ABSTRACT
Objectives Rheumatic heart disease (RHD) remains the leading acquired heart disease in the young worldwide. We aimed at assessing outcomes and influencing factors in the contemporary era.
Methods Hospital-based cohort in a high-income island nation where RHD remains endemic and the population is captive. All patients admitted with newly diagnosed RHD according to World Heart Federation echocardiographic criteria were enrolled (2005–2013). The incidence of major cardiovascular events (MACEs) including heart failure, peripheral embolism, stroke, heart valve intervention and cardiovascular death was calculated, and their determinants identified.
Results Of the 396 patients, 43.9% were male with median age 18 years (IQR 10–40). 127 (32.1%) patients presented with mild, 131 (33.1%) with moderate and 138 (34.8%) with severe heart valve disease. 205 (51.8%) had features of acute rheumatic fever. 106 (26.8%) presented with at least one MACE. Among the remaining 290 patients, after a median follow-up period of 4.08 (95% CI 1.84 to 6.84) years, 7 patients (2.4%) died and 62 (21.4%) had a first MACE. The annual incidence of first MACE and of heart failure were 59.05‰ (95% CI 44.35 to 73.75) and 29.06‰ (95% CI 19.29 to 38.82), respectively. The severity of RHD at diagnosis (moderate vs mild HR 3.39 (0.95 to 12.12); severe vs mild RHD HR 10.81 (3.11 to 37.62), p<0.001) and ongoing secondary prophylaxis at follow-up (HR 0.27 (0.12 to 0.63), p=0.01) were the two most influential factors associated with MACE.
Conclusions Newly diagnosed RHD is associated with poor outcomes, mainly in patients with moderate or severe valve disease and no secondary prophylaxis.

INTRODUCTION
Rheumatic heart disease (RHD), a disease of poverty,1 has almost disappeared from wealthy countries, but remains highly prevalent in developing countries and among indigenous populations in the Pacific.2–7 The burden of RHD is still a major challenge in the developing world with approximately 345 000 deaths per year worldwide.8 RHD is the result of an inadequate response to invasive group A streptococcal infections, namely acute rheumatic fever (ARF).9 Although they are part of a continuum, RHD and ARF have often been studied separately. The presentations do vary, however, with some patients presenting with ARF and no overt cardiac involvement, and nearly half of those diagnosed with RHD at an advance stage having no history of ARF.10–11

There is, however, limited contemporary data on the characteristics of patients with newly diagnosed RHD.10 Also, a handful of clinical studies assessing predictors of outcomes in ARF and RHD either present a highly selected population12 or date back to the 1950s when access to interventions was extremely limited.13 The two contemporary hospital-based registers have so far described characteristics of patients with no or limited (up to 30 months) follow-up.10–11

We present the results of a hospital-based cohort study in New Caledonia, a high-income country where RHD remains endemic among the indigenous population.9 The objective was twofold: to describe the characteristics and outcomes of patients with newly diagnosed RHD according to standardised and prespecified diagnostic criteria and to assess factors associated with outcomes, focusing on patients with no major cardiovascular events (MACEs) at entry.

METHODS
Settings RHD remains prevalent in New Caledonia among Oceanic populations including Melanesians and Polynesians.6 New Caledonia (22.276 S, 166.458 E) is an overseas French territory of approximately 270 000 inhabitants located in the southwest Pacific Ocean.14 The Centre Hospitalier Territorial de Nouvelle Calédonie is the only centre that provides specialist Cardiology, Paediatrics and Infectious Disease services in the archipelago and uses computer-based notes. The New Caledonian social security system provides free of charge access to good quality medicine, imaging and microbiological diagnostic testing. Air transport for urgent referral for remote communities is widely available across the archipelago. Patients in need for heart valve surgery are referred either to neighbouring Australia or to mainland France with no additional cost for the patient.

Participants Patients admitted with newly diagnosed RHD from 1 January 2005 to 31 December 2013 were
considered eligible for the study. Hospital records of all individuals with a primary or secondary International Classification of Diseases, 10th revision separation diagnosis of ARF or RHD were examined. Patients who fulfilled World Heart Federation (WHF) criteria of ‘definite’ RHD\textsuperscript{13} with quantification of heart valve disease\textsuperscript{16} were included in the study (see online supplementary table S1). Patients were asked to give oral consent to be enrolled in the study at time of follow-up interview.

