NATIONAL SURVEILLANCE FOR HEPATITIS B INDICATORS

Measuring the progress towards the targets of the National Hepatitis B Strategy

Annual Report 2021

WHO Collaborating Centre for Viral Hepatitis
The Peter Doherty Institute for Infection and Immunity
Prepared by: Anh Nguyen, Nicole Romero, Nicole Allard, Jennifer MacLachlan and Benjamin Cowie

CONTACT INFORMATION

WHO Collaborating Centre for Viral Hepatitis
Victorian Infectious Diseases Reference Laboratory, Doherty Institute
Contact: Nicole Romero
Level 5, 792 Elizabeth Street, Melbourne VIC 3000
Email: nicole.romero@mh.org.au

FUNDING

The Australian Government Department of Health and Aged Care
While the Australian Department of Health provides financial support for this project, the material contained or the views expressed in this resource should not be taken to represent the views of the Australian Department of Health.

ACKNOWLEDGMENTS

We would like to acknowledge the following national jurisdictional organisations for the provision of the data used in preparing the statistics contained in this report:

- Australian Bureau of Statistics
- Australian Government Department of Health and Aged Care
- Australian Government Department of Services Australia
- Australian Government Department of Social Services

We would also like to acknowledge Kelly Hosking and Jane Davies from the Hepatitis B Sero-coding Project, Northern Territory Government and Menzies School of Health Research for providing Aboriginal and Torres Strait Islander specific data and context. Additionally, we would like to acknowledge the members of the WHO Collaborating Centre for Viral Hepatitis' Epidemiology and Public Health Research Advisory Group for their guidance.

SUGGESTED CITATION

Nguyen A, Romero N, Allard N, MacLachlan JH, Cowie BC. National Surveillance for Hepatitis B Indicators: Measuring the progress towards the targets of the National Hepatitis B Strategy – Annual Report 2021. Melbourne: WHO Collaborating Centre for Viral Hepatitis, The Doherty Institute; 2022.

ABBREVIATIONS

ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
CHB	Chronic hepatitis B
DC	Decompensated cirrhosis
DSS	Department of Social Services
FoI	Force of infection
GHSS	Global Health Sector Strategy
HCC	Hepatocellular carcinoma
LHS	Latin-hypercube sampling
MBS	Medicare Benefits Schedule
National Strategy	Australia's 3rd National Hepatitis B Strategy 2018 - 2022
NNDSS	National Notifiable Diseases Surveillance
NOM	Net overseas migration
NSW	New South Wales
NT	Northern Territory
PBS	Pharmaceutical Benefits Scheme
PR	Plausible range
QLD	Queensland
SA	South Australia
TAS	Tasmania
VIC	Victoria
WA	Western Australia
WHO	World Health Organization
COVID-19	Coronavirus disease 2019

CONTENTS

EXECUTIVE SUMMARY

CHRONIC HEPATITIS B PREVALENCE

- In 2021, an estimated 200,385 people were living with chronic hepatitis B (CHB) in Australia, representing 0.78% of the population.
- Substantial changes to the number of people migrating into and out of Australia will have an impact on the future number of people living with CHB. Due to the unpredictability of migration patterns in the next few years, modelled projection estimates will be updated as new information becomes available.

CHRONIC HEPATITIS B DIAGNOSIS

- An estimated 145,281 (72.5%) people living with CHB in 2021 had been diagnosed.
- The proportion diagnosed in 2021 was below the 2022 National Strategy target of 80% diagnosed, with 15,206 more people required to reach this target.
- At the current rate of progress, Australia will not reach the National Strategy 2022 diagnosis target of 80% until 2030, and not reach the WHO's 2030 diagnosis target of 90% until 2039.
- Australia is estimated to have met the WHO 2025 target of diagnosing 60% of people living with CHB in 2004.

CHRONIC HEPATITIS B ENGAGEMENT IN CARE

- During 2021, an estimated 52,121 (26.0%) people were engaged in care for their CHB, receiving either antiviral treatment or the recommended annual viral load test.
- The proportion engaged in care in 2021 remains substantially below the 2022 National Strategy target of 50% in care, with 48,184[i] more people required to be in care to reach this target.
- At the current rate of progress, Australia will not reach the National Strategy 2022 target of 50% in care until 2043.

CHRONIC HEPATITIS B TREATMENT

- In 2021, 25,410 (12.7%) people were dispensed drugs for the treatment of hepatitis B through the Pharmaceutical Benefits Scheme.
- In May 2020, hepatitis B treatment during pregnancy was added as an indication to the Pharmaceutical Benefits Scheme, which increased the number of people receiving treatment through the PBS.
- In 2021, 29.4% of people living with CHB in Australia were estimated to be eligible for treatment.
- The proportion on treatment in 2021 remains below the 2022 National Strategy target of 20% of all people living with CHB being on treatment, with 14,712[1] more people requiring treatment to reach this target.
- At the current rate of progress, Australia will not reach the National Strategy 2022 treatment target of 20% until 2032 and not reach the WHO 2030 treatment target of 80% of those eligible for treatment until 2040.

[i] Based on the projected modelled estimate of 200,609 people living with CHB in 2022

DEATHS ATTRIBUABLE TO CHRONIC HEPATITIS B

- The modelled number of deaths attributable to CHB in 2021 was 453. Three hundred and eighty five (385) were attributable to hepatocellular carcinoma (HCC), while 68 were due to decompensated cirrhosis (DC).
- The National Strategy target of 30% reduction in attributable deaths by 2022 (when compared to the end of 2017) will not be reached under current trends. Given an ageing population, substantial increases in future treatment uptake are needed to reduce mortality.
- It is estimated that at the current rate of progress, Australia will reach the National Strategy 2022 and WHO 2030 targets after 2050.

JURISDICTIONAL DISPARITIES

- Substantial differences in estimated prevalence, access to care and burden of disease were noted between states and territories in 2021:
    - Prevalence of CHB ranged from 0.27% (TAS) to 1.73% (NT).
    - The proportion diagnosed ranged from 50.8% (TAS) to 77.6% (NSW).
    - The proportion in care ranged from 12.5% (WA) to 30.5% (ACT), with the proportion of all those living with CHB receiving antiviral treatment ranging from 8.5% (WA) to 15.7% (ACT).

INTRODUCTION

In Australia approximately 0.9% of the population is living with chronic hepatitis B (CHB) [1-3], with people born overseas and Aboriginal and Torres Strait Islander peoples representing three quarters of those affected[4]. CHB is a significant public health burden and is now the most prevalent blood-borne viral infection in Australia[4,5]. CHB is a leading cause of liver cancer, the 6th most common cause of cancer mortality in Australia[6]. Substantial improvements in access to appropriate care, monitoring and treatment are required to address hepatitis B related mortality nationally.

Australia's National Hepatitis B Strategies have been fundamental to guiding the response to hepatitis B since 2010, with significant progress occurring over this period. The 3rd National Hepatitis B Strategy 2018 - 2022[7] (National Strategy), released in 2018 sets goals to make significant progress towards eliminating hepatitis B as a public health threat, including reducing the burden of disease and eliminating the negative impact of stigma, discrimination, and legal and human rights issues on people's health. The National Strategy highlights priority areas and populations, and outlines targets to measure progress throughout the span of the strategy. New strategies post 2022 are in the process of being finalised.

The targets under the current National Strategy reported in this analysis are listed in Table 1 below, which includes cascade of care indicators.

Table 1. Australia's National Hepatitis B Strategy 2022 targets.

Targets addressed in this report	2022 targets
People living with chronic hepatitis B who are diagnosed	80%
People living with chronic hepatitis B receiving care	50%
People living with chronic hepatitis B receiving antiviral treatment	20%
Hepatitis B attributable mortality	30% reduction*
Targets not addressed in this report	
Hepatitis B childhood vaccination coverage	95%
Newly acquired hepatitis B infections across all age groups	50%
Experience of stigma among people living with hepatitis B	Reduce

**Reduction from 2017*

Measuring the progress towards the targets of the National Strategy will allow current gaps to be identified, and priority areas to be highlighted to help shape the public health and policy response to hepatitis B in Australia.

Australia has also endorsed the World Health Organization (WHO) Global Health Sector Strategy (GHSS) on Viral Hepatitis for the period 2016 – 2021[8], and recently endorsed the strategy for 2022 – 2030[9], which calls for the elimination of hepatitis B as a public health threat by 2030. The indicators and targets included in this strategy span impact, programmatic coverage and policy milestones. This report will only cover a select number of indicators that are generated through our model. The new strategy has included new 2025 targets as a roadmap to achieving the 2030 targets, and updated treatment and mortality targets for 2030. The updated treatment target has changed, to require reporting of treatment uptake as the proportion of people living with CHB on treatment who are eligible *and* diagnosed; this is compared to the previous target which referred only to eligibility status, not diagnosis. Due to uncertainties in Australia of the proportion

diagnosed, proportion eligible for treatment, and likely variable treatment eligible between populations that have and have not been diagnosed, estimates for this target will not be reliable. Given this, the report will focus on the WHO GHSS on Viral Hepatitis 2016-2021 target. The targets reported on are listed in Table 2 below.

Table 2. The WHO Global Health Sector Strategy on Viral Hepatitis B targets (2016-2021 and 2022-2030)

Targets addressed in this report	2025 target	2030 targets
People living with chronic hepatitis B who are diagnosed[1,2]	60%[2]	90%[1,2]
People living with chronic hepatitis B eligible for antiviral treatment who are receiving treatment	-	80%[1]
People living with chronic hepatitis B diagnosed and eligible for antiviral treatment who are receiving treatment	50%[2]	80%[2]
Hepatitis B attributable mortality	7 deaths per 100 000[2]	4 deaths per 100 000[2]

[1]*WHO GHSS on Viral Hepatitis 2016 – 2021*
[2]*WHO GHSS on Viral Hepatitis 2022 - 2030*

REPORT BACKGROUND

This report summarises work undertaken by the WHO Collaborating Centre for Viral Hepatitis at the Doherty Institute on the Surveillance for Hepatitis B Indicators Project funded by The Australian Government Department of Health and Aged Care. The objective of this project is to develop disease burden estimation and mathematical modelling approaches to inform the surveillance, monitoring, and evaluation of progress towards achieving the objectives of the 3rd National Hepatitis B Strategy 2018 - 2022 and reporting against Hepatitis B Indicators in the National Blood-Borne Viruses and Sexually Transmissible Infections Surveillance and Monitoring Plan 2018 - 2022. This report will not assess vaccination, reduction in local transmission or stigma targets specifically. Further reporting against these indicators can be found in the National Viral Hepatitis Mapping Reports[4], the Kirby Institute's Annual Surveillance Reports[10], and the Centre for Social Research in Health Stigma Indicators Monitoring Project Reports[11].

This report for the year 2021 is the fifth publicly available National Surveillance for Hepatitis B Indicators Annual Report. All reports can be accessed here.

REPORT UPDATES

Estimates included in this report are derived using a mathematical model for the natural history of hepatitis B in Australia, extending on previous work[2,3,12,13]. The model accounts for diversity in prevalence and impact of overseas migration, incorporating detailed disease phase dynamics, and examining the impact of domestic and overseas vaccination programs, together with the impact of antiviral treatment on mortality attributable to CHB at a population level. Further information regarding the model can be found in the associated paper[2].

To ensure estimates most accurately reflect the current epidemiology and clinical pattern of CHB in Australia, data inputs and assumptions are updated annually to incorporate new information. For that reason historical indicator estimates provided in this report will differ from previous outputs reported in the Kirby Institute's Annual Surveillance Reports,[10] the Doherty Institute's National Viral Hepatitis Mapping Project Reports[4,5,14], and the National Surveillance for Hepatitis B Indicators: Annual Report[15-18].

Several improvements were made to the model since 2020 estimates were reported. These include:

- Updates were made to historic CHB prevalence for countries with the highest numbers of people living with CHB in Australia based on newly available data and re-examination of historic data sources. This update has lowered the prevalence in migrants entering Australia from 1951 – 1990 in several key countries, and for countries where specific prevalence estimates were applied to year of birth, have lowered estimates for those born before 2000. This change better reflects the true prevalence of CHB in incoming migrants to Australia. This has impacted the estimated number of people living with CHB and attributable mortality, which has also had a flow on effect on diagnosis, care and treatment uptake estimates.
- The transition rate from HCC to resolved for those on treatment has been decreased to more accurately reflect the true likelihood of transition. This update has increased the estimated number of deaths due to CHB.
- Projected estimates of future net overseas migration (NOM) included in the model were updated to consider the impact of COVID-19[19]. Previous 2020 estimates assumed that COVID-19 would have a moderate-term impact on migration numbers in the future. However, based on real world data, COVID-19 appears to have had a short-term impact on migration. This has been incorporated and updated for future projections within the model.
- Hepatitis B treatment during pregnancy was added to the Pharmaceutical Benefits Scheme in mid-2020, and these items have been included in treatment figures in this year's report.
- Based on findings from efforts to de-duplicate hepatitis B notifications in New South Wales and Victoria, a conservative estimate of 8% of duplicate notifications was applied to revise the estimated proportion diagnosed in all states and territories.

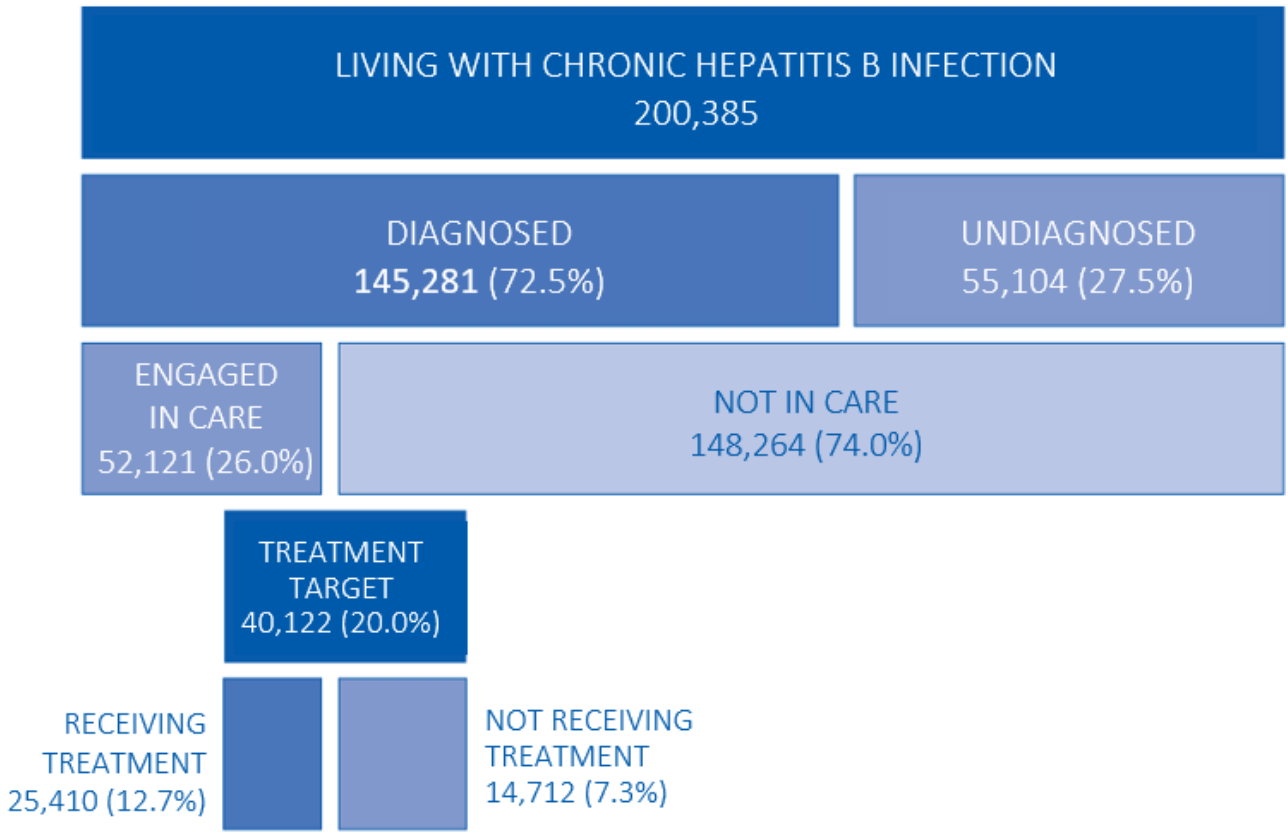
SUMMARY OF ESTIMATES

Table 3. Summary of hepatitis B indicator estimates, 2021.

State/ Territory	People living with CHB	Diagnosed (%)	In care (%)	Treatment uptake (%)	Total deaths attributable to CHB	HCC deaths attributable to CHB	DC deaths attributable to CHB
ACT	2,840	71.5%	30.5%	15.7%	<10	<10	<10
NSW	72,058	77.6%	30.7%	15.1%	161	141	21
NT	4,325	68.0%	23.7%	10.8%	11	<10	<10
QLD	31,665	71.9%	20.5%	9.6%	71	59	13
SA	10,181	64.0%	18.4%	10.9%	22	18	<10
TAS	1,566	50.8%	19.2%	9.1%	<10	<10	<10
VIC	56,837	63.5%	29.5%	13.3%	129	111	18
WA	20,912	56.7%	12.5%	8.5%	49	40	<10
Australia	200,385	72.5%	26.0%	12.7%	453	385	68

Note: Jurisdictional estimates were standardized to ensure the sum of indicator variables across the jurisdictions aligns with the modelled national estimate.
Estimates less than 10 have been suppressed due to difficulties in ensuring accuracy in small numbers.

