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Mapping HIV outcomes: geographical and clinical forecasts of numbers of people living with HIV in Australia

napwa national association of people living with HIV/AIDS

National Centre in HIV Epidemiology and Clinical Research

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Investigators

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Other contributors

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Data sources

This study utilised the data and results from numerous studies including:

- Australia's National HIV Registry
- Australian Census Data (2001, 2006) from the Australian Bureau of Statistics
- Australian HIV Observational Database (AHOD)
- HIV Futures Six: Making Positive Lives Count
- Bettering the Evaluation And Care of Health (BEACH)
- International peer-reviewed HIV literature

This report is the first in a series of reviews looking at patterns of demographic shifts and trends in the Australian HIV-positive population. A core objective of this work is to build a detailed coverage of changes in factors associated with HIV across time, as well as consider significant areas of data for future policy development and planning within the national HIV response.

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Executive Summary

Significant advances in HIV antiretroviral therapy have substantially decreased Acquired Immune Deficiency Syndrome (AIDS) associated mortality and morbidity in industrialised countries [1-2]. Although the health and survival of people living with HIV has improved, they require ongoing clinical management is required, including constant adherence to potent antiretroviral drugs (ARVs). Patients on antiretroviral therapy may develop drug resistance leading to virological failure and potentially immunological and clinical failure. There is a limited number of ARV classes available currently available, and disease progression or toxicities can drive the need to change treatment regimens. HIV-positive people are also at substantially greater risk of cancers, cardiovascular disease, mental health disorders, and other co-morbidities compared to people without HIV infection.

The aim of the project was to estimate the current and forecast the future

- size, age and location of the population of people living with HIV in Australia;
- numbers of people requiring antiretroviral therapies, by first-, second-, and subsequent lines of therapies;

These outcomes were estimated by using an agent-based computer model. This approach simulates a population of individual people and tracks every virtual individual over time including the differential progression of disease, treatment outcomes, and clinical outcomes in infected individuals according to probabilistic rates informed by the best available Australian and international data.

This study uses data from the following sources:

- National HIV surveillance data from Australia's National HIV Registry, for the baseline information on HIV diagnoses in Australia;
- Australian Census Data (2001 and 2006) from the Australian Bureau of Statistics migration and demographic data, to determine the rates of movement and the baseline mortality of the general population;
- Peer-reviewed literature, to determine the impact of patient variables on the outcomes of rates of disease progression and mortality;
- Australian HIV Observational Database (AHOD), for information on the failure rate of HAART regimens.

Key findings:

- The total number of people living with diagnosed HIV in Australia is estimated to be 20,956 in 2010. By 2020, the total number of people living with diagnosed HIV in Australia is predicted to be 28,422 (that is, a 36% increase). This does not account for the 10-20% of HIV infections that are thought to be undiagnosed.
- New South Wales is the state with the highest population of people living with HIV, with 9,924 people in 2010, estimated to increase to 11,721 by 2020.
- The population of people living with HIV is mostly found in the central areas of the major capital cities, on the coast between Sydney and Brisbane and in far North Queensland.
- Tasmania and Queensland have experienced the largest relative increases in HIV diagnoses over the past 10 years.
- The simulations predict that over the next decade, increasing numbers of people living with HIV will live outside major metropolitan areas.
- Statistical regions with the largest expected increase in HIV-positive populations are expected to be based mainly in Queensland and Victoria.
- In 2010, females make up an estimated 9% of the population living with HIV. By 2020, females are predicted to be 10.5% of the population living with HIV.
- Western Australia and the Northern Territory are jurisdictions which have the highest numbers of the female population as a percentage of the diagnosed HIV population, being 18.2 % and 17.5% respectively in 2010 and further increases are expected over the next 10 years.
- The population of people living with HIV has aged substantially. In 1985 the proportion of the population aged over 55 years was 2.7%. By 2000 it was 11.2%. In 2010, it was 25.7% and by 2020 it is expected to be 44.3%.
- The total potential demand for antiretroviral therapy (eligible to consider treatment) in Australia is estimated to be 18,362 people in 2010 and 25,580 in 2020 (that is, a 39% increase); the estimated number of people eligible for second-line and subsequent lines of therapies is expected to increase from 7,050 and 5,489 in 2010 to approximately 8,355 (19% increase) and 11,385 (107% increase) in 2020.

Conclusions

The population of people living with HIV is expected to change over the coming years. The population is expected to substantially shift in its age distribution, which will present challenges for health providers as age-related medical issues such as the incidence of cancers start to increase. As people living with HIV become more treatment-experienced, there will be clinical need to replace current therapies with new treatment options. Movement of people with HIV away from traditional centres will also require the HIV sector to accommodate people in non-metropolitan settings.

These forecasts are valuable in planning for the needs of people living with HIV in Australia, particularly those requiring more complex case management in areas that currently do not have an established HIV service sector or referral pathways in place.

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Background

Significant advances in HIV antiretroviral therapy have substantially decreased Acquired Immune Deficiency Syndrome (AIDS) associated mortality and morbidity in industrialised countries [1-2]. Although the health and survival of people living with HIV has improved, patients develop drug resistance to antiretrovirals (ARVs) leading to virological failure and potentially immunological and clinical failure. HIV-infected people are also at substantially greater risk of cancers, cardiovascular disease, mental health disorders, and other co-morbidities compared to uninfected people.

People living with HIV in Australia are surviving longer, getting older, and are becoming more treatment experienced with second line, third line or more complex antiretroviral regimens. Increasingly, HIV-positive population in Australia requires long-term management of side effects, including dealing with more co-morbidities and aged care support. Cases with complex treatment demands require specialist care by expert HIV clinicians and other non HIV specialists. The changing and increasingly complex health needs of people living with HIV in Australia will have implications for the health workforce to deliver accessible HIV clinical services. These issues are of large importance and will increase in significance in the coming decades. Thus, it is important to understand the profile of Australia's HIV-infected population, the treatment pathways currently experienced, and the co-morbidities affecting this population. It is also important to forecast the demands for clinical service in the future in order to effectively plan to ensure adequate infrastructure is in place to care for Australians living with HIV in the future. This study attempts to map the clinical demands and geographical distributions associated with people living with HIV in Australia. These calculations are carried out through the development of an agent-based mathematical model, directly informed by all relevant data available.

The development and use of micro-simulation agent-based modelling is becoming increasingly common. This approach simulates a population of individual people and tracks every individual over time including the differential progression of disease, treatment outcomes, and clinical outcomes in infected individuals according to probabilistic rates.

Introduction to methods

Mathematical models can be useful for understanding complex epidemics. They can combine various data and information sources into a single framework to understand how these different factors interact and together contribute to an observed outcome at a population level. For example, epidemiological transmission models contain explicit mechanisms linking individual-level behaviours (e.g., sexual events and condom usage) with population-level outcomes (e.g., incidence and prevalence) and have been used to analyse a variety of infectious