Data collected at the time of diagnosis
For each participant, the following data were retrospectively collected: demographics (age, sex), ethnicity, month and year of diagnosis, family history of RHD, ARF at presentation, valve disease on first echocardiogram and its severity,\textsuperscript{16} New York Heart Association (NYHA) class, LVEF on echocardiogram, pulmonary hypertension on echocardiogram (defined as pulmonary artery systolic pressure >35 mm Hg), presence of supraventricular arrhythmias (defined as paroxysmal or permanent atrial fibrillation, atrial flutter or atrial tachycardia). Mild heart valve disease included mild single left-sided valve disease and mild multiple heart valve disease (eg, mild mitral regurgitation and mild aortic regurgitation). Heart valve disease was considered moderate if one of the left-sided valves presented with moderate mitral regurgitation, mitral stenosis or aortic regurgitation. One single severe left-sided regurgitative/stenotic valve lesion was considered severe heart valve disease.\textsuperscript{16}

Follow-up
Patients were invited to attend a specialist clinic from March 2013 to December 2013. If patients could not attend, a questionnaire was filled over the telephone either with the patient or the general practitioner, and the latest medical reports were collected.

Data on treatment included use of secondary prophylaxis (benzathine penicillin G injections or oral treatment) at any time from diagnosis and at the time of interview (ie, ongoing secondary prophylaxis). The National Register of Secondary Prophylaxis was consulted when data were missing on the hospital chart. The population being captive, all major events (see below) such as heart failure, stroke or embolism would lead to admission to the single hospital in the archipelago. Vital status and cause of death were checked in the national register of the causes of death in March 2014 for patients lost to follow-up between March and December 2013. Use of cardiac interventions through the office in charge of overseas referrals was also checked in March 2014.

Outcomes and factors associated with events
MACEs, based on information available in the hospital chart, included heart failure (defined by NYHA class III or IV), peripheral embolism, stroke, heart valve intervention and cardiovascular death. Heart valve interventions included percutaneous mitral valvuloplasty and open-heart valve surgery. Additional adverse events were collected: severe haemorrhage (defined as leading to death, intracranial bleeding, bleeding associated with haemoglobin drop of ≥2 g/dL or need for transfusion of at least 2 red cell packs), infective endocarditis, heart valve thrombosis (in patients with a mechanical valve), cardiogenic shock and pregnancy-related complications (defined as maternal or foetal complications, including heart failure, need for surgery, termination of pregnancy, preterm birth and low birth weight). A team of two research nurses collected the data. A third party (MM) arbitrated in case of disagreement.

Statistical methods
Descriptive data were reported for the entire study population fulfilling the WHF criteria for RHD. Only patients with no MACE at hospital admission were further eligible for the analysis on incident MACE. The results are reported as median and IQR or as numbers and percentages. Categorical variables were compared using χ\textsuperscript{2} test or Fisher’s exact test, and continuous variables using Student’s t test. The incidence of cardiovascular

Figure 1  Flow chart of the study.
ARF, acute rheumatic fever; MACE, major cardiovascular event; RHD, rheumatic heart disease; WHF, World Heart Federation.
events was calculated per 1000 person-years. Factors associated with MACE were analysed using a Cox proportional hazard model. Time to event was calculated as time from diagnosis to first event or last follow-up. HRs for the Cox model were calculated accordingly with their 95% CIs. Sensitivity analysis was performed in regards to the use and duration of secondary prophylaxis as this information was missing in a significant number of patients; we, therefore, added the variable ‘ongoing secondary prophylaxis at follow-up’ in the final model. Significance was defined as p values <0.05. All data were verified and analysed at the Paris Cardiovascular Research Centre, INSERM 970, Paris, France, with the use of Statistical Analysis System software (N9.3).