Figure 1. Chronic hepatitis B cascade of care, Australia, 2021.



PROGRESS TOWARDS NATIONAL CASCASE OF CARE TARGETS

Despite the continued increase in the number of people diagnosed with chronic hepatitis B, and in those receiving antiviral treatment, Australia will not reach the 2022 targets contained in the current National Strategy, as shown in Table 4 below.

Table 4. Heat map of progress towards National Hepatitis B Strategy 2018 – 2022 targets

Progress towards National Hepatitis B Strategy 2018 - 2022 targets				
Year	**Diagnosis**	**Care**	**Treatment**	**Mortality**
	Proportion of people with CHB diagnosed	**Proportion of people with CHB who received treatment or monitoring**	**Proportion of people with CHB who received treatment**	**Percentage reduction of CHB attributable mortality from 2017**
	2022 Target - 80%	2022 Target - 50%	2022 Target - 20%	2022 Target - 30% reduction
2017	68.3%	24.2%	9.9%	-
2018	68.7%	25.0%	10.6%	-0.5%
2019	68.9%	25.3%	11.1%	-1.4%
2020	70.4%	24.9%	11.8%	-3.2%
2021	72.5%	26.0%	12.7%	-5.1%
2022	**73.8%**	**27.2%**	**13.3%**	**-6.3%**
2023	74.6%	28.1%	13.8%	-7.0%
2024	75.4%	29.0%	14.4%	-7.7%
2025	76.2%	29.9%	15.1%	-8.4%
2026	77.0%	30.9%	15.9%	-9.0%
2027	77.9%	31.8%	16.6%	-9.7%
2028	78.8%	32.8%	17.4%	-10.4%
2029	79.7%	33.8%	18.2%	-11.1%
2030	80.7%	34.8%	19.1%	-11.6%
2031	81.6%	35.9%	19.9%	-12.3%
2032	82.6%	37.0%	20.7%	-12.8%
2033	83.6%	38.1%	21.4%	-13.2%
2034	84.7%	39.2%	22.2%	-13.7%
2035	85.7%	40.4%	22.9%	-13.9%

Projected year to reach target	2030	2043	2032	>2050

Key: Colour gradient represents progress towards reaching the target. Green = target achieved, Red = substantial progress still required to meet target.

PROGRESS TOWARDS GLOBAL HEALTH SECTOR STRATEGY TARGETS

Australia has already met or is on track to meet WHO's 2025 GHSS on Viral Hepatitis targets. Australia met the 2025 target of diagnosing 60% of people living with CHB in 2004 and the target of treating 50% of eligible people who have been diagnosed with CHB in 2019, noting there are many uncertainties in the estimation of this indicator. Additionally, the current CHB attributable mortality is already well below the target rates of 7 per 100,000 by 2025 and 4 per 100,000 by 2030. However, Australia is not currently on track to reach WHO's 2030 diagnosis and treatment targets, as shown in Table 5 below.

Table 5. Heat map of progress towards WHO GHSS on Viral Hepatitis 2030 targets

Year	Diagnosis	Treatment		Mortality
	Proportion of people with CHB diagnosed[1,2]	Proportion of people eligible for CHB treatment who are receiving treatment[1]	Proportion of people diagnosed and eligible for CHB treatment who are receiving treatment[2]	CHB attributable mortality rate (deaths per 100,000)[2]
	2030 target - 90%	2030 target - 80%	2030 target - 80%	2030 target - 4 per 100,000
2017	68.3%	35.0%	47.1%	1.74
2018	68.7%	37.2%	49.8%	1.72
2019	68.9%	38.9%	52.0%	1.71
2020	70.4%	40.6%	53.1%	1.74
2021	72.5%	43.2%	54.8%	1.76
2022	73.8%	44.8%	55.8%	1.75
2023	74.6%	46.3%	57.1%	1.74
2024	75.4%	48.1%	58.7%	1.73
2025	76.2%	50.1%	60.5%	1.72
2026	77.0%	52.3%	62.4%	1.71
2027	77.9%	54.5%	64.4%	1.70
2028	78.8%	56.8%	66.3%	1.69
2029	79.7%	59.1%	68.2%	1.68
2030	**80.7%**	**61.4%**	**70.0%**	**1.67**
2031	81.6%	63.7%	71.8%	1.66
2032	82.6%	65.9%	73.4%	1.65
2033	83.6%	68.0%	74.8%	1.63
2034	84.7%	70.1%	76.2%	1.62
2035	85.7%	72.1%	77.4%	1.61
Projected year to reach target	2038	2040	2038	Achieved

Key: Colour gradient represents progress towards reaching the target. Green = target achieved, Red = substantial progress still re quired to meet target.

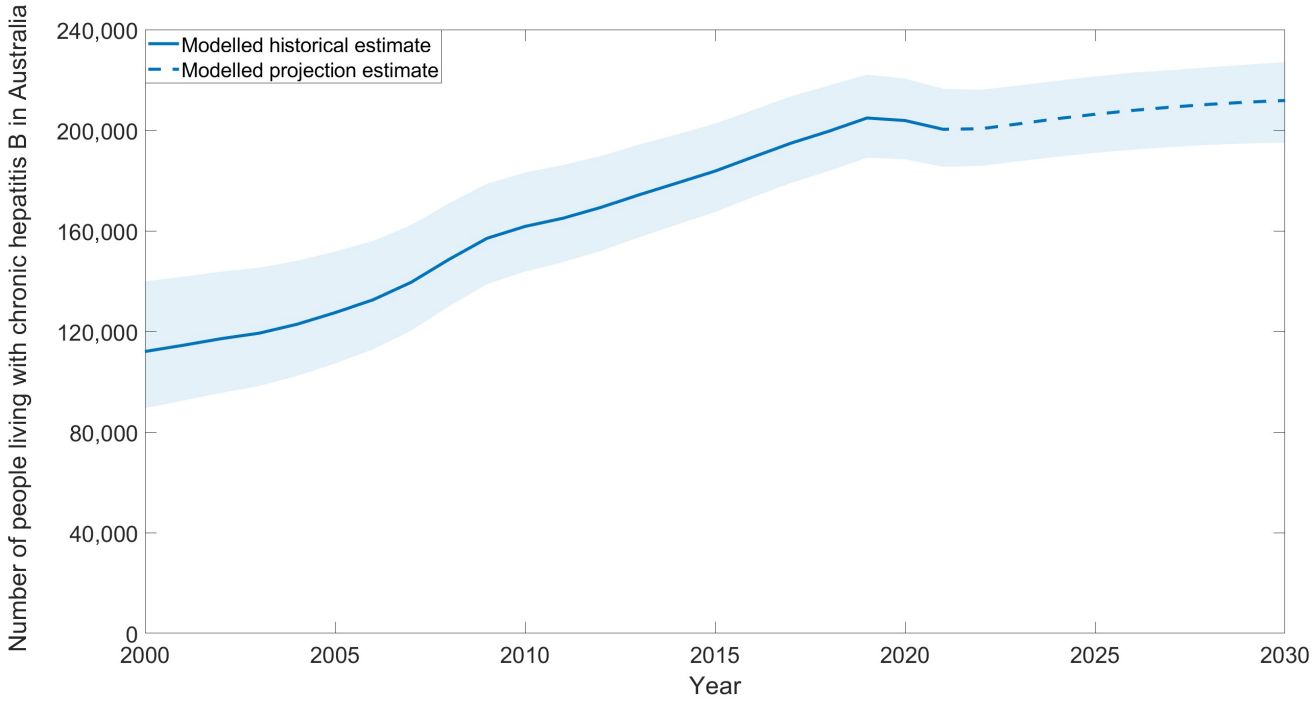
[1]WHO GHSS on Viral Hepatitis 2016 – 2021, [2]WHO GHSS on Viral Hepatitis 2022 - 2030

CHRONIC HEPATITIS B PREVALENCE

NATIONAL ESTIMATES

During 2021, an estimated 200,385 (plausible range (PR) 185,479 to 216,476) people were living with CHB in Australia, representing 0.78% of the population. Modelled estimates show that the number of people living with CHB has increased over time in Australia, with an additional 88,340 people living with CHB in 2021 when compared to 2000 (Figure 2, Appendix Table A1). Due to the impacts of COVID-19 on migration in 2020, the estimated number of people living with CHB has dropped for the first time since 1994, and in 2021 was still below the 2019 peak of 204,878 people living with CHB.

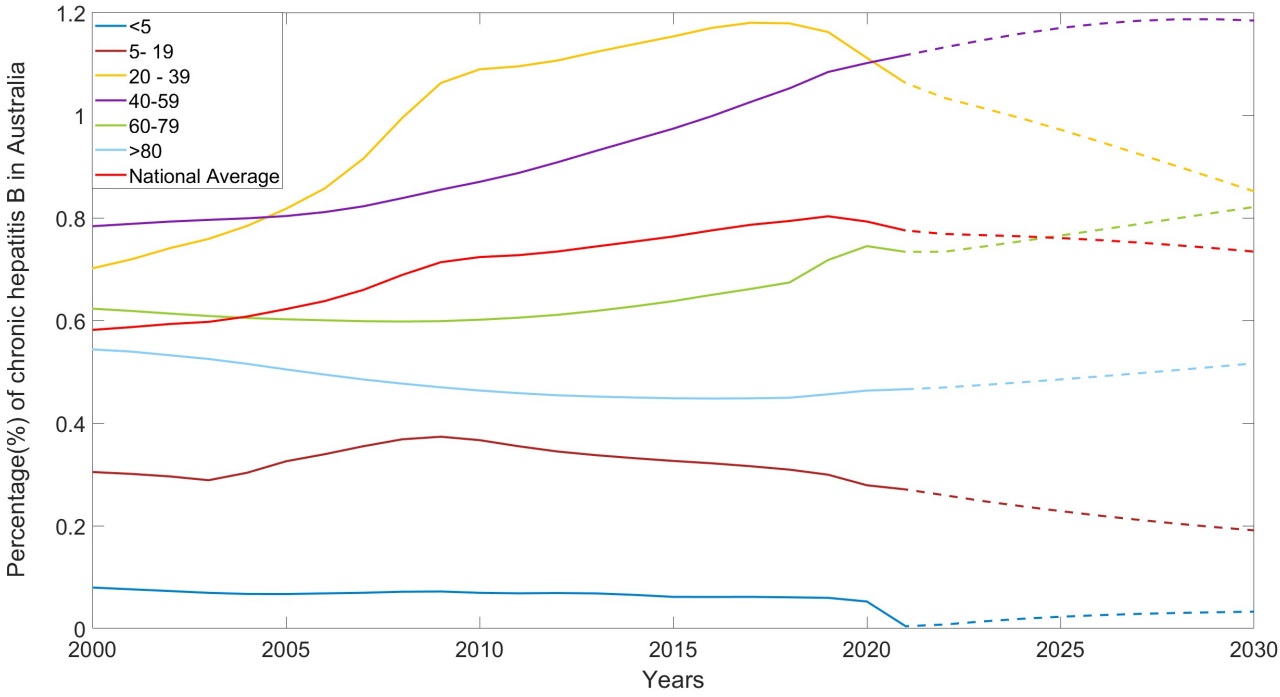
Figure 2. Estimated number of people living with chronic hepatitis B in Australia, 2000 – 2030.



Shaded areas show plausible ranges of estimates determined by the 10th and 90th percentiles of simulations.

The prevalence of CHB has increased substantially over time, from 0.60% in 1970 to 0.78% in 2021, and this trend varies according to age group (Figure 3). The majority of people living with CHB in Australia were born overseas and acquired hepatitis B in childhood prior to migration, and therefore changes in total numbers, countries of origin, and age distributions of Australia's migrant population will affect the estimates of hepatitis B in Australia, for example due to the COVID-19 pandemic. The decreasing trends observed (from 1991 onwards in the under 5-year age group, and from 2009 onwards in the 5 – 19 years age group) highlights the impact of childhood hepatitis B vaccination programs both domestically and internationally. Further detailed information on the epidemiology of CHB in Australia according to priority groups can be found in the Viral Hepatitis Mapping Project National Report[4,5,20].

Figure 3. Estimated prevalence of chronic hepatitis B in Australia by age group, 2000 – 2030.



Dotted lines represent modelled projection estimates.

During 2021, the distribution of people living with CHB in each disease phase (without cirrhosis) was estimated to be 23.6% in immune tolerance, 5.5% in immune clearance, 47.0% in immune control and 17.6% in immune escape phase. In addition, an estimated 5.3% of people living with CHB had cirrhosis and 1.0% had advanced liver disease (hepatocellular carcinoma or decompensated cirrhosis). The proportion of people living with CHB in each disease phase varies by age group (Appendix Figure A1) and has remained stable for several years. These estimates have implications for public health messaging and policy around CHB management and treatment eligibility to prevent liver disease and the importance of engaging priority populations, allowing prioritisation of those at greatest risk of disease progression.

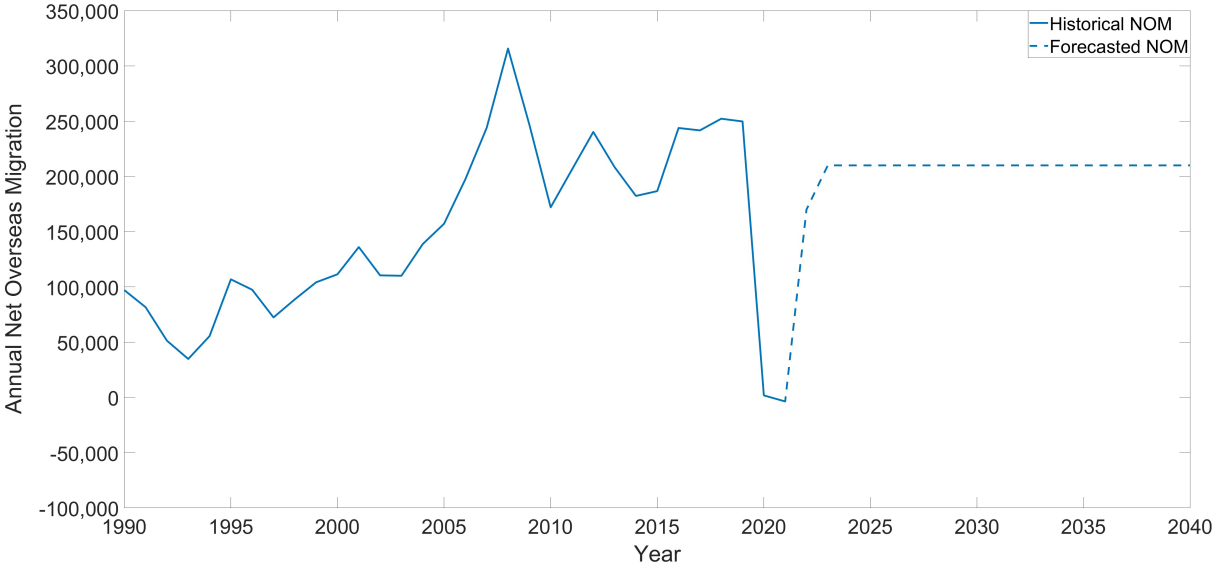
Uncertainty in estimated future number of people living with CHB in Australia due to impacts of COVID-19 on migration

Changing patterns of migration to Australia, and the impact of infant hepatitis B vaccination programs in countries with high prevalence of CHB, have a significant impact on projections of the number of people living with CHB in Australia. These future migration patterns are dependent on various factors including local and international economic conditions, government policy, and of relevance, the impact of the COVID-19 pandemic on travel and migration. In our 2020 report, we explored the effect of changes in migration numbers due to COVID-19 on the future projected number of people living with CHB by investigating different possible scenarios of future net overseas migration proposed by Wilson and colleagues[19]. These scenarios include:

I. Short impact scenario where migration and demographic trends bounce back strongly over 2 – 3 years
II. Moderate impact scenario where the effects of a migration downturn are felt for about 5 years; and
III. Longer impact scenario with an extended migration depression of up to a decade.

Our previous report assumed that future net overseas migration would follow the moderate impact scenario for our future projections. The net overseas migration data for 2021 shows a net loss (-3,610) at the end of the year. With international travel returning to pre-pandemic conditions, net overseas migration is also expected to increase again in 2022, which aligns to the estimation from the short impact scenario, therefore this scenario has been used for our future projections (Figure 4).

