and 1:2.1, respectively [1]. Various factors could contribute to these differences, including TB contacts, health-seeking behaviour and smoking [25–28]. In PNG, the prevalence of tobacco smoking in males is 37.3% vs. only 14.5% in females [29]. As a result, it appears that smoking may not be a major risk factor affecting the female:male ratio in the Balimo setting. However, it should be noted that cooking fires are used extensively in this setting, which may affect more females and children.

The age distribution of TB cases in the Balimo region showed cases aged 0–14 years to be the largest group. In the analysis of pulmonary and extrapulmonary TB cases, the very low number of pulmonary cases in children aged up to 14 years is also of note. This corresponds with the general presentation of TB in children, which tends to be paucibacillary and have lymph node involvement [30]. However, from an epidemiological perspective high numbers of TB cases in children is concerning, as they tend to indicate recent *Mycobacterium tuberculosis* transmission, as well as ongoing transmission within the community [31]. The impact of TB in children in this region requires further research.

Given that many of the TB cases reported in this study are clinically diagnosed without bacteriological confirmation, there is the possibility of TB misdiagnosis among presenting patients. Furthermore, factors such as case detection bias should also be considered, particularly in relation to high case numbers in children, and of extrapulmonary TB. However, treatment outcomes suggest that over-diagnosis is not a major concern. More than 70% of TB patients with a known treatment outcome were classified as 'treatment success', meaning that they were either cured or successfully completed treatment, in the absence of classification as treatment failure. In a region where successful treatment is often the best supporting evidence for a TB diagnosis, this suggests that at

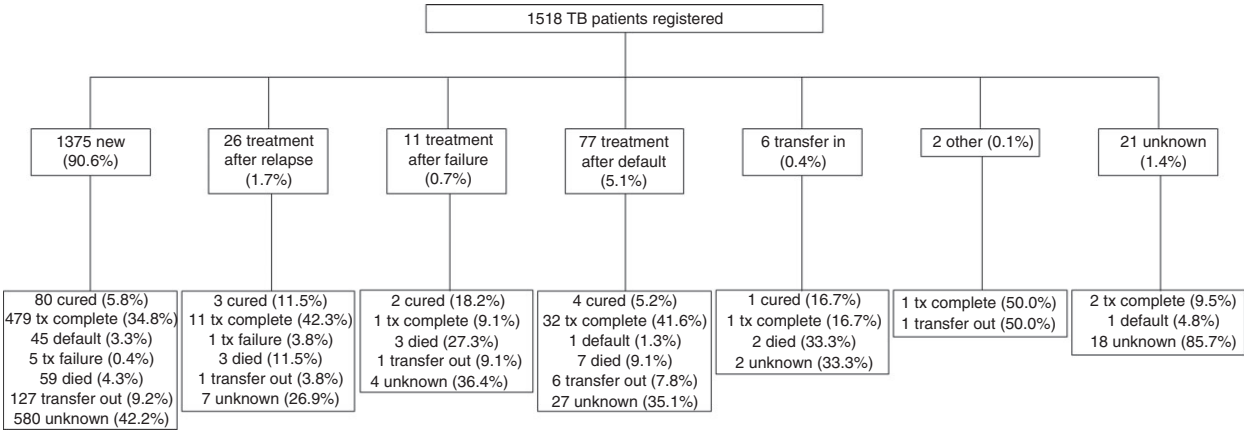

Figure 4 Incoming patient status and treatment outcomes for all tuberculosis (TB) patients registered during the study period. All unknown treatment outcomes are included, regardless of whether the patient had been under treatment long enough to have completed their course of medication.