RESULTS
Characteristics of patients with newly diagnosed RHD
Among the 679 patients with newly diagnosed RHD or ARF, 396 patients were included (figure 1). In total, 174 (43.9%) were male with a median age of 18 years (IQR 10–40). And 274 (71.9%) were indigenous Melanesians, 85 (22.3%) were Polynesians and 22 (5.8%) were of other ethnicity. Also, 205 (51.8%) presented with ARF. Based on standardised echocardiograms, 127 (32.1%) patients had mild heart valve disease, 131 (33.1%) had moderate valve disease and 138 (34.8%) had severe heart valve disease at the time of diagnosis. Mitral regurgitation was the most frequent heart valve disease, followed by aortic regurgitation and mitral stenosis (table 1). Multiple valve disease was present in 56.3% of cases. Moderate or severe tricuspid regurgitation was present in 4.5% of patients. 32 (8.1%) patients had permanent or paroxysmal atrial fibrillation. Thirty-seven (9.3%) patients had LVEF <60%. Characteristics of patients did not vary according to the year of RHD diagnosis (data not shown). Female indigenous patients were more likely to be unemployed (p=0.026) and presented more often with mitral stenosis (p=0.02) on univariate analysis compared with their male counterparts.

Among the 396 patients included, 106 (26.8%) presented with MACE at entry. There were 83/106 patients admitted with heart failure, among which 12 leading to urgent valve intervention (ie, within 30 days), 5 with concomitant stroke and 1 with concomitant stroke and urgent intervention. In addition, 12/106 patients were admitted with stroke; 10/106 underwent urgent intervention and 1 was admitted with stroke and underwent intervention.

Patients with no MACE at presentation were eligible for further analysis. Characteristics of these 290 patients with no MACE at entry are depicted in online supplementary table S2. Briefly, median age was 13 (IQR 10–31) years, 131 (45.2%) were male and 185 (63.8%) presented with ARF. Patients with ARF were younger (p<0.01), had more often a family history of ARF (p=0.01), less atrial arrhythmias (p<0.01) and had different heart valve disease pattern (p<0.01) compared with those with no ARF.

Outcomes and their determinants in patients with no MACES at entry
The 290 patients were followed up for median 4.08 (95% CI 1.84 to 6.84) years. Vital status and cardiac interventions data were available in all participants. Overall, there were 62 MACE; the annual incidence of MACE was 59.05‰ (95% CI 45.43 to 73.75); and median follow-up period to MACE was 10.49 (95% CI 2.04 to 35.03) months. Taken individually, the annual incidence of heart failure (34 patients) was 29.06‰ (95% CI 19.29 to 38.82). The annual incidence of stroke was 7.26‰ (95% CI 2.52 to 12.01) (see online supplementary table S3). The survival rate was 97.89% (CI 95% 95.97 to 99.64) at 4 years, and 96.21% (CI 95% 89.95 to 98.60) at 8 years after diagnosis. During the study period, seven patients (2.4%) died, of whom four from cardiovascular death (ie, incidence of RHD-attributable mortality of 3.16‰ (95% CI 0.06 to 6.26) per year). Causes of cardiovascular death included heart failure (N=2), stroke (N=1) and infective endocarditis (N=1). Other events were noted during the study period: atrial fibrillation in seven patients (2.4%), infective endocarditis in eight patients (2.8%), cardiogenic shock in two patients (0.7%) and major haemorrhage in eight patients (2.8%). Among the 59 women in
Valvular heart disease

Figure 2  Kaplan–Meier survival free of major cardiovascular events (including heart valve interventions, heart failure, stroke, peripheral embolism and cardiovascular death) according to the severity of heart valve disease on echocardiogram at diagnosis.

childbearing age (ie, 15–45 years of age), 9 (15.2%) developed complications during subsequent pregnancies.

Among the 290 patients, secondary prophylaxis was prescribed at least at one point in time in 235 (83.0%) patients, no secondary prophylaxis was ever prescribed in 48 (17.0%) patients (missing data in 7 cases). Continuation of secondary prophylaxis was reported in 159 out of 222 (71.6%) patients (missing data in 7 cases). Continuation of secondary prophylaxis was ever prescribed in 48 (17.0%) patients in regards to ethnicity)