Figure 4. Historical and projected national net overseas migration (NOM) numbers 1991 – 2040

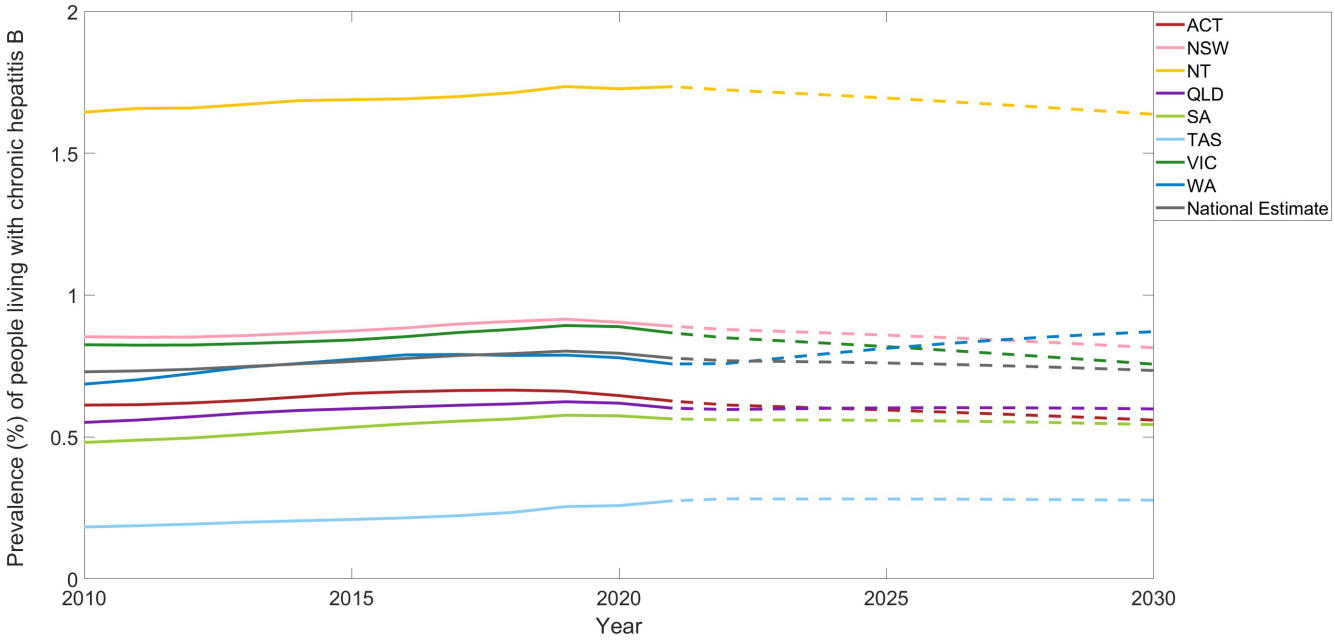


STATE AND TERRITORY ESTIMATES

Modelled estimates show that the number of people living with CHB has generally increased over time in all jurisdictions. Due to the impact of COVID-19 on migration, the number of people living with CHB has slightly declined since the end of 2019 in ACT, NSW and VIC and declined from 2020 in QLD, SA and WA (Appendix Table A1).

Prevalence across jurisdictions varies due to differing population demographics, with the highest prevalence in 2021 estimated in NT (1.73%) and the lowest in TAS (0.27%). Among other jurisdictions, NSW (0.89%) and VIC (0.87%) had estimated prevalence above the national average (0.78%), and WA (0.76%), ACT (0.63%), QLD (0.60%) and SA (0.56%) were below (Table 6, Figure 5). Future projections show the CHB prevalence will decrease or stay stable in all jurisdictions except for WA (0.11% increase by 2030) and the fastest decrease in CHB prevalence will take place in the VIC and NT (0.11% and 0.10% decrease by 2030, respectively). This may be partly attributable to the differences in historic and projected migration patterns over time between these jurisdictions, which are potentially subject to change.

Figure 5. Prevalence of chronic hepatitis B by jurisdiction, 2010 – 2030



Dotted lines represent modelled projection estimates.

Table 6. Estimated number of people living with chronic hepatitis B and prevalence by jurisdiction, 2021.

State/Territory	People living with CHB	Plausible range		Prevalence (%)
		Minimum	Maximum	
ACT	2,840	2,613	3,115	0.63%
NSW	72,058	66,460	78,083	0.89%
NT	4,325	4,226	4,439	1.73%
QLD	31,665	29,774	32,906	0.60%
SA	10,181	9,448	11,040	0.56%
TAS	1,566	1,429	1,694	0.27%
VIC	56,837	52,139	62,645	0.87%
WA	20,912	19,390	22,554	0.76%
Australia	200,385	185,479	216,476	0.78%

Note: Jurisdictional estimates were standardized to ensure the sum of indicator variables across the jurisdictions aligns with the modelled national estimate.

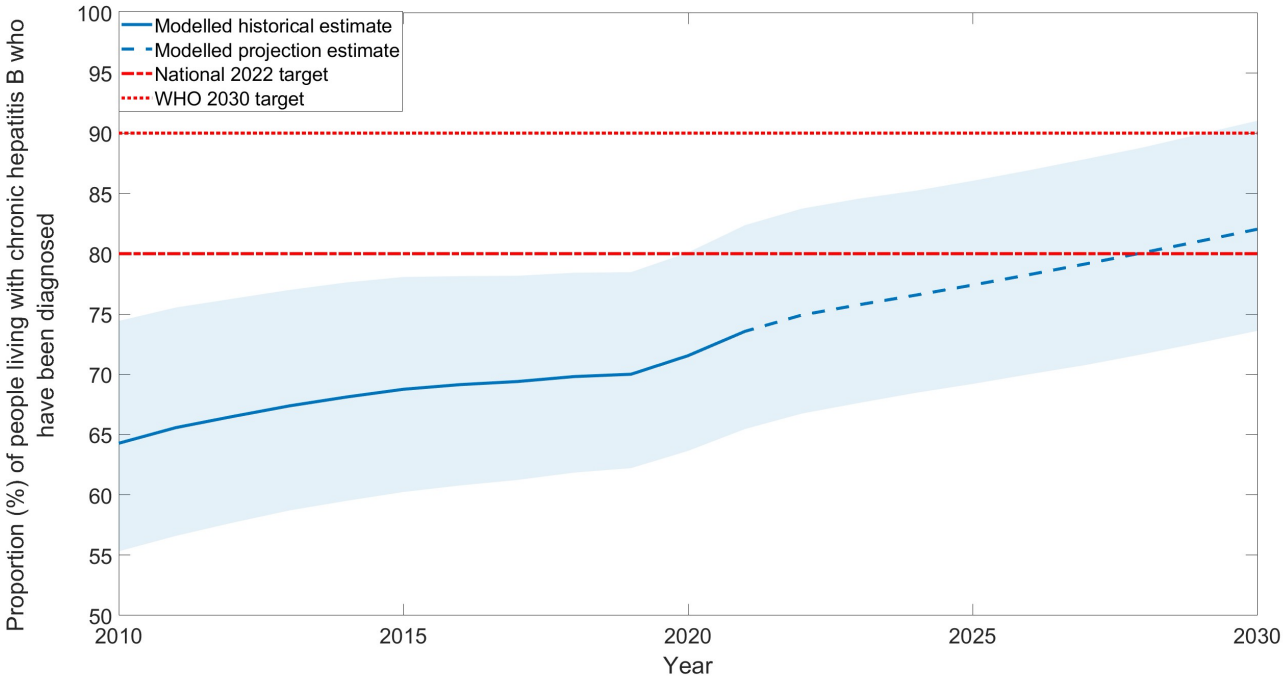
CHRONIC HEPATITIS B DIAGNOSIS

NATIONAL ESTIMATES

In 2021, an estimated 145,281 people living with CHB in Australia had been diagnosed, representing 72.5% (PR 65.5% to 82.4%) of all Australians living with CHB. Historical trends show modest improvements in this proportion, having increased from 65.6% diagnosed in 2011 (Figure 6, Appendix Table A2). Although thousands of individuals are diagnosed with CHB in Australia each year, the population living with CHB also generally continues to increase, therefore the rate of diagnosis must increase substantially to have an impact on the total proportion diagnosed.

The number of people living with CHB who have been diagnosed is calculated using hepatitis B notifications, sourced from the National Notifiable Diseases Surveillance System (NNDSS) [21]. However, NNDSS data contains duplicates when individuals have been diagnosed in multiple jurisdictions, inflating the number of people diagnosed and making the true proportion diagnosed less than previously estimated. Data linkage projects in New South Wales and Victoria estimated that approximately 8% of notifications were internal duplicates, occurring repeatedly within the same jurisdiction. Given this finding, the reported proportion diagnosed assumes 8% of notifications are duplicates, which is most likely a conservative estimate. A national data linkage project is currently underway to generate robust estimates of national duplicate notifications, and these will be incorporated into future reporting when available.

Figure 6. Estimated proportion of people living with chronic hepatitis B in Australia who have been diagnosed, 2010 – 2030.



Shaded areas show plausible ranges of estimates determined by the 10th and 90th percentiles of simulations. Estimates assume 8% of hepatitis B notifications are duplicates.

The proportion diagnosed in 2021 remains below the National Strategy target of 80%, with 15,206[1] more people living with CHB requiring diagnosis to reach this target by 2022. Since 2010 the annual number of national notifications has been fluctuating, but followed a decreasing trend[21]. This reflects declines in the number of serology tests performed since the onset of the COVID-19 pandemic, with an average of 14% lower during 2020 and 2021 compared to 2019[22,23]. This is likely due to the health system impacts of the pandemic and the interruption to usual care observed for many aspects of health care. This trend does not appear to be abating during 2022, with preliminary data indicating the number of serology tests conducted during January to September 2022 was 20% lower than during the same period in 2019.

Combining future population estimates, including the underlying assumptions about migration numbers and demographics, with the assumption that notifications will continue to follow the 2017 - 2020 trend through 2030, Australia is projected to reach the National Strategy target for proportion diagnosed of 80% in 2030 and the WHO's 2030 target of 90% of people living with hepatitis B diagnosed in 2039.

The plausible range indicates that the diagnosis proportion could be as small as 65.5% and as large as 82.4% - which in the latter case would mean that Australia has already reached the 2022 diagnosis target. However, this is unlikely as the target was not achieved in 82.1% of model simulations.

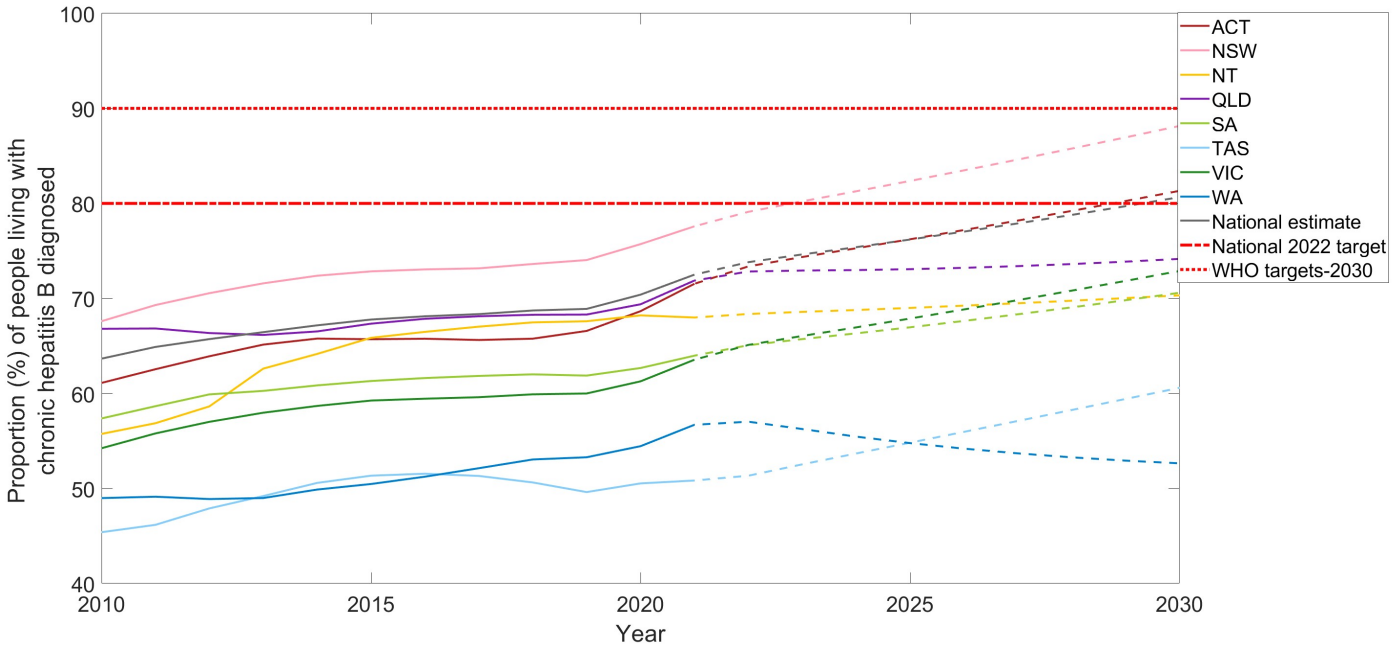
STATE AND TERRITORY ESTIMATES

Since 2011 modest increases in the estimated proportion of people living with CHB who have been diagnosed have been observed in all jurisdictions (Figure 7, Appendix Table A2). The estimated proportion diagnosed varied greatly between jurisdictions, with NSW (77.6%) having the highest proportion diagnosed in 2021 (Table 7). Estimates for all other states and territories were below the national average of 72.5%, with QLD (71.9%), ACT (71.5%), NT (68.0%), SA (64.0%), VIC (63.5%), WA (56.7%) and TAS (50.8%). As the proportion diagnosed is dependent on routinely collected surveillance data, disparities between states and territories will be influenced by variations in screening practices, underlying population differences in each jurisdiction and duplicate notifications. These estimates assume all jurisdictions have the same level of duplicate notifications of 8%, however this will be updated accordingly when jurisdiction-specific estimates of duplicate notifications are derived using the data linkage work described above.

No jurisdiction has yet reached the 2022 National Strategy target of 80% of people living with CHB being diagnosed, however NSW is on track to reach this target by the end of 2022 and will reach the WHO 2030 target of 90% people diagnosed in 2032 (Figure 7). This however is dependent on the true number of duplicates present in NSW notification data. Following trends in notifications, ACT is estimated to reach the National target in 2029 but will not reach the WHO 2030 target until 2038. All other jurisdictions would reach the National target after 2030. The proportion of people diagnosed with CHB in WA is forecasted to decrease after 2022 due to a combination of increasing CHB prevalence, and a low average annual change in notifications. A significantly increased rate of diagnosis is required in most jurisdictions to reach the National Strategy target by 2022 and WHO target by 2030.

[1] Based on the projected modelled estimate of 200,609 people living with CHB in 2022, to reach the 80% diagnosis target we need to have diagnosed 160,487 people by 2022.

Figure 7. Estimated proportion of people living with chronic hepatitis B who have been diagnosed by jurisdiction, 2010 – 2030.



Dotted lines represent modelled projection estimates.

Table 7. Estimated proportion of people living with chronic hepatitis B who have been diagnosed by jurisdiction, 2021.

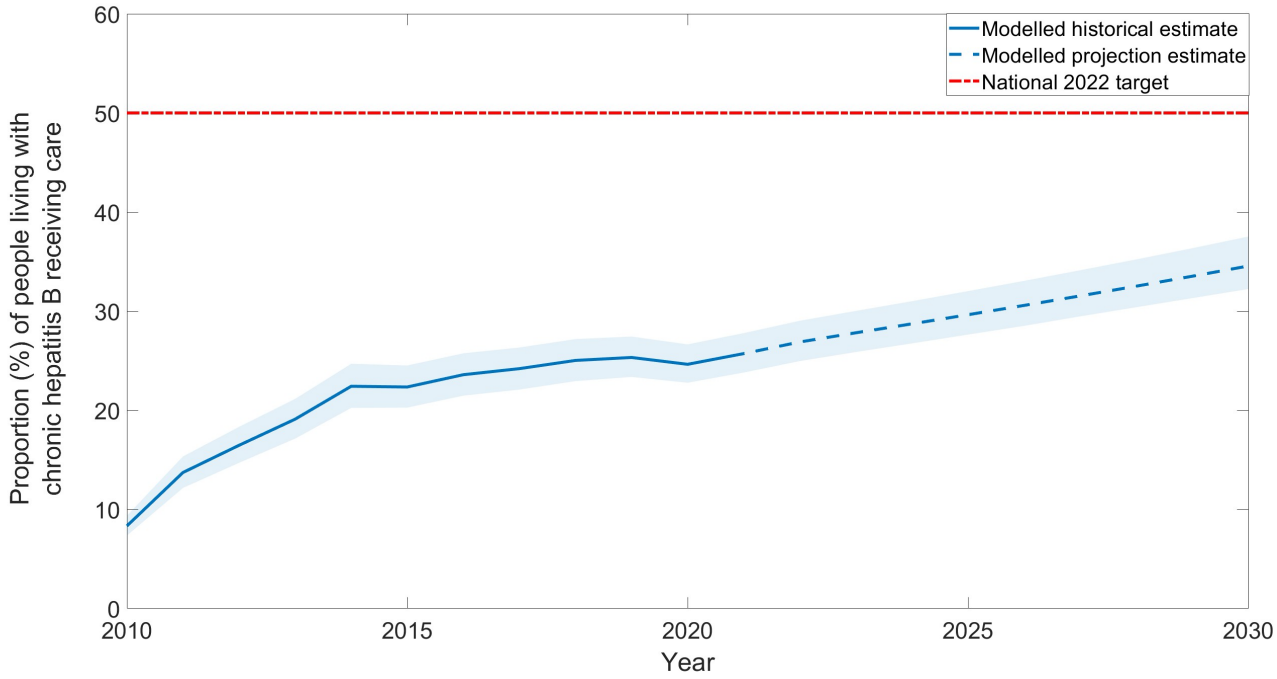
State/Territory	Proportion diagnosed	Plausible range	
		Minimum	Maximum
ACT	71.5%	63.4%	83.3%
NSW	77.6%	70.5%	87.7%
NT	68.0%	65.5%	69.2%
QLD	71.9%	68.5%	77.0%
SA	64.0%	59.0%	76.5%
TAS	50.8%	46.2%	54.1%
VIC	63.5%	56.0%	73.8%
WA	56.7%	54.5%	66.7%
Australia	72.5%	65.5%	82.4%

CHRONIC HEPATITIS B CARE

NATIONAL ESTIMATES

During 2021, 52,121 (26.0%) people were engaged in care for CHB, receiving either antiviral treatment or monitoring to detect changes that may prompt commencing antivirals (defined as receiving hepatitis B viral load testing at least yearly). This proportion has improved over time, increasing from 13.7% in 2011 (Figure 8, Appendix Table A3). Although this increase was relatively rapid between 2011 to 2014, the rate of increase has been substantially slower since 2015. In 2020, for the first time in a decade and presumably due to the impacts of the COVID-19 pandemic, a reduction in the proportion of people engaged in care for their CHB was observed. The number of individuals engaged in monitoring continued to decline during 2021, however this was offset by increases in treatment numbers, and consequently care uptake remained stable.