Table 7 Univariate and multivariate logistic regression examining predictors of treatment failure in all tuberculosis (TB) patients. A total of 680 complete observations were included in the multivariate model

		Univariate			Multivariate	
Predictor variables		*n*	OR (95% CI)	*P*	OR (95% CI)	*P*
Sex	Female	343	1.0		1.0	
	Male	385	1.45 (0.97–2.16)	0.07	1.45 (0.94–2.22)	0.09
Age	0–14	188	1.0		1.0	
	15–24	140	0.62 (0.34–1.15)	0.13	0.81 (0.42–1.56)	0.53
	25–34	132	0.75 (0.41–1.37)	0.36	0.90 (0.46–1.73)	0.75
	35–44	102	0.62 (0.31–1.23)	0.17	0.67 (0.31–1.43)	0.30
	45–54	78	0.84 (0.42–1.70)	0.64	1.10 (0.52–2.37)	0.80
	55–64	64	1.18 (0.59–2.37)	0.64	1.63 (0.78–3.41)	0.20
	65+	12	1.41 (0.36–5.46)	0.62	1.65 (0.42–6.52)	0.48
Patient status	New	655	1.0		1.0	
	Prev. treated	67	1.43 (0.77–2.68)	0.26	1.47 (0.77–2.79)	0.24
TB type	Pulmonary	194	1.0		1.0	
	EP	530	1.46 (0.91–2.35)	0.12	1.47 (0.86–2.50)	0.16
LLG area	Balimo	110	1.0		1.0	
	Gogodala	492	1.97 (0.99–3.93)	0.06	2.49 (1.15–5.40)	0.02
	Bamu	104	3.00 (1.36–6.64)	0.01	4.11 (1.70–9.96)	<0.01

EP, extrapulmonary; LLG, local level government; OR, odds ratio; TB, tuberculosis.

BDH the recognition of non-laboratory confirmed cases of TB by clinicians is reasonable. Despite this, the use of non-TB treatments such as amoxicillin and aspirin has previously been described in the Balimo region [6], although whether these are used concomitantly with TB treatment is unknown. The possibility of symptom resolution even if extrapulmonary TB has been incorrectly diagnosed should therefore be considered. However, regardless of the accuracy of TB diagnoses in this setting, misdiagnoses of TB may in fact place greater burdens on the health system, particularly if symptoms are not resolved.

It is also of note that in this study, a relatively high proportion of pulmonary TB cases had a positive smear result, being 65.8% vs. 31% of pulmonary TB cases with bacteriological confirmation across PNG [1]. The low proportion of smear-negative pulmonary TB cases may reflect additional challenges in pulmonary TB diagnosis, particularly in this setting where chest X-ray was not available at the time of the study.

The increased likelihood of new patients being diagnosed with extrapulmonary TB, while previously treated patients were more likely to be diagnosed with pulmonary TB, may have several possible explanations. The higher proportion of pulmonary TB diagnoses in previously treated cases may be influenced by emerging drug resistance in the region. DR-TB is known to occur in Balimo and is likely to be more prevalent among pulmonary cases, particularly if these cases are more likely to truly be TB. An additional possibility for the increased likelihood of previous treatment among pulmonary cases is the status of the Balimo region as an area endemic for melioidosis [32–34], which frequently presents with pulmonary symptoms, and may initially be misdiagnosed as TB. Furthermore, limited diagnostic facilities in general result in challenges to infectious disease investigation and management in this region.

Treatment outcomes were unknown for just over 25% of patients who completed treatment at least 6 months before the end of the study period. This proportion may reflect the flexibility with which DOTS is often administered in the region, where patients may take their treatment packs back to their home village for the duration of treatment [6]. In this study, the only factor found to be significantly associated with poorer treatment outcomes was the LLG area in which a patient resided, with poorer outcomes more likely in the rural LLGs. This finding may be linked to the challenges associated with obtaining health care for those patients who have a rural residence. TB patients living in or around the Balimo Urban LLG will face substantially lower travel and economic burdens in obtaining care initially, and continuing treatment once diagnosed.

Conclusions

The extremely high reported incidence of TB, and particularly the high proportion of extrapulmonary TB, demonstrates a heavy burden of TB disease in the Balimo region. Increased understanding of the epidemiology of TB in this setting provides important information in the context of TB control and elimination in Western Province and PNG more broadly. Although improved resources and facilities are an urgent need at BDH, this study has also demonstrated the substantial success of healthcare workers (HEOs, clinical nurses and laboratory technicians) in diagnosing, treating and managing TB in this non-doctor-led model of care setting, and the dedication of these staff to this task. The burden of disease in this newly described TB-endemic region emphasises the need for the role of BDH to be considered in the broader Western Province TB control programme.

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