Table 2  Univariate analysis of factors associated with major cardiovascular events in 280 patients (missing data in 10/290 patients in regards to ethnicity)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Univariate HR (95% CI)</th>
<th>Univariate p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild RHD</td>
<td>1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Moderate RHD</td>
<td>8.1 (2.8 to 23.3)</td>
<td></td>
</tr>
<tr>
<td>Severe RHD</td>
<td>24.9 (8.8 to 70.8)</td>
<td></td>
</tr>
<tr>
<td>ARF vs no ARF</td>
<td>0.17 (0.09 to 0.30)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex (male)</td>
<td>0.8 (0.5 to 1.3)</td>
<td>0.34</td>
</tr>
<tr>
<td>Melanesian*</td>
<td>0.6 (0.4 to 1.1)</td>
<td>0.09</td>
</tr>
<tr>
<td>Age group (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5–20</td>
<td>1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>21–40</td>
<td>6.1 (2.9 to 12.41)</td>
<td></td>
</tr>
<tr>
<td>&gt;40</td>
<td>15.2 (8.0 to 28.8)</td>
<td></td>
</tr>
<tr>
<td>Ongoing secondary prophylaxis at FU*</td>
<td>0.13 (0.07 to 0.23)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Analysis for 217 patients.
ARF, acute rheumatic fever; FU, follow-up; RHD, rheumatic heart disease.

valvuloplasty, 5 (1.7%) mitral valve repair, 23 (7.9%) mitral valve replacement and 18 (6.2%) aortic valve replacement.

Characteristics significantly associated with MACE on multivariate analysis were the severity of heart valve disease at diagnosis (moderate vs mild HR 3.36, 95% CI 1.10 to 10.34; severe vs mild RHD 10.54, 95% CI 3.50 to 31.75, p<0.001), ARF at diagnosis (HR 0.46, 95% CI 0.24 to 0.89, p=0.02) and older age (21–40 vs 5–20 years old, HR 2.88, 95% CI 1.34 to 6.22; >40 vs 5–20 years old, HR 5.15, 95% CI 2.44 to 10.88, p<0.001) (figure 2, tables 2 and 3). After sensitivity analysis including secondary prophylaxis at the time of interview, two factors remained associated with outcomes: the severity of heart valve disease at diagnosis (moderate vs mild HR 3.22, 95% CI 0.90 to 11.49; severe vs mild RHD HR 11.07, 95% CI 3.21 to 38.22, p<0.001) and ongoing secondary prophylaxis at the time of interview (HR 0.33, 95% CI 0.14 to 0.79, p=0.013) (table 4).

DISCUSSION

We present here contemporary longitudinal data of patients admitted for RHD with the longest follow-up published to date. A significant proportion of patients (~25%) are still diagnosed at the onset of complications or at a stage when heart valve interventions are urgently needed. Half our patients presented with ARF. Approximately 20% needed heart valve intervention during the study period (median follow-up ~4 years). The annual incidence of complications and RHD-related mortality is high even in young patients who are initially admitted with uncomplicated RHD (~59‰ per year). We identify factors associated with outcomes: the severity of heart valve disease at diagnosis and continuation of secondary prophylaxis. Our results suggest that early diagnosis and secondary prophylaxis is cornerstone to reducing the burden of RHD.

Our study population is young and mainly indigenous, in keeping with population-based studies in the region. The characteristics of our population are overall consistent with the two other RHD hospital-based registers published to this date. Half our patients had ARF, as in other upper-middle-income settings. A history of ARF is more often reported in wealthier settings, suggesting the impact of health-care services in the ability to diagnose the condition. The heart valve disease pattern is slightly different from that described in the heart of Soweto study, with a higher proportion of mild mitral and aortic regurgitation in our study, likely due to the
Table 4  Sensitivity analysis of factors associated with major cardiovascular events in 217 patients (overall missing data in 73/290 patients in regards to secondary prophylaxis in 63 cases and ethnicity in 10 cases)

<table>
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<th>Factor</th>
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<td>11.07 (3.21 to 38.22)</td>
<td></td>
</tr>
<tr>
<td>ARF vs no ARF</td>
<td>0.54 (0.25 to 1.14)</td>
<td>0.10</td>
</tr>
<tr>
<td>Sex (male)</td>
<td>0.82 (0.47 to 1.45)</td>
<td>0.50</td>
</tr>
<tr>
<td>Melanesian</td>
<td>1.07 (0.54 to 2.13)</td>
<td>0.84</td>
</tr>
<tr>
<td>Age group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5–20 years</td>
<td>1</td>
<td>0.31</td>
</tr>
<tr>
<td>21–40 years</td>
<td>1.97 (0.79 to 4.92)</td>
<td></td>
</tr>
<tr>
<td>&gt;40 years</td>
<td>2.10 (0.72 to 6.10)</td>
<td></td>
</tr>
<tr>
<td>Ongoing secondary prophylaxis at FU</td>
<td>0.33 (0.14 to 0.79)</td>
<td>0.013</td>
</tr>
</tbody>
</table>

ARF, acute rheumatic fever; FU, follow-up; RHD, rheumatic heart disease.