Figure 8. Estimated proportion of people living with chronic hepatitis B in Australia who were engaged in care (receiving either treatment or monitoring), 2010 – 2030.



Shaded areas show plausible ranges of estimates determined by the 10th and 90th percentiles of simulations.

It is recommended that all people living with CHB should be engaged in care[24-26], and Australia currently falls well short of meeting this recommendation. The proportion engaged in care remains below the 2022 National Strategy target of 50% and based on current trends, this target will not be reached until 2043. A further 48,184[2] more people, nearly double the current number, are required to be in monitoring or on treatment to reach this target by 2022. It should be noted that these projections incorporate uncertain underlying assumptions about future migration, composition of migrants by country of birth and age distribution.

[2] Based on the projected modelled estimate of 200,609 people living with CHB in 2022, we estimate that 100,305 people living with CHB are required to be engaged in care to reach the target of 50%.

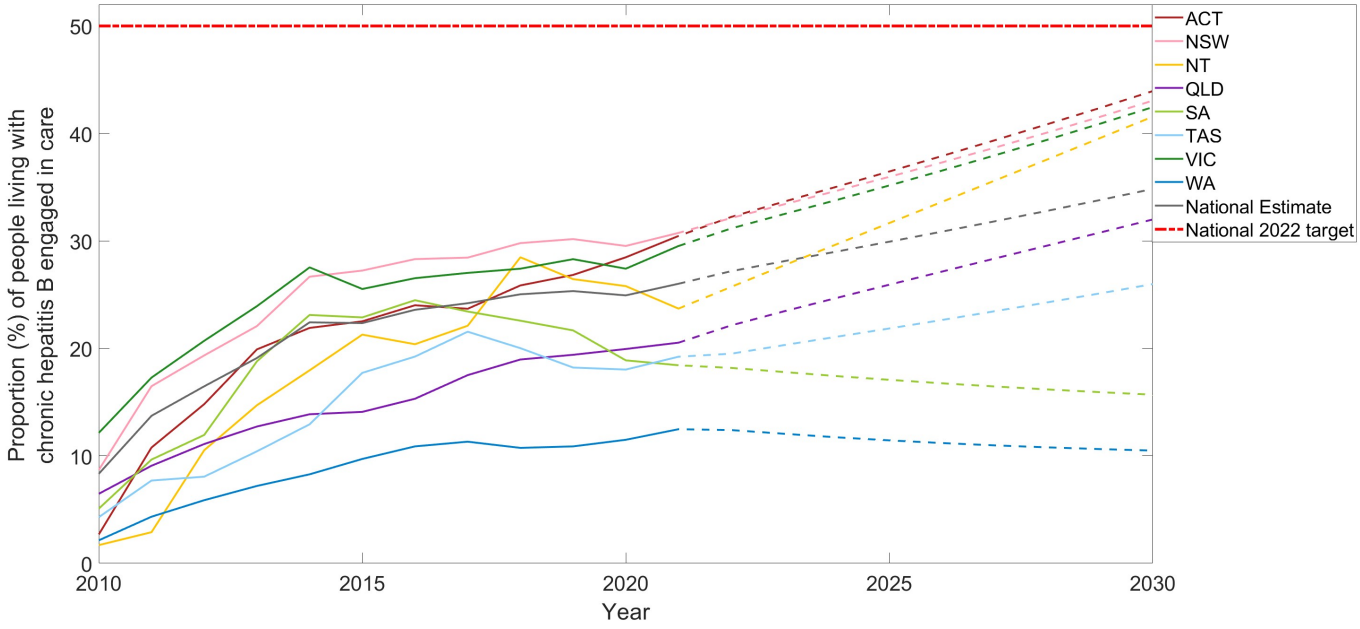
STATE AND TERRITORY ESTIMATES

Since 2011, the proportion of people living with CHB who are engaged in care[24-26] has varied greatly between states and territories (Figure 9, Table 8). Despite some fluctuations, generally the proportion of people living with CHB who are engaged in care increased in most states and territories during 2011 - 2019. However in 2020, many jurisdictions saw a decrease in the proportion engaged in care, including NSW, NT, SA, TAS and VIC (Figure 9). In 2021, this proportion increased in all jurisdictions, except for NT and SA, which had a 2.1% and 0.5% decrease respectively, compared to the previous year. Aside from the impacts of COVID-19 and resulting disruptions to health care, this may also be partly attributable to data reporting, as anomalies in the expected number of viral load tests performed in some jurisdictions have been observed in the Viral Hepatitis Mapping Project National Report[4,5]. The sharp decline in monitoring uptake in SA from 2019 onwards, in contrast to a continuing increase in treatment numbers, suggests a change in the billing of viral load tests through Medicare. Further data are being sought from SA Health to assess if the decline in monitoring is attributable to the provision of viral load testing outside of the MBS. Additionally, WA estimates are also currently under review due to the low apparent uptake of care compared to treatment uptake.

No jurisdiction has yet reached the 2022 National Strategy target of 50% of people living with CHB engaged in care. Following trends from 2016 to 2019, ACT, NT, NSW, and VIC will not reach this target until 2034, 2035, 2035 and 2036, respectively. All other jurisdictions will reach the 2022 target after the national estimate of 2043.

Drastic improvements need to be made across all jurisdictions to engage all people living with CHB. It can be observed that jurisdictions with a higher proportion of people living with CHB diagnosed did not always have a higher proportion engaged in care, suggesting that jurisdictions likely encounter different challenges in improving the cascade of care for CHB.

Figure 9. Estimated proportion of people living with chronic hepatitis B who were engaged into care (receiving either treatment or monitoring) by jurisdiction, 2010 – 2030.



Dotted lines represent modelled projection estimates. Please note that future care projections are subject to significant uncertainty.

Table 8. Estimated proportion of people living with chronic hepatitis B who were engaged in care by jurisdiction, 2021.

State/Territory	Proportion in care	Plausible range	
		Minimum	Maximum
ACT	30.5%	27.8%	33.2%
NSW	30.7%	27.7%	32.5%
NT	23.7%	22.4%	23.5%
QLD	20.5%	18.7%	20.7%
SA	18.4%	14.8%	17.3%
TAS	19.2%	18.7%	22.2%
VIC	29.5%	25.0%	30.0%
WA	12.5%	11.4%	13.3%
Australia	26.0%	23.8%	27.8%

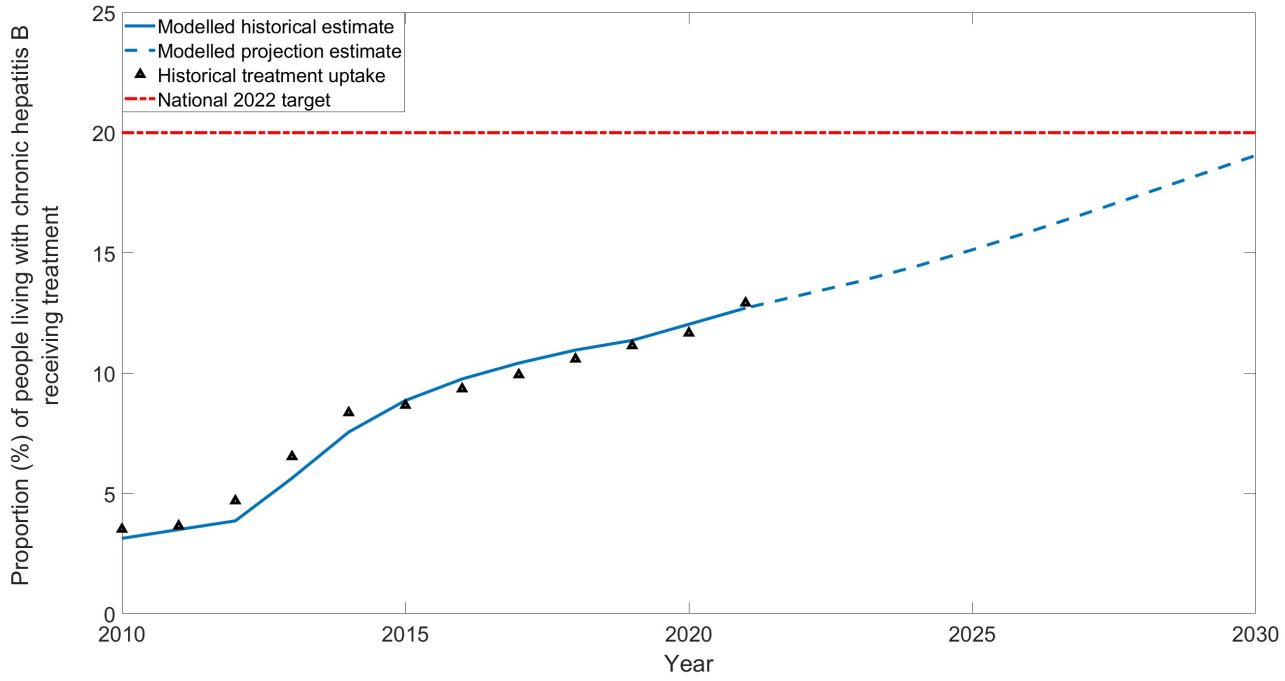
CHRONIC HEPATITIS B TREATMENT

NATIONAL ESTIMATES

During 2021, 25,410 people were dispensed drugs for the treatment of hepatitis B through the Pharmaceutical Benefits Scheme (PBS), which is 12.7% (PR 12.0% to 14.0%) of the estimated number people living with CHB. It should be noted that in May 2020, hepatitis B treatment during pregnancy was added to the Pharmaceutical Benefits Scheme, and these items have been included in treatment figures in this report. As some hepatitis B treatment during pregnancy was previously funded outside the PBS, this will have the impact of increasing the measured number of individuals receiving treatment. Detailed reporting of treatment for hepatitis B during pregnancy will be explored in the 2021 National Viral Hepatitis Mapping Report.

For Australia to achieve the 2022 National Strategy target of 20% of people receiving antiviral treatment, rapid increases in treatment uptake need to occur, with an additional 14,712[3] people living with CHB needing to receive antiviral treatment by 2022. This would represent an increase of 7.3% from 2021 to 2022, compared to the current increase of 0.9% from 2020 to 2021.

Figure 10. Estimated proportion of people living with chronic hepatitis B in Australia who were dispensed drugs for the treatment of hepatitis B through the Pharmaceutical Benefits Scheme, 2010-2030.



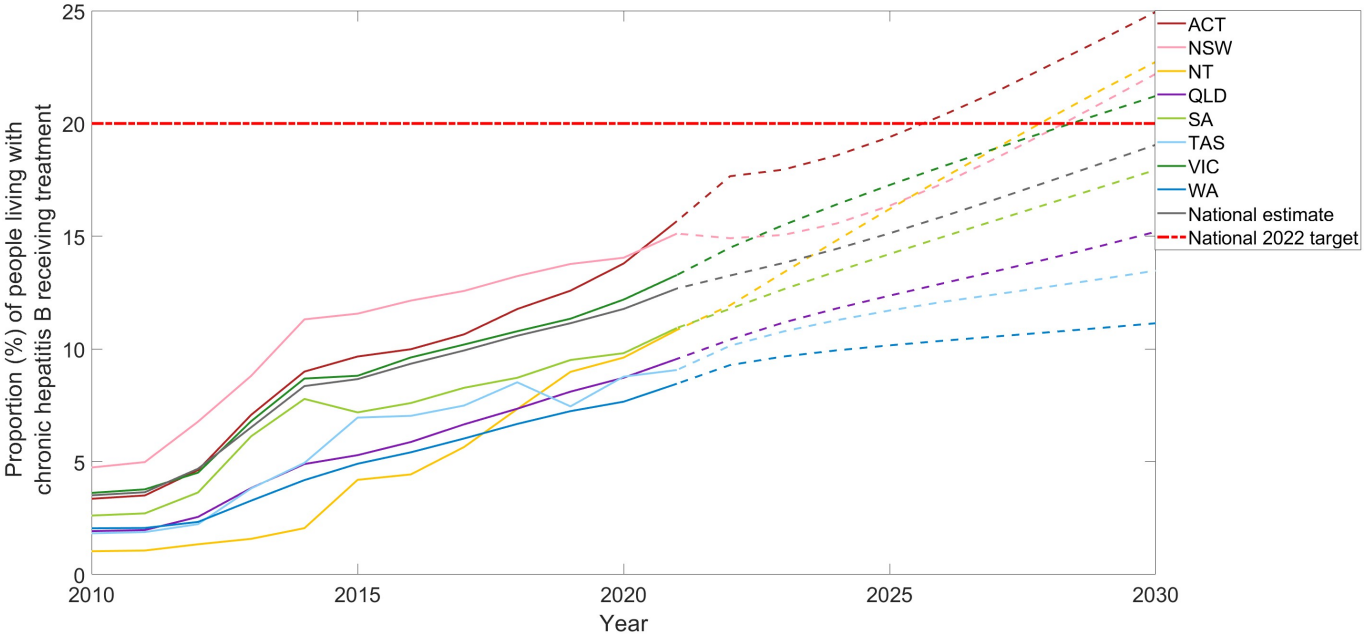
STATE AND TERRITORY ESTIMATES

The proportion of people living with CHB receiving antiviral treatment has increased over time in all states and territories (Figure 11, Appendix Table A4). Treatment uptake varied greatly between jurisdictions, with ACT (15.7%), NSW (15.1%) and VIC (13.3%) estimated to have the highest proportion of people with CHB receiving treatment in 2021 (Table 9). All other states and territories

[3] Based on the projected modelled estimate of 200,609 people living with CHB in 2022, we estimate that 40,122 people living with CHB require treatment to reach the target of 20%.

were at or below the national average (12.7%) for treatment uptake, including SA (10.9%), NT (10.8%), QLD (9.6%), TAS (9.1%) and WA (8.5%). A relatively rapid increase in treatment uptake was observed in most jurisdictions until 2014 to 2015, when the rate of increase slowed. Uniquely, NT have seen the opposite pattern over time, with substantial treatment uptake seen in more recent years compared to other jurisdictions, with increases from 2014 to 2019 (Figure 11). Notably, ACT has observed rapid improvements in the last several years, increasing on average 1.3% yearly since 2017, compared to the national yearly average increase of 0.7% (Figure 11). In 2021, no jurisdiction had reached the 2022 National Strategy target of 20% treatment uptake.

Figure 11. Estimated proportion of people living with chronic hepatitis B who were dispensed drugs for the treatment of hepatitis B through the PBS by jurisdiction, 2010-2030.



Dotted lines represent modelled projection estimates.

Table 9. Estimated proportion of people living with chronic hepatitis B who were dispensed drugs for the treatment of hepatitis B through the PBS by jurisdiction, 2021.

State/Territory	Proportion receiving treatment	Plausible range	
		Minimum	Maximum
ACT	15.7%	14.6%	17.4%
NSW	15.1%	13.1%	15.4%
NT	10.8%	9.7%	10.2%
QLD	9.6%	8.7%	9.6%
SA	10.9%	9.8%	11.4%
TAS	9.1%	8.4%	10.0%
VIC	13.3%	11.5%	13.8%
WA	8.5%	7.6%	8.9%
Australia	12.7%	12.0%	14.0%

Under current trends, no jurisdiction will reach the national 2022 treatment uptake target of 20% with ACT, NT, NSW, and VIC estimated to have the highest proportion of people living with CHB receiving treatment and will reach the target in 2026, 2028, 2029 and 2029, respectively.

CHRONIC HEPATITS B TREATMENT ELIGIBILITY

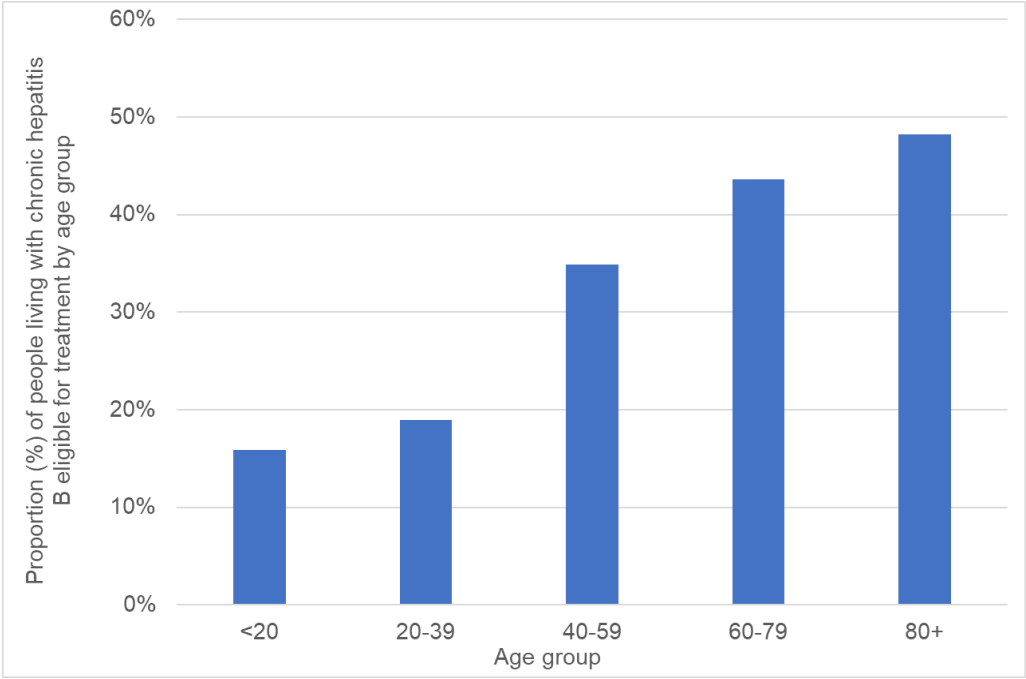
Due to the dynamic natural history of hepatitis B, not all people living with CHB require treatment. Current guidelines recommend antiviral therapy only for those in immune clearance or immune escape (see Appendix Figure A2), or those with cirrhosis and detectable HBV replication irrespective of phase[27]. Published estimates of the proportion of people living with CHB who are eligible for treatment range from 10% to 31% [2,28-32], and are influenced by hepatitis B genotype, age group, sex, and other factors. Here we generate estimates of this proportion in Australia, based on modelling of many of these parameters.

The WHO GHSS on Viral Hepatitis 2022-2030 has updated the treatment target to report the proportion of people living with CHB on treatment of those who are not only eligible, but diagnosed as well. To estimate this in Australia a significant number of consecutive assumptions need to be made, which results in high uncertainty in the final figure. As mentioned previously in the 'Chronic Hepatitis B Diagnosis' section, it is estimated that approximately 8% of the notifications used as the source for the proportion diagnosed are duplicates, however this figure is a conservative estimate and the true proportion diagnosed is uncertain. Additionally, there are very likely unmeasured differences in the population that has been diagnosed compared to those not diagnosed, though an assumption has been made that the proportion of people eligible for treatment is the same across both groups. Due to the natural history of CHB, this is unlikely to be the case. Given the uncertainties in this estimate, we will be focusing on the WHO GHSS on Viral Hepatitis 2018-2022 target, reporting against the proportion of people eligible for CHB treatment who have been treated. This target also more closely reflects Australia's National Strategy Target, which does not incorporate diagnosis criteria.

In 2021, an estimated 58,848 (PR 53,073 to 65,979) people living with CHB were eligible for antiviral treatment nationally, representing 29.4% (PR 26.5% to 32.9%) of the total. This suggests the National Strategy target of 20% of people living with CHB receiving antiviral treatment by 2022 remains conservative. Based on this modelling, Australia treated 43.2% of those estimated to require treatment in 2021, and would have needed to treat an additional 33,438 people to reach everyone who was eligible. If trends were to remain stable, Australia will not reach the WHO GHSS 2018 - 2021 target of 80% of eligible people with CHB treated in 2030 until 2040. Furthermore, following current trends, reaching the WHO target of 80% of eligible people living with CHB receiving treatment by 2030 would require an average annual treatment increase of 1.4% from 2021 to 2030. When measuring against the WHO GHSS 2022 – 2030 target, it is estimated that 54.8% of people who have been diagnosed with CHB and were eligible for treatment were receiving treatment in 2021, and Australia would not reach the target until 2038.

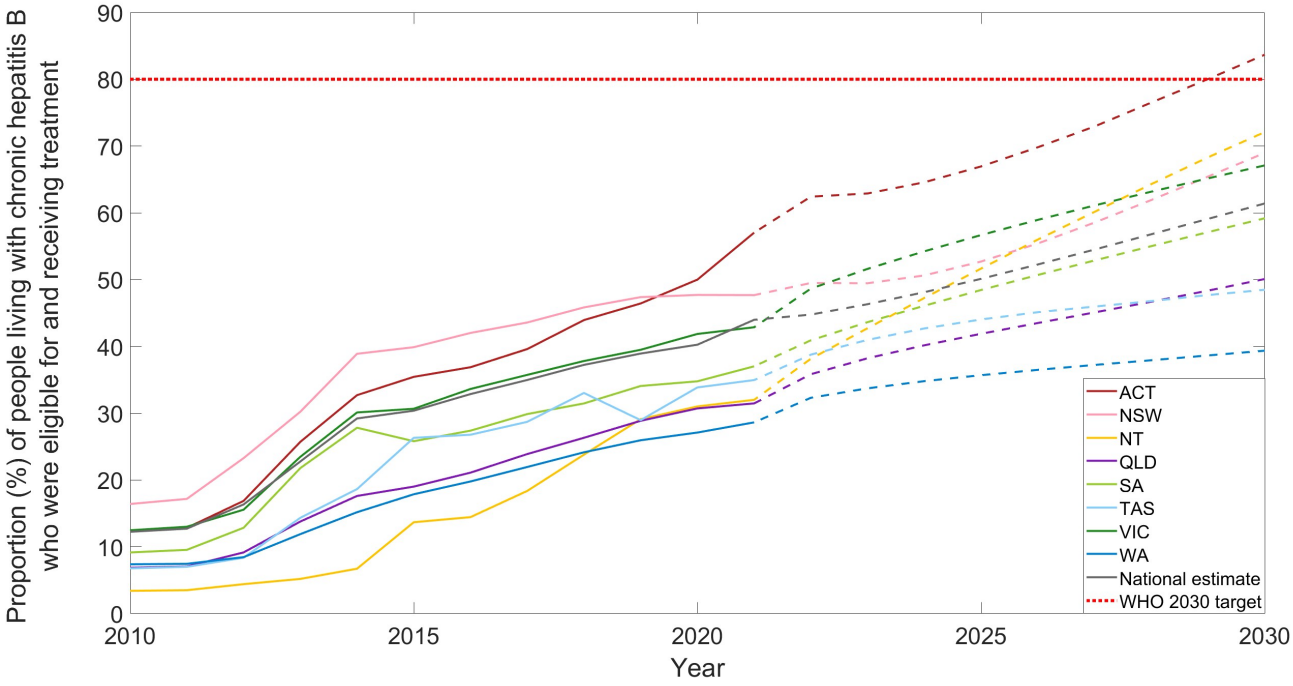
Eligibility for CHB treatment varies according to age group, with the proportion of people living with CHB eligible for treatment increasing according to age (Figure 12). Treatment uptake according to age group will be explored in the 2021 National Viral Hepatitis Mapping Report.

Figure 12. Estimated proportion of people living with chronic hepatitis B eligible for treatment by age group, 2021



In 2021, NT (31.2%), NSW (29.8%) and VIC (29.5%) were estimated to have the highest proportion of people living with CHB who are eligible for treatment, followed by QLD (28.8%), WA (28.7%), SA (28.6%), ACT (28.0%) and TAS (26.1%) (Figure 13). If the future treatment uptake for eligible people living with CHB follow current trends ACT will reach the WHO 2030 target of 80% of eligible people with CHB treated by 2029 (Figure 13).

Figure 13. Estimated proportion of people living with chronic hepatitis B in Australia who were eligible for and dispensed drugs for the treatment of hepatitis B by jurisdictions, 2010 – 2030.



Dotted lines represent modelled projection estimates.

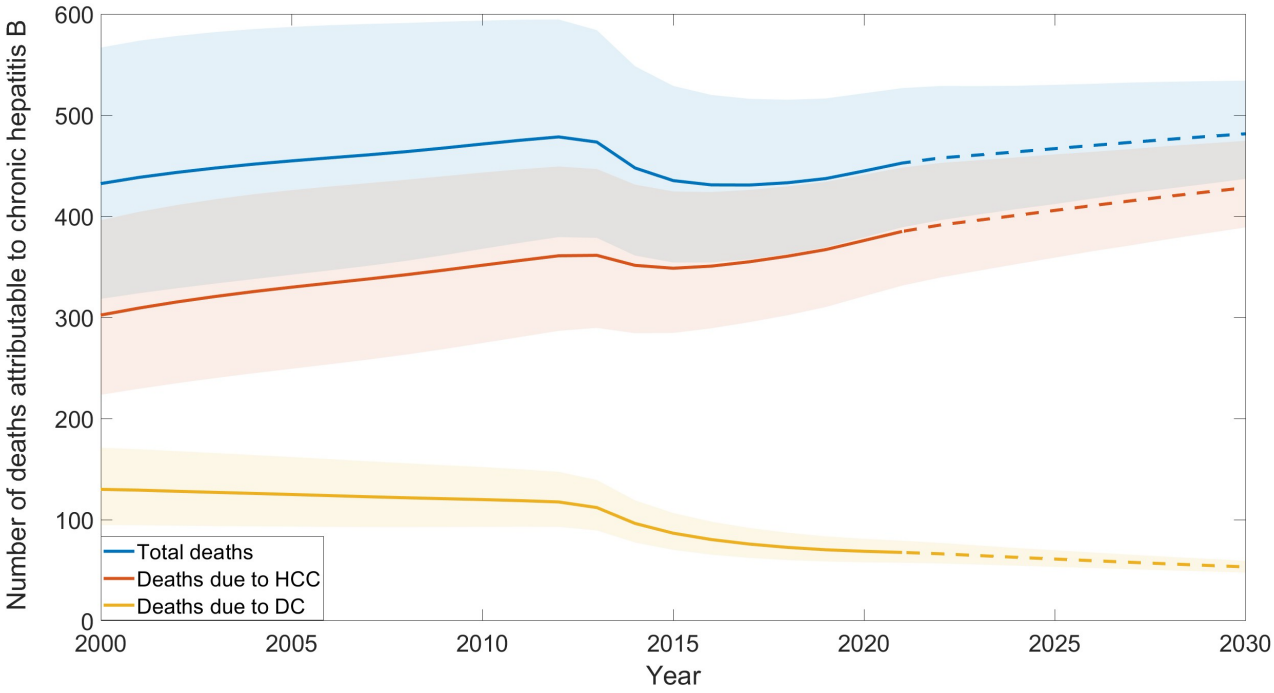
DEATHS ATTRIBUTABLE TO CHRONIC HEPATITIS B

NATIONAL ESTIMATES

In 2021, an estimated 453 people (PR 390 to 530) died due to complications of CHB in Australia. The total number of estimated attributable deaths has changed over time, increasing from 432 in 2000 to a peak of 478 deaths in 2012 followed by a gradual decline, despite increasing population numbers. (Figure 14, Appendix Table A5). This decrease in estimated deaths is due to the introduction and scaling up of effective antiviral treatment in Australia during the last two decades, and the resulting reduction in CHB-associated mortality in those at greatest risk of adverse outcomes. In recent years, the number of deaths has plateaued and started increasing instead of continuing to decrease, in part due to ageing, an increasing population and treatment uptake not increasing sufficiently. The increase in deaths attributable to CHB at the end of 2021 relative to the end of 2017 was 5.1% nationally, and it is highly unlikely that the National Strategy target of a 30% reduction in hepatitis B attributable mortality by 2022 will be reached. To reach this target, the total number of CHB attributable deaths must fall to 302 deaths.

Despite increases in total number of deaths in recent years, the mortality rate has been steadily decreasing since 2003 (2.26 deaths per 100,000 total population). In 2021 the population level CHB attributed mortality rate was 1.76 deaths per 100,000, well below the WHO GHSS target aiming for a mortality rate of 7 deaths per 100,000 by 2025 and 4 deaths per 100,000 by 2030. This target reflects the high baseline CHB mortality at a global level, and a higher baseline prevalence of CHB in most countries, and it is likely Australia has never exceeded these mortality levels. Due to this, local targets are needed which are tailored to the Australian situation.

Figure 14. Estimated number of deaths attributable to chronic hepatitis B in Australia over time, 2000 – 2030.



Shaded areas show plausible ranges of estimates determined by the 10th and 90th percentiles of simulations. Dotted lines represent modelled projection estimates.

Deaths due to CHB are caused by the development of decompensated cirrhosis (DC) and/or hepatocellular carcinoma (HCC), the most common form of liver cancer. In Australia, 85% of estimated deaths due to CHB were attributable to HCC, which was responsible for 385 (PR 332 to 449) deaths in 2021, while 68 (PR 58 to 81) people were estimated to have died due to DC. HCC deaths saw a slight decrease after a peak of 361 in 2013, with numbers continuing to increase in recent years. Contrastingly, the decline for DC deaths has continued after dropping from a peak of 130 in 2000 (Figure 14).

The impact of treatment in reducing the risk of death due to CHB may be more pronounced for DC compared to HCC due to the underlying clinical factors in relation to treatment impact. While antiviral treatment has been demonstrated to substantially reduce the risk of development of HCC, this effect is not immediate and antiviral therapy has limited impact on survival once HCC has already been diagnosed. In contrast, antiviral treatment not only prevents progression to cirrhosis and then to DC, but additionally can be effective even when provided late in the disease course, resulting in re-compensation of liver disease. Without the availability of antiviral treatment in Australia, the number of attributable deaths would have continued to increase over time to 767 CHB attributable deaths estimated in 2021. Our assessment estimates that in 2021, 314 lives were saved due to treatment, with a total of 2,707 lives saved since the year 2000 following the introduction of antiviral treatment for CHB in Australia.

STATE AND TERRITORY ESTIMATES

In 2021, the absolute burden of disease attributable to hepatitis B was greatest in jurisdictions with the largest populations, NSW and VIC (161 and 129 deaths respectively), followed by QLD (71), WA (49) and SA (22). A smaller burden was seen in other jurisdictions, though it is difficult to reliably estimate in territories with smaller populations of people living with CHB.

The CHB attributable mortality rate differs according to jurisdictions, relating predominantly to the total prevalence of CHB in the population, and to other factors such as age distribution of people living with CHB, and treatment uptake. Although some fluctuations over time have been observed, the attributable mortality rate follows a decreasing trend over time. The highest rate estimated was in NT, with 4.4 deaths occurring per 100,000 people. NSW (1.99 per 100,000), VIC (1.97 per 100,000) and WA (1.77 per 100,000) had a higher CHB attributable mortality rate compared to the national estimate of 1.76 deaths per 100,000. QLD (1.35 per 100,00), ACT (1.32 per 100,000), SA (1.22 per 100,000) and TAS (0.53 per 100,000) had below average mortality rates (Figure 15). All jurisdictions are below the WHO GHSS 2025 target aiming for 7 deaths per 100,000 and all are on track to meet the WHO 2030 target.

Figure 15. Estimated attributable chronic hepatitis B mortality rate (per 100,000 total population) by jurisdictions 2000 – 2030

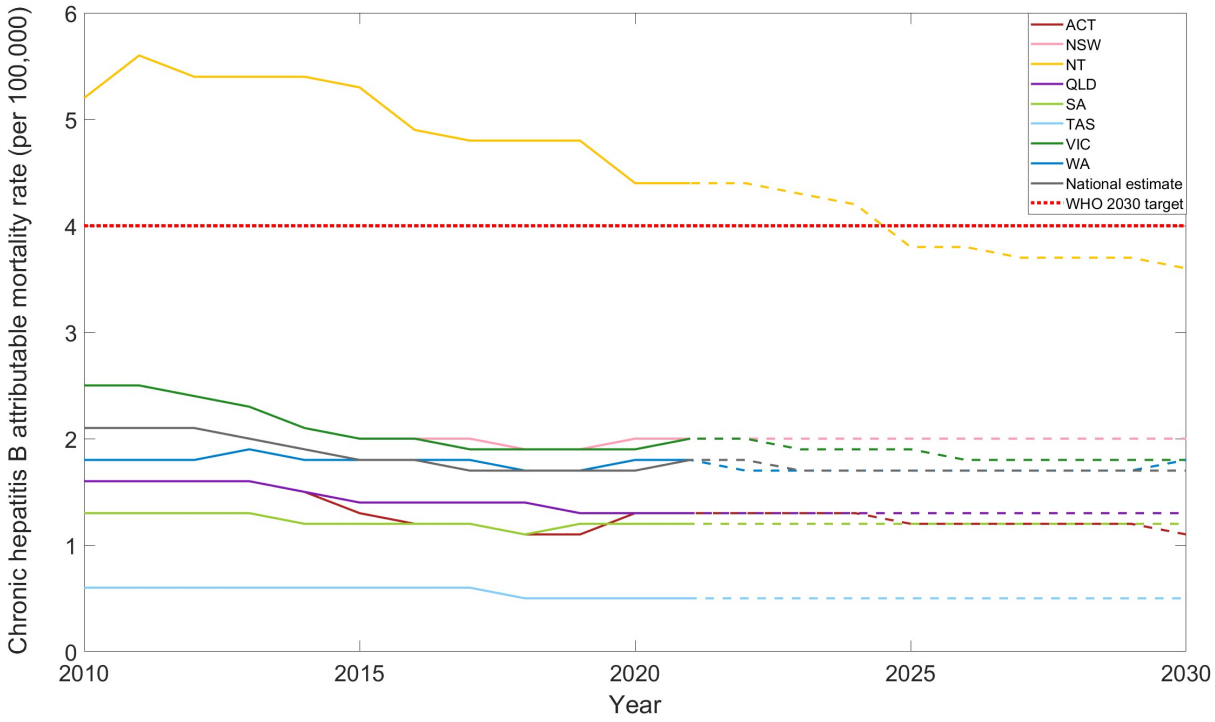


Table 10. Estimated number of total deaths attributable to chronic hepatitis B and population numbers by jurisdiction, 2021.