Strengths and limitations

We provide the longest follow-up data from a hospital-based RHD register including precise clinical features of the condition such as echocardiographic baseline characteristics. We used standardised criteria for RHD diagnosis and heart valve disease quantification. The study settings allowed accurate assessment of outcomes, the population being captive in a country with national mortality, overseas referrals for heart surgery and secondary prophylaxis registers. This study consistently adds to the knowledge on the burden of RHD and highlights the relatively low mortality but high morbidity of the condition in a country where medical and surgical interventions are accessible. We acknowledge, however, a series of limitations. We describe here outcomes of patients admitted to a tertiary centre with potential referral bias of most severe cases. However, many children with ARF and mild mitral regurgitation were admitted to our institution given that it is the only centre providing paediatric care.

Approximately 55% of our patients were under secondary prophylaxis at follow-up. All our patients had been diagnosed with RHD <10 years before. One-fourth of our patients were, however, ≥40 years old in whom secondary prophylaxis was usually stopped. The majority of children and adolescents were on secondary prophylaxis at the time of interview. However, as in other hospital-based or population-based registers, there is room for improvement in terms of adherence to guidelines.

We identified two factors associated with poor outcomes. The severity of valve disease at diagnosis is understandably associated with adverse events, such as heart failure or need of heart valve interventions. Continuation of secondary prophylaxis was associated with better outcomes. Patients diagnosed with RHD during an ARF attack presented better outcomes, but this was not confirmed when adjusting for secondary prophylaxis. Our results, therefore, stress the importance of early diagnosis, when heart valve disease is still mild, which bears excellent prognosis. Identifying children with ARF is an opportunity to limit the burden of disease. Our results may also suggest that screening for these mild but definite lesions could be of interest in order to avoid disease progression and future complications.

Key messages

What is already known on this subject?
Rheumatic heart disease remains the leading acquired heart disease in the young worldwide, affecting patients in developing countries and among indigenous populations. Studies have mainly focused on population-based prevalence and mortality estimates. There is little knowledge on the morbidity related to rheumatic heart disease.

What might this study add?
We provide contemporary data supporting low mortality but high morbidity among indigenous populations affected by rheumatic heart disease in high-income settings. We identified two factors associated with cardiovascular outcomes: diagnosis at an early stage and continuation of secondary prophylaxis.

How might this impact on clinical practice?
This study provides further demonstration that rheumatic heart disease is a burden among young indigenous populations. Early diagnosis and secondary prophylaxis is cornerstone to limit the advent of complications and need for cardiac surgery, and should promote prevention policies.

Table 4  Sensitivity analysis of factors associated with major cardiovascular events in 217 patients (overall missing data in 73/290 patients in regards to secondary prophylaxis in 63 cases and ethnicity in 10 cases)
specialist care. We collected part of the data retrospectively, and missing data have contributed to diminishing the sample study. Diagnosis of ARF was at the discretion of the physician and did not necessarily fulfill modified Jones or Australasian criteria. However, all presented with definite RHD according to standardized WHF criteria, which implies at least one major criterion for ARF. Restricting our study population to patients with strict echocardiographic criteria further reduced our sample size. We focused our analysis on patients admitted with uncomplicated RHD, which underestimates the burden of the disease, but allows the identification of factors associated with the advent of adverse outcomes.

CONCLUSIONS

Newly diagnosed RHD is often revealed by complications, and outcomes are poor at follow-up especially when heart valve disease is moderate or severe and in the absence of secondary prophylaxis. Our results add to the limited data on the burden of RHD and should warrant early diagnosis when heart valve disease is still mild to introduce and continue secondary prophylaxis.

Acknowledgements

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Contributors

All authors have been involved in one or more of the following: conception and design, acquisition of data or analysis and interpretation of data, drafting the article or revising it critically for important intellectual content, final approval of the enclosed manuscript.

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Competing interests

None declared.

Patient consent

Institut National de la Santé et de la Recherche Médicale waived written consent.

Ethics approval

IRB Ethical Review Committee of the Institut National de la Santé et de la Recherche Médicale (French Institute of Health and Medical Research), Paris, France.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data sharing statement

All data are available upon request from the corresponding author.

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