State/Territory	Total deaths attributable to CHB	Plausible range		People living with CHB
		Minimum	Maximum	
ACT	<10	<10	<10	2,840
NSW	161	139	189	72,058
NT	11	11	12	4,325
QLD	71	65	79	31,665
SA	22	18	26	10,181
TAS	<10	<10	<10	1,566
VIC	129	107	156	56,837
WA	49	43	57	20,912
Australia	453	390	530	200,385

Estimates less than 10 have been suppressed due to difficulties in ensuring accuracy in small numbers.

Table 11. Estimated number of HCC deaths and DC deaths attributable to chronic hepatitis B by jurisdictions in 2021.

State/Territory	HCC deaths attributable to CHB	HCC Plausible range		DC deaths attributable to CHB	DC Plausible range	
		Minimum	Maximum		Minimum	Maximum
ACT	<10	<10	<10	<10	<10	<10
NSW	141	121	164	21	18	25
NT	<10	<10	10	<10	<10	<10
QLD	59	54	65	13	11	14
SA	18	12	22	<10	<10	<10
TAS	<10	<10	<10	<10	<10	<10
VIC	111	92	133	18	15	23
WA	40	35	46	9	<10	11
Australia	385	332	449	68	58	81

Estimates less than 10 have been suppressed due to difficulties in ensuring accuracy in small numbers.

IMPACT OF TREATMENT ON MORTALITY

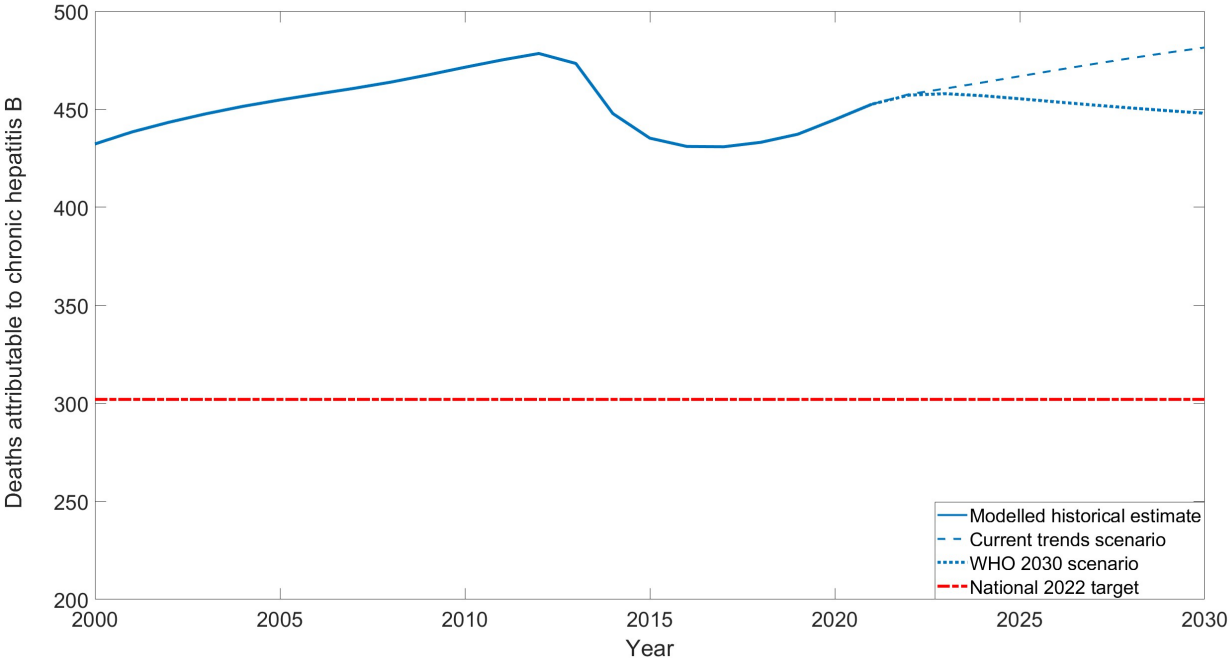
Although there has been a reduction in deaths since the introduction of antiviral treatment, further reductions depend on future treatment uptake. Two treatment uptake scenarios were modelled to consider the impact of future treatment uptake on future mortality:

I. Current trends scenario: Assumes the number of people receiving treatment will follow similar trends to a pre-COVID era (2016 – 2019)

i. WHO 2030 scenario: Assumes future treatment uptake will follow the level of increase required to meet the WHO GHSS 2030 treatment target (80% of eligible people receiving treatment). From modelled estimates, 80% of eligible people receiving treatment equates to approximately 25% of all people living with CHB.

Results highlight different trajectories of future mortality according to the treatment uptake scenario (Figure 19). Under the current trends' treatment scenario, it is estimated that the number of deaths attributable to CHB will continue to increase. However, under the WHO 2030 scenario, mortality would be projected to decline from 2023. In 2030 it is projected there will be 448 deaths under the WHO 2030 scenario vs 481 deaths under the current trends scenario, a cumulative difference of 148 by 2030.

Figure 19. Impact of future treatment uptake on estimated number of deaths attributable to chronic hepatitis B in Australia, 2010 – 2030.



METHODOLOGICAL NOTES

To ensure estimates most accurately reflect the current epidemiology and clinical pattern of CHB in Australia, data inputs and assumptions are updated regularly to incorporate new information. For that reason new estimates may differ in some respects from previous outputs reported in the Kirby Institute's Annual Surveillance Reports[10], the Doherty Institute's National Viral Hepatitis Mapping Project Reports[4,5,14], and the National Surveillance for Hepatitis B Indicators: 2020 Annual Report[18].

SUMMARY OF MATHEMATICAL MODEL INPUTS

Mathematical Model Inputs	Source
Disease progression estimates	Published and grey literature, expert opinion
Australian demographic data	Australian Bureau of Statistics
Migration: Net overseas migration 1951 – 2021 2022 - 2050	 Australian Bureau of Statistics Wilson et al. NOM projections[19] and Australian Bureau of Statistics[33]
Migration: country of birth and age distribution 1951 – 1974 1974 – 1990 1991 – 2003 2004 - 2050	 Federation to Century's End Australian Bureau of Statistics Department of Social Services, Australian Bureau of Statistics Australian Bureau of Statistics
CHB prevalence by country of birth	Published literature
CHB phase distribution	Published and grey literature, expert opinion
Treatment uptake	Pharmaceutical Benefits Scheme
Vaccination uptake	Australian Immunisation Register data

MATHEMATICAL MODEL

The estimates presented in this report were derived from the recently published mathematical model [2]. The model is a dynamic, age-structured deterministic mathematical model that incorporates important demographic features such as births, migration, deaths, and aging over time. To optimise accurate representation of the transmission, epidemiology and progression of hepatitis B, the model incorporates 9 exclusive health states, representing the natural history of hepatitis B; susceptible, immune (through vaccination), acute infection, immune tolerant, immune clearance, immune control, immune escape, decompensated cirrhosis, hepatocellular carcinoma and resolved infection. Chronic hepatitis B health states have also been differentiated into no-cirrhosis and cirrhosis classifications and stratified by those receiving treatment and those not receiving treatment. This results in the model consisting of a total of 21 health states. Each health state is broken down into 18 age categories (those aged between 0 and 84 are grouped into 5-year age categories plus a final 85+ age group). Age groups were chosen to reflect

the Australian population and to allow exploration of age-specific and health-state specific estimates, such as disaggregated mortality estimates for DC and HCC.

The model diagram can be found in Appendix Figure A2. Various data inputs and elements of the model are described below.

Disease progression estimates

Disease progression and transitions between each health state, including the impact of treatment on these, were generated based predominantly on a review of published and grey literature. Details of these transition estimates have been published elsewhere[2].

Transmission

A dynamic, age-adjusted measure of the force of infection is incorporated in the model to account for local transmission over time. The impact of vaccine uptake over time was modelled using the Australian Immunisation Register data by age and year. Measures of vaccine efficacy by age group were used to estimate the proportion of individuals receiving effective vaccination for hepatitis B in the Australian population.

Demographic data

The Australian Bureau of Statistics (ABS) provided the majority of the demographic data used in the model. This included total population numbers[34,35], births[34], deaths[36,37] and life tables[38] used to derive age-group mortality rates by taking the average rate across the 5 years included in each given age group.

Migration

In addition to Australia-specific demographic data, incoming migration by age and country of birth were also incorporated. Data regarding net overseas migration (NOM) produced by the ABS provided the total number of people entering the population from 1951 to 2021 as well as estimates of the proportion of future NOM entering each jurisdiction from 2022 to 2050[39]. Estimates of future NOM from Wilson and colleagues[19] was used for the total number of people entering the population from 2022 to 2050. Age and country of birth distributions within this were calculated using different sources dependent on time period and data availability:

- *2004 to 2021,* ABS NOM by country of birth and age distribution data were used to estimate the total number of people entering the population each year[40,41].
- *1991 to 2003,* ABS NOM was used to estimate the total number of people entering the population each year[40]. DSS settlement data[42] were used to estimate the age distribution by country of birth by age by year.
- *1975 to 1990*, ABS NOM data[40] were used to estimate the total number of people entering the population each year. Combined with ABS permanent migration data by country of birth[43] these sources were used to estimate the number of migrants entering by country of birth. National age distribution data were not available prior to 1991, so data from the state of Victoria (representing 25% of Australia's population) on age distribution during 1975 to 2006 were applied as they were found to be a reasonable approximation.
- *1951 to 1974*, the Department of Immigration resource Federation to Century's End was used to determine the number of permanent settlers to Australia by country of birth[44].

Prevalence

At the start of the modelled period (1951), the baseline prevalence of the Australian population was assumed to be 0.5%[45], representing a low prevalence country. The number of people living with CHB migrating to Australia each year was derived using the estimated prevalence of CHB according to country of birth. To account for changing age-specific source population prevalence over time (due predominantly to infant vaccination programs), we derived varying prevalence estimates across different time periods and applied these to migration data according to age group and year of arrival for country of birth for the majority of migrants to Australia. Prevalence for the top 4 countries of birth for CHB was estimated using a separate method (see 'Direct estimation of immunisation impact' section, below). Different data sources were used for different time periods:

- *1991 to 2050,* For those migrating into Australia born in 1991 or later, prevalence estimates derived for the Viral Hepatitis Mapping Project National Report 2018-2019[4] were applied. These prevalence estimates were taken predominately from local seroprevalence surveys,[46-48] supplemented with global systematic reviews[49,50]. Antenatal estimates were adjusted upwards to correct for the discrepancy in CHB prevalence by sex[51].
- *1951 to 1990,* For those migrating into Australia born prior to 1991, prevalence estimates derived by the CDC as of 2008 were applied[45]. Countries were divided into three categories, based on the prevalence during this period; low prevalence (0.5%), intermediate prevalence (5%) and high prevalence (10%). These estimates are higher compared to those during 1991-2020 which takes into account prevalence estimates in the pre-vaccination era.

Direct estimation of immunisation impact

A literature review was conducted to obtain age- and year-prevalence estimates for the 4 countries which had the highest numbers of people living with CHB in Australia - China, Vietnam, Philippines and Taiwan[4,14,49,52-56]. Specific prevalence estimates by country and year of birth were applied to incoming migrants.

Phase distribution

Individuals living with CHB migrate into Australia in different disease phases. The proportion of individuals living with CHB in each disease phase (immune tolerant, immune clearance, immune control, and immune escape) by age group were derived for different world regions using published data and expert opinion[57-59]. All source countries were categorised into three world regions (Asia/Pacific, Africa, and Other) to account for differences in natural history.

Treatment

This model incorporates the impact of treatment by estimating differential uptake rates by disease phase, with proportions according to disease phase determined using expert opinion and literature reviews, which were then fitted to treatment uptake derived from PBS data.
Data obtained from PBS records were used to derive the number of people on treatment in Australia each year since 2000. It excludes individuals prescribed lamivudine or tenofovir for HIV infection and includes hepatitis B treatment during pregnancy.

Plausible range

The plausible ranges reported were derived by allowing the force of infection, migrant population prevalence, proportion of migrants with CHB living with cirrhosis, CHB mortality, and other

disease transition estimates to vary according to prior knowledge of possible distributions[2]. In addition, for modelled future projection estimates the total number of migrants entering the population varied for 2021 – 2030 according to the short, moderate and long impact scenarios[19]. This was achieved using Latin-hypercube sampling (LHS), as described by Marino et al.[60] The national mathematical model was run using 1000 different combinations of these varied parameters (while the jurisdiction models were run using 100 different combinations of these varied parameters), which produced a range of overall estimates. The minimum and maximum estimates defined by the 10th and 90th percentiles respectively were then used to define the plausible range around the point estimate value.

Jurisdictional estimates

The national model was applied to each state and territory using state specific demographic information obtained from the ABS. Some of the data sources differed from the national model due to availability and appropriateness of data. For years when ABS NOM by jurisdiction was not available (1951 to 1971), we imputed total numbers entering the population for each jurisdiction by applying a proportion (derived from available jurisdiction NOM breakdown) to the national NOM by year. The age distribution of incoming migrants by country of birth was imputed for missing years based on the overall age distribution of permanent settlers arriving in 1991 (obtained from DSS settlement data) which were applied back to 1951.

Although the national model does not currently explicitly model the differential prevalence among Aboriginal and/or Torres Strait Islander peoples, this was incorporated into the model for state and territories where this proportionally has the greatest effect on the number of people living with CHB (QLD and NT). This also ensures that estimates in QLD and NT more accurately reflect the true population. This was incorporated by adjusting the prevalence among the proportion of Aboriginal and/or Torres Strait Islander peoples living in both jurisdictions[61-63].

Prior to 1990, Census data poorly reflect the actual number of Aboriginal and/or Torres Strait Islander peoples living in Australia[64], which underestimates the population and has a substantial impact on output estimates. To better reflect total population numbers in the years prior to 1990, reported populations and number of births were adjusted upwards each year in accordance with the proportion of Aboriginal and/or Torres Strait Islander population and births during the 1991 to 2016[65]. Differential phase information for Aboriginal and/or Torres Strait Islander peoples living with CHB was estimated[66] to reflect the differences in natural history. Data were provided from the Hepatitis B Sero-Coding Project, Northern Territory Government. Further model development will incorporate adjustments for the remaining states and territories, dependent on the availability of appropriate data.

Each jurisdiction was modelled separately to adequately capture trends in the epidemiology of CHB over time. Jurisdictional estimates were then standardized to ensure the sum of indicator variables across the jurisdictions matches the modelled national estimate.

METHODOLOGY FOR INDICATORS

1: Estimating the number of people living with chronic hepatitis B in Australia

The total number of people living with chronic hepatitis B in Australia and the number according to age group and state and territory are direct outputs of the model. Prevalence of CHB was

calculated using the number of people living with chronic hepatitis B as the numerator and the total population according to ABS numbers as the denominator.

2: Estimating the proportion of people living with chronic hepatitis B in Australia who have not been diagnosed

The number of people living with hepatitis B who have been diagnosed is derived using the model output of the number of people who have ever lived with CHB in Australia since 1951 as the denominator and the cumulative number of notifications of hepatitis B from 1971 to 2021 as the numerator. Notification data has been sourced from the National Notifiable Diseases Surveillance (NNDSS) system. The proportion of people living with chronic hepatitis B in Australia who have not been diagnosed is one minus the proportion who have been diagnosed.

NNDSS data may contain duplicates if individuals have been diagnosed in multiple jurisdictions, inflating the number ever diagnosed. A national linkage study has commenced under the auspices of this project which aims to quantify the extent of duplicate reporting across jurisdictions to the NNDSS for both hepatitis B and hepatitis C, allowing identification of the true number of individuals diagnosed and refining of modelled estimates. When the results of this national notifications linkage project are available the results will be incorporated into this model. As of August 2022, ethics and data release has been approved and data transfer and linkage will occur in the coming months. In the interim, based on de-duplication efforts in NSW and VIC, a conservative estimate of 8% of national notifications representing repeat notifications has been applied in this report for the first time.

3: Estimating the proportion of people living with chronic hepatitis B who are engaged in care, receiving either treatment or monitoring

The proportion of people living with CHB who are receiving care was calculated using the number of people receiving either treatment or monitoring as the numerator and the modelled number of people living with CHB as the denominator.

The number of people receiving monitoring was obtained from Medicare Benefits Schedule (MBS) records and calculated by assessing the number of individuals who received a viral load test in a given year while not receiving treatment items in the past 12 months, in order to identify those undergoing off-treatment monitoring separately from those monitored during treatment. This number was then combined with the number of individuals who were receiving treatment, to generate the number in care. The number of people receiving treatment was obtained from PBS records and excludes individuals prescribed lamivudine or tenofovir for HIV infection.

These data do not include services that were not provided by Medicare, such as those paid for by individual patients, or subsidised by state government services. However, previous analyses and comparison with other source data demonstrate that the vast majority of testing and treatment services for patients with hepatitis B are provided through Medicare and included in these estimates[1].

4: Estimating the proportion of people living with chronic hepatitis B who are dispensed drugs for the treatment of hepatitis B through the Pharmaceutical Benefits Scheme

The proportion of people living with CHB who are receiving treatment was calculated using the number of people receiving treatment (obtained from PBS data) as the numerator and the modelled number of people living with CHB as the denominator.

The proportion eligible for treatment is derived by dividing the modelled number of people eligible for treatment by the modelled number of all people living with chronic hepatitis B.

5: Estimating the burden of disease attributable to chronic hepatitis B in Australia

The number of deaths attributable to CHB, and specifically due to DC and HCC, in Australia is a direct output of the model.

APPENDIX

Table A1. Model output for the number of people living with chronic hepatitis B in Australia per year, 1970-2030.

Year	National	ACT	NSW	NT	QLD	SA	TAS	VIC	WA
1970	74674	671	25155	1130	10574	6274	1222	24134	5514
1971	75260	692	25332	1231	10654	6248	1200	24294	5607
1972	75560	712	25408	1335	10705	6202	1175	24359	5664
1973	74944	730	25178	1423	10649	6094	1139	24126	5604
1974	74575	748	25051	1515	10617	6006	1105	23956	5578
1975	74187	762	24931	1597	10530	5898	1072	23821	5575
1976	73077	766	24560	1658	10394	5729	1038	23463	5470
1977	72800	780	24583	1739	10302	5594	1006	23356	5439
1978	73322	800	24989	1834	10275	5495	977	23489	5463
1979	73845	827	25483	1921	10268	5352	945	23609	5441
1980	75224	861	26374	1991	10358	5273	920	23961	5486
1981	77325	902	27475	2048	10564	5285	901	24493	5657
1982	79753	939	28630	2122	10849	5340	884	25059	5929
1983	81379	966	29378	2183	11027	5389	864	25438	6134
1984	82110	989	29739	2254	11055	5406	845	25639	6184
1985	83264	1017	30397	2329	11122	5393	827	25934	6245
1986	85343	1054	31450	2413	11305	5403	812	26444	6464
1987	88256	1104	32902	2496	11570	5427	800	27167	6792
1988	92251	1168	34880	2581	11974	5460	788	28171	7231
1989	96652	1229	36954	2662	12504	5521	776	29253	7754
1990	99827	1285	38467	2737	12862	5547	760	30061	8107
1991	102285	1344	39695	2808	13157	5559	743	30648	8331
1992	103873	1389	40554	2863	13430	5539	722	30930	8445
1993	103896	1410	40699	2907	13512	5463	696	30751	8458
1994	103666	1430	40723	2954	13550	5372	671	30472	8493
1995	104754	1464	41404	3019	13714	5311	650	30562	8630
1996	106860	1495	42608	3091	13990	5282	634	30924	8836
1997	108188	1515	43384	3151	14230	5235	614	31069	8990
1998	109015	1535	43798	3213	14429	5174	597	31141	9127
1999	110317	1561	44437	3289	14659	5120	581	31359	9310
2000	112045	1596	45311	3342	14904	5074	561	31716	9540
2001	114508	1628	46534	3374	15288	5038	552	32240	9854
2002	117128	1658	47724	3401	15894	5011	551	32717	10171
2003	119311	1702	48491	3421	16484	5005	556	33184	10469
2004	122873	1761	49570	3456	17186	5179	606	34229	10885
2005	127475	1815	51038	3492	18012	5509	668	35549	11393
2006	132598	1867	52747	3498	18919	5893	713	36969	11991
2007	139529	1939	55023	3527	20107	6352	767	38973	12841
2008	148660	2043	57867	3617	21764	6904	831	41579	14054
2009	157044	2165	60199	3709	23417	7475	895	44047	15137
2010	161770	2234	61257	3788	24461	7847	932	45337	15914
2011	165035	2283	61811	3862	25287	8050	958	46050	16735
2012	169353	2354	62652	3961	26326	8253	986	47051	17770

2013	174321	2429	63918	4051	27357	8530	1022	48356	18659
2014	179024	2512	65445	4091	28163	8826	1051	49747	19188
2015	183757	2607	67036	4122	28803	9113	1078	51283	19714
2016	189366	2703	68903	4170	29585	9392	1123	53202	20287
2017	194877	2808	70902	4212	30362	9652	1188	55169	20584
2018	199650	2897	72513	4239	31139	9906	1279	56901	20777
2019	204878	2948	73874	4296	32058	10272	1422	58772	21236
2020	203865	2915	73103	4304	32140	10322	1459	58336	21285
2021	200385	2840	72058	4325	31665	10181	1566	56837	20912
2022	200609	2831	71835	4356	31905	10185	1617	56551	21329
2023	202568	2852	71883	4386	32527	10267	1624	56815	22215
2024	204601	2874	71943	4416	33165	10351	1632	57086	23134
2025	206369	2892	71921	4442	33761	10420	1640	57280	24013
2026	207902	2907	71830	4465	34318	10474	1646	57409	24853
2027	209212	2919	71676	4485	34836	10515	1650	57476	25654
2028	210304	2928	71461	4503	35315	10544	1653	57484	26416
2029	211184	2935	71186	4518	35755	10559	1655	57435	27141
2030	211844	2938	70852	4531	36155	10562	1655	57325	27826

Table A2. Model output for the proportion of people living with chronic hepatitis B in Australia who have been diagnosed, 2011-2021.

Year	National (%)	ACT (%)	NSW (%)	NT (%)	QLD (%)	SA (%)	TAS (%)	VIC (%)	WA (%)
2010	63.7%	61.1%	67.6%	55.7%	66.8%	57.4%	45.4%	54.2%	49.0%
2011	64.9%	62.5%	69.3%	56.9%	66.8%	58.7%	46.2%	55.8%	49.1%
2012	65.7%	63.9%	70.5%	58.6%	66.4%	59.9%	47.9%	57.0%	48.9%
2013	66.4%	65.1%	71.6%	62.6%	66.2%	60.3%	49.2%	58.0%	49.0%
2014	67.2%	65.8%	72.4%	64.2%	66.5%	60.8%	50.6%	58.7%	49.9%
2015	67.8%	65.7%	72.8%	65.9%	67.3%	61.3%	51.3%	59.2%	50.5%
2016	68.1%	65.8%	73.1%	66.5%	67.9%	61.6%	51.5%	59.4%	51.2%
2017	68.3%	65.6%	73.2%	67.0%	68.1%	61.8%	51.3%	59.6%	52.1%
2018	68.7%	65.8%	73.6%	67.5%	68.3%	62.0%	50.6%	59.9%	53.0%
2019	68.9%	66.6%	74.0%	67.6%	68.3%	61.9%	49.6%	60.0%	53.3%
2020	70.4%	68.7%	75.7%	68.2%	69.4%	62.7%	50.5%	61.3%	54.4%
2021	72.5%	71.5%	77.6%	68.0%	71.9%	64.0%	50.8%	63.5%	56.7%

Table A3. Model output for the proportion of people living with chronic hepatitis B in Australia who are engaged in care, 2011-2021.

Year	National (%)	ACT (%)	NSW (%)	NT (%)	QLD (%)	SA (%)	TAS (%)	VIC (%)	WA (%)
2010	8.3%	2.7%	8.7%	1.7%	6.5%	5.1%	4.3%	12.1%	2.1%
2011	13.7%	10.8%	16.5%	2.9%	9.1%	9.7%	7.7%	17.3%	4.3%
2012	16.5%	14.8%	19.3%	10.5%	11.1%	11.9%	8.1%	20.7%	5.9%
2013	19.1%	19.9%	22.1%	14.7%	12.7%	18.8%	10.4%	23.9%	7.2%
2014	22.4%	21.9%	26.7%	18.0%	13.9%	23.1%	12.9%	27.5%	8.3%

2015	22.3%	22.5%	27.2%	21.3%	14.1%	22.9%	17.7%	25.5%	9.7%
2016	23.6%	24.0%	28.3%	20.4%	15.3%	24.5%	19.2%	26.5%	10.9%
2017	24.2%	23.7%	28.4%	22.1%	17.5%	23.4%	21.5%	27.0%	11.3%
2018	25.0%	25.9%	29.8%	28.5%	19.0%	22.6%	20.0%	27.4%	10.7%
2019	25.3%	26.8%	30.2%	26.4%	19.4%	21.7%	18.2%	28.3%	10.9%
2020	24.9%	28.5%	29.5%	25.8%	19.9%	18.9%	18.0%	27.4%	11.5%
2021	26.0%	30.5%	30.7%	23.7%	20.5%	18.4%	19.2%	29.5%	12.5%

Table A4. Model output for the proportion of people living with chronic hepatitis B in Australia who are dispensed drugs for the treatment of hepatitis B through the PBS, 2011-2021.

Year	National (%)	ACT (%)	NSW (%)	NT (%)	QLD (%)	SA (%)	TAS (%)	VIC (%)	WA (%)
2010	3.5%	3.4%	4.7%	1.0%	1.9%	2.6%	1.8%	3.6%	2.0%
2011	3.6%	3.5%	5.0%	1.1%	2.0%	2.7%	1.9%	3.8%	2.1%
2012	4.7%	4.6%	6.8%	1.3%	2.6%	3.6%	2.2%	4.5%	2.3%
2013	6.5%	7.1%	8.8%	1.6%	3.8%	6.1%	3.8%	6.8%	3.3%
2014	8.4%	9.0%	11.3%	2.1%	4.9%	7.8%	4.9%	8.7%	4.2%
2015	8.7%	9.7%	11.6%	4.2%	5.3%	7.2%	7.0%	8.8%	4.9%
2016	9.3%	10.0%	12.1%	4.4%	5.9%	7.6%	7.0%	9.6%	5.4%
2017	9.9%	10.6%	12.6%	5.7%	6.7%	8.3%	7.5%	10.2%	6.0%
2018	10.6%	11.8%	13.2%	7.3%	7.4%	8.7%	8.5%	10.8%	6.7%
2019	11.1%	12.6%	13.8%	9.0%	8.1%	9.5%	7.5%	11.3%	7.2%
2020	11.8%	13.8%	14.0%	9.6%	8.7%	9.8%	8.8%	12.2%	7.7%
2021	12.7%	15.7%	15.1%	10.8%	9.6%	10.9%	9.1%	13.3%	8.5%

Table A5. Model output for the total number of deaths attributable to chronic hepatitis B in Australia, 2011-2021.

Year	National	ACT	NSW	NT	QLD	SA	TAS	VIC	WA
2010	471	<10	178	12	69	21	<10	139	42
2011	475	<10	178	13	71	22	<10	139	44
2012	478	<10	178	13	73	22	<10	137	45
2013	473	<10	174	13	74	22	<10	134	47
2014	448	<10	162	13	71	21	<10	126	46
2015	435	<10	156	13	69	21	<10	123	46
2016	431	<10	154	12	68	20	<10	122	46
2017	431	<10	154	12	68	20	<10	122	46
2018	433	<10	155	12	69	20	<10	123	46
2019	437	<10	156	12	69	21	<10	124	47
2020	445	<10	158	11	70	21	<10	127	48
2021	453	<10	161	11	71	22	<10	129	49

Table A6. Model output for the total number of HCC deaths attributable to chronic hepatitis B in Australia, 2011-2021.

Year	National	ACT	NSW	NT	QLD	SA	TAS	VIC	WA
2010	352	<10	135	<10	50	16	<10	104	31
2011	356	<10	136	<10	51	17	<10	104	32
2012	361	<10	137	<10	53	17	<10	104	34
2013	361	<10	136	<10	54	17	<10	103	35
2014	351	<10	131	<10	53	17	<10	101	35
2015	349	<10	129	<10	53	16	<10	100	35
2016	351	<10	129	<10	53	16	<10	100	36
2017	355	<10	131	<10	54	17	<10	102	36
2018	361	<10	132	<10	55	17	<10	103	37
2019	367	<10	135	<10	56	17	<10	105	38
2020	376	<10	137	<10	57	18	<10	108	39
2021	385	<10	141	<10	59	18	<10	111	40

Table A7. Model output for the total number of DC deaths attributable to chronic hepatitis B in Australia, 2011-2021.

Year	National	ACT	NSW	NT	QLD	SA	TAS	VIC	WA
2010	120	<10	43	<10	19	<10	<10	35	11
2011	119	<10	42	<10	20	<10	<10	34	11
2012	118	<10	41	<10	20	<10	<10	33	12
2013	112	<10	38	<10	20	<10	<10	30	12
2014	96	<10	31	<10	18	<10	<10	26	11
2015	87	<10	27	<10	16	<10	<10	23	11
2016	80	<10	25	<10	15	<10	<10	22	10
2017	76	<10	23	<10	14	<10	<10	21	10
2018	73	<10	22	<10	14	<10	<10	20	10
2019	70	<10	21	<10	13	<10	<10	19	<10
2020	69	<10	21	<10	13	<10	<10	19	<10
2021	68	<10	21	<10	13	<10	<10	18	<10

Figure A1. Estimated proportion of people living with chronic hepatitis B in each phase of infection by age group, 2021.

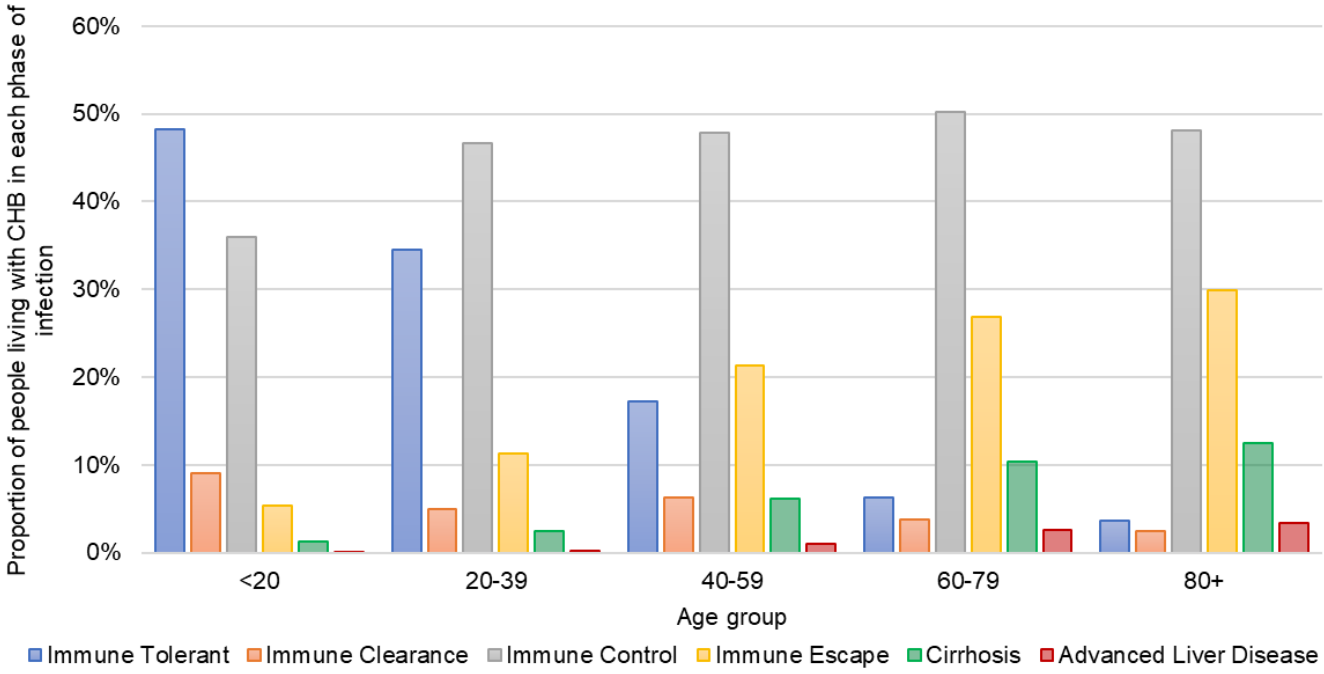
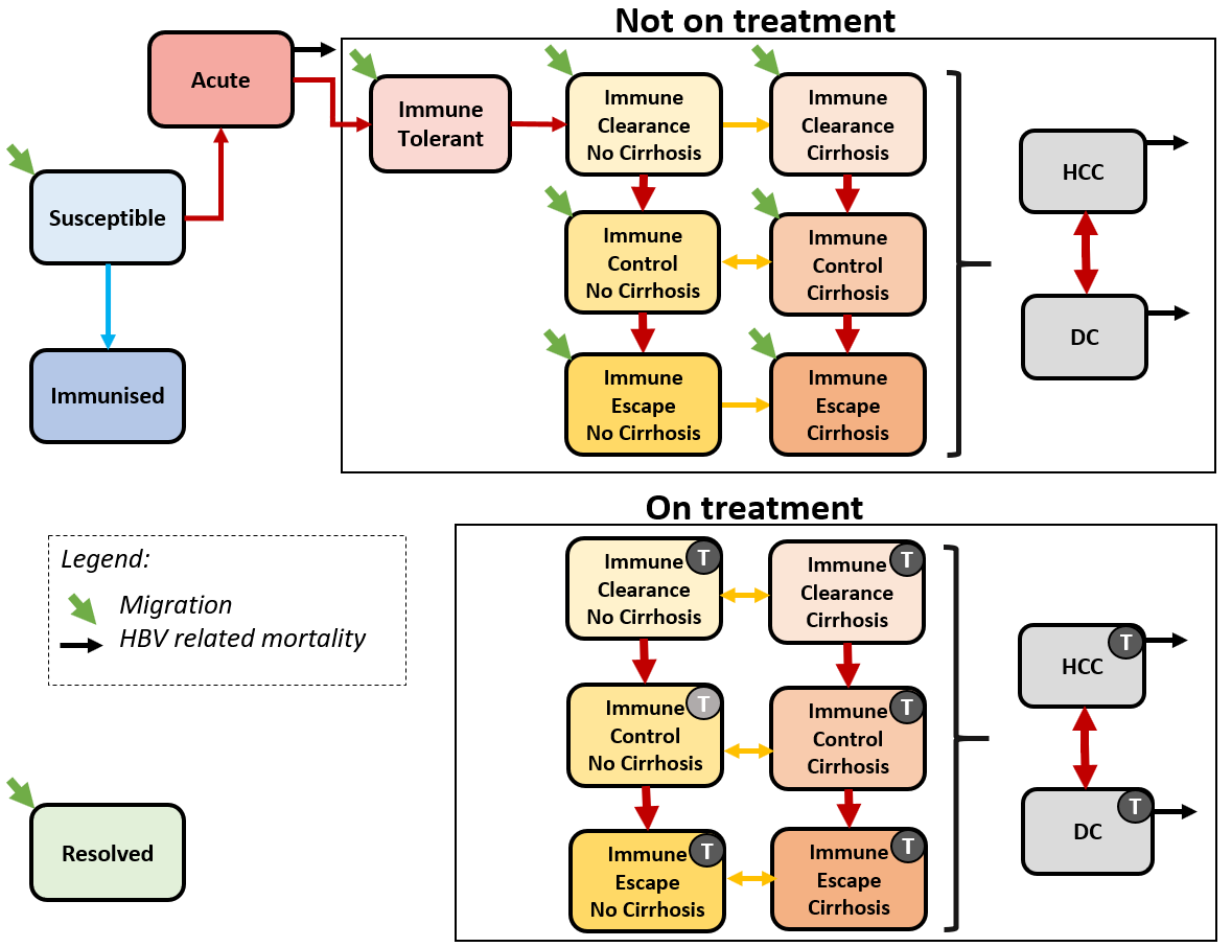

Proportion of people living with CHB in each phase of infection
60%
50%
40%
30%
20%
10%
0%
<20
20-39
40-59
60-79
80+
Age group
Immune Tolerant
Immune Clearance
Immune Control
Immune Escape
Cirrhosis
Advanced Liver Disease

Figure A2: Schematic diagram of the mathematical model describing the progression of hepatitis B infection and indicating key transitions.



Chronic hepatitis B phases are within the boxes. Phases with a 'T' indicate individuals in that phase receiving treatment. Light grey treatment icon indicates those who have transitioned into this phase while on treatment. HCC = hepatocellular carcinoma; DC = decompensated cirrhosis. Coloured arrows represent transitions between states. Each health state is stratefied by age. Resolution of infection is possible from acute infection and from CHB phases and results in the transition into the resolved state.

REFERENCES

1. MacLachlan J, Allard N, Carville K, Haynes K, Cowie B. Mapping progress in chronic hepatitis B: geographic variation in prevalence, diagnosis, monitoring and treatment, 2013-15. *Australian and New Zealand Journal of Public Health*. 2018;42(1):62-68. doi:10.1111/1753-6405.12693
2. McCulloch K, Romero N, MacLachlan J, Allard N, Cowie B. Modeling progress toward elimination of hepatitis B in Australia. *Hepatology*. 2020;71(4):1170-1181. doi: https://doi.org/10.1002/hep.30899
3. Cowie BC. *Novel approaches to an improved understanding of the epidemiology and control of hepatitis B virus infection in Australia*. University of Melbourne; 2009. http://repository.unimelb.edu.au/10187/6755
4. MacLachlan JH, Smith C, Towell V, Cowie BC. *Viral Hepatitis Mapping Project: National Report 2018-19*. 2020. https://ashm.org.au/programs/Viral-Hepatitis-Mapping-Project/
5. MacLachlan JH, Thomas LA, Cowie BC. *Viral Hepatitis Mapping Project: National Report 2017*. 2019.
6. Australian Institute of Health and Welfare. *Cancer in Australia 2017*. 2017. *Cancer series no101Cat no CAN 100*. Accessed 28/06/17. http://www.aihw.gov.au/publication-detail/?id=60129558547
7. *Third National Hepatitis B Strategy 2018-2022*. 2018. http://www.health.gov.au/internet/main/publishing.nsf/Content/ohp-bbvs-1/$File/Hep-B-Third-Nat-Strategy-2018-22.pdf
8. *Global Health Sector Strategy on Viral Hepatitis, 2016–2021*. 2016. Accessed September 1st 2017.
9. Global HIV HaSTIP. *Global health sector strategies on, respectively, HIV, viral hepatitis and sexually transmitted infections for the period 2022-2030*. 2022.
10. The Kirby Institute. *HIV, viral hepatitis and sexually transmissible infections in Australia: Annual Surveillance Report 2018*. 2018. http://kirby.unsw.edu.au/surveillance/Annual-Surveillance-Reports
11. Broady TB, L.; Hopwood, M.; Cama, E.; Treloar, C.;. *Stigma Indicators Monitoring Project: Summary Report. Phase Two*. 2020. http://doi. org/10.26190/5ebca29f38662
12. MacLachlan JH, Allard N, Towell V, Cowie BC. The burden of chronic hepatitis B virus infection in Australia, 2011. *Australian and New Zealand Journal of Public Health*. Oct 2013;37(5):416-22. doi:10.1111/1753-6405.12049
13. Allard NL, MacLachlan JH, Cowie BC. The cascade of care for Australians living with chronic hepatitis B: measuring access to diagnosis, management and treatment. *Australian and New Zealand Journal of Public Health*. Jun 2015;39(3):255-9. doi:10.1111/1753-6405.12345
14. MacLachlan JH, Thomas LA, Allard N, Cowie BC. *Hepatitis B Mapping Project: Estimates of chronic hepatitis B prevalence, diagnosis, monitoring and treatment by Primary Health Network – National Report 2016*. 2018. http://www.ashm.org.au/HBV/hepatitis-b-mapping-reports/
15. Romero N, McCulloch K, Allard N, MacLachlan JH, Cowie BC. *National Surveillance for Hepatitis B Indicators: Measuring the progress towards the targets of the National Hepatitis B Strategy – Annual Report 2017*. 2019
16. Romero N, McCulloch K, Allard N, MacLachlan JH, Cowie BC. *National Surveillance for Hepatitis B Indicators: Measuring the progress towards the targets of the National Hepatitis B Strategy – Annual Report 2018*. 2019b.

17. Romero N, McCulloch, K., Allard, N., MacLachlan, J., Cowie, B.C. *National Surveillance for Hepatitis B Indicators: Measuring progress towards the targets of the National hepatitis B Strategy - Annual Report 2019*. 2020.
18. McCulloch K, Romero N, MacLachlan J, Cowie BC. *National Surveillance for Hepatitis B Indicators:Measuring the progress towards the targets of the National Hepatitis B Strategy – Annual Report 2020*. 2021.
19. Wilson T, Temple J, Charles-Edwards E. Will the COVID-19 pandemic affect population ageing in Australia? *Journal of Population Research*. 2021;doi:10.1007/s12546-021-09255-3
20. MacLachlan JH, Stewart S, BC. C. *Viral Hepatitis Mapping Project: National Report 2020*. 2021. https://www.ashm.org.au/programs/Viral-Hepatitis-Mapping-Project/
21. National Notifiable Diseases Surveillance System. Department of Health, Australian Government. Accessed 31/03/2021, http://www9.health.gov.au/cda/source/cda-index.cfm
22. MacLachlan JH, Romero NR. *Impacts of COVID-19 on BBVSTI testing, care and treatment: Medicare data analysis*. 2020. https://www.doherty.edu.au/whoccvh/centre-activities/australian-viral-hepatitis-mapping-project
23. Australian Government Services Australia. Medicare Benefits Schedule Item Reports. Accessed 10/11/2022, http://medicarestatistics.humanservices.gov.au/statistics/mbs_item.jsp
24. Terrault NA, Lok ASF, McMahon BJ, et al. Update on prevention, diagnosis, and treatment of chronic hepatitis B: AASLD 2018 hepatitis B guidance. *Hepatology*. Apr 2018;67(4):1560-1599. doi:10.1002/hep.29800
25. European Association for the Study of the Liver. Electronic address eee, European Association for the Study of the L. EASL 2017 Clinical Practice Guidelines on the management of hepatitis B virus infection. *J Hepatol*. Aug 2017;67(2):370-398. doi:10.1016/j.jhep.2017.03.021
26. Lubel JS, Strasser SI, Thompson AJ, et al. Australian consensus recommendations for the management of hepatitis B. *The Medical Journal of Australia*. May 16 2022;216(9):478-486. doi:10.5694/mja2.51430
27. Terrault NA, Bzowej NH, Chang KM, Hwang JP, Jonas MM, Murad MH. AASLD guidelines for treatment of chronic hepatitis B. *Hepatology*. Nov 13 2015;doi:10.1002/hep.28156
28. Vinikoor MJ, Sinkala E, Kanunga A, et al. Eligibility for hepatitis B antiviral therapy among adults in the general population in Zambia. *PLOS ONE*. 2020;15(1):e0227041. doi:10.1371/journal.pone.0227041
29. Tan M, Bhadoria AS, Cui F, et al. Estimating the proportion of people with chronic hepatitis B virus infection eligible for hepatitis B antiviral treatment worldwide: a systematic review and meta-analysis. *The Lancet Gastroenterology & Hepatology*. 2020;doi:10.1016/s2468-1253(20)30307-1
30. Hutton DW, Tan D, So SK, Brandeau ML. Cost-effectiveness of screening and vaccinating Asian and Pacific Islander adults for hepatitis B. *Annals of internal medicine*. Oct 2 2007;147(7):460-9.
31. Robotin MC, Kansil MQ, George J, et al. Using a population-based approach to prevent hepatocellular cancer in New South Wales, Australia: effects on health services utilisation. *BMC Health Serv Res*. Jul 21 2010;10:215. doi:10.1186/1472-6963-10-215
32. Butler J, Korda R, Watson KJ, Watson D. *The impact of chronic hepatitis B in Australia: Projecting mortality, morbidity and economic impact*. 2009.

33. *Population Projections, Australia, 2017 (base) - 2066*. 2018. https://www.abs.gov.au/ausstats/abs@.nsf/latestProducts/3222.0Media%20Release12017%20(base)%20-%202066
34. *Australian Historical Population Statistics (Cat. No. 3105.0.65.001).* 2019.
35. Australian Demographic Statistics (Cat. No. 3101). (2017).
36. Deaths in Australia, 2004 to 2014. (Cat. No. 3302.0). (2015).
37. Deaths in Australia, 1997 to 2007. (Cat. No. 3302.0). (2008).
38. Life Tables, States, Territories and Australia. 2009 to 2016. (Cat. No. 3302.0.55.001). (2016).
39. Populations Projections, Series B, Australia (cat 3222.0) (2018).
40. *Net Overseas Migration by State 1972 - 2019: Customised Data Report*. 2021.
41. *Net Overseas Migration by country of birth and age group (2004 - 2020): Customised Data Report*. 2021.
42. *Settlement Data: Permanent Arrivals 1991 - 2019*. 2019.
43. *Migration, Australia, 2005-2006 (Cat. No. 3412.0)*. 2007.
44. *Immigration: Federation to Century's End*. 2001.
45. CDC. *Travellers' Health: Yellow Book: Health Information for International Travel, 2005 - 2006.* 2007:7. https://folk.uib.no/mihtr/Fredskorpset/FK082006.html#dis9
46. Reekie J, Gidding HF, Kaldor JM, Liu B. Country of birth and other factors associated with hepatitis B prevalence in a population with high levels of immigration. *Journal of gastroenterology and hepatology*. Sep 2013;28(9):1539-44. doi:10.1111/jgh.12245
47. Turnour CE, Cretikos MA, Conaty SJ. Prevalence of chronic hepatitis B in South Western Sydney: evaluation of the country of birth method using maternal seroprevalence data. *Australian and New Zealand Journal of Public Health*. Feb 2011;35(1):22-26.
48. He WQ, Duong MC, Gidding H, et al. Trends in chronic hepatitis B prevalence in Australian women by country of birth, 2000 to 2016. *Journal of Viral Hepatitis*. 2020;27(1):74-80. doi:10.1111/jvh.13202
49. Schweitzer A, Horn J, Mikolayczyk R, Ott J. Worldwide prevalence of chronic hepatitis B virus infection: estimations based on a systematic review of data published between 1965 and 2013. *The Lancet*. 2015;386(10003):1546-55.
50. Kowdley KV, Wang CC, Welch S, Roberts H, Brosgart CL. Prevalence of chronic hepatitis B among foreign-born persons living in the United States by country of origin. Meta-Analysis
Research Support, Non-U.S. Gov't. *Hepatology*. Aug 2012;56(2):422-33. doi:10.1002/hep.24804
51. Cowie BC, Karapanagiotidis T, Enriquez A, Kelly H. The Victorian Hepatitis B Serosurvey 1995-2005. *Journal of Gastroenterology and Hepatology*. 2008;23(Suppl. 6):A379.
52. Cui F, Shen L, Li L, et al. Prevention of Chronic Hepatitis B after 3 Decades of Escalating Vaccination Policy, China. *Emerging Infectious Diseases*. May 2017;23(5):765-772. doi:10.3201/eid2305.161477
53. Liang X, Bi S, Yang W, et al. Epidemiological serosurvey of hepatitis B in China--declining HBV prevalence due to hepatitis B vaccination. *Vaccine*. Nov 5 2009;27(47):6550-7.
54. Polaris Observatory. Hepatitis B prevalence estimates. CDA Foundation. Accessed 3/10/2017, http://polarisobservatory.org/polaris_view/hepB.htm
55. Su WJ, Chen SF, Yang CH, Chuang PH, Chang HF, Chang MH. The Impact of Universal Infant Hepatitis B Immunization on reducing the Hepatitis B Carrier Rate in Pregnant Women. *J Infect Dis*. Dec 20 2018;doi:10.1093/infdis/jiy706

56. Nguyen TH, Vu MH, Nguyen VC, et al. A reduction in chronic hepatitis B virus infection prevalence among children in Vietnam demonstrates the importance of vaccination. *Vaccine*. 2014;32(2):217-222. doi:10.1016/j.vaccine.2013.11.004
57. Di Bisceglie AM, Lombardero M, Teckman J, et al. Determination of hepatitis B phenotype using biochemical and serological markers. *Journal of Viral Hepatitis*. 2017;24(4):320-329. doi:doi:10.1111/jvh.12643
58. Spradling PR, Xing J, Rupp LB, et al. Distribution of disease phase, treatment prescription and severe liver disease among 1598 patients with chronic hepatitis B in the Chronic Hepatitis Cohort Study, 2006–2013. *Alimentary Pharmacology & Therapeutics*. 2016;44(10):1080-1089. doi:doi:10.1111/apt.13802
59. Shimakawa Y, Lemoine M, Njai HF, et al. Natural history of chronic HBV infection in West Africa: a longitudinal population-based study from The Gambia. *Gut*. Dec 2016;65(12):2007-2016. doi:10.1136/gutjnl-2015-309892
60. Marino S, Hogue IB, Ray CJ, Kirschner DE. Review: A methodology for performing global uncertainty and sensitivity analysis in systems biology. Review Article. *Journal of Theoretical Biology*. 1/1/2008 2008;254:178-196. doi:10.1016/j.jtbi.2008.04.011
61. Davies J, Li SQ, Tong SY, et al. Establishing contemporary trends in hepatitis B sero-epidemiology in an Indigenous population. *PloS One*. 2017;12(9):e0184082. doi:10.1371/journal.pone.0184082
62. Graham S, Guy RJ, Cowie B, et al. Chronic hepatitis B prevalence among Aboriginal and Torres Strait Islander Australians since universal vaccination: a systematic review and meta-analysis. *BMC Infectious Diseases*. Aug 31 2013;13(1):403. doi:10.1186/1471-2334-13-403
63. Graham S, MacLachlan JH, Gunaratnam P, Cowie BC. Chronic hepatitis B prevalence in Australian Aboriginal and Torres Strait Islander people before and after implementing a universal vaccination program: a systematic review and meta-analysis. *Sexual health*. 2019;16(3):201-211.
64. Madden RC, Pulver LRJ. Aboriginal and Torres Strait Islander Population: More Than Reported. Journal Article. *Australian Actuarial Journal*. 2009;(2):181.
65. *Experimental Estimates and Projections, Aboriginal and Torres Strait Islander Australians 1991 to 2021 (Cat. No. 3238.0)*. 2012.
66. Hosking KA, Davies J, Steward GI, Mobsby MJ, Nihill PJ, Connors C. Big Mob Big Job: Hepatitis B Sero-coding the Top End. presented at: 11th Australasian Viral Hepatitis Conference; 13-15 August 2018; Adelaide, Australia http://www.amsant.org.au/wp-content/uploads/2018/11/Big-Mob-Big-Job-Hep-B-sero-coding-the-Top-End-Kelly-Hosking.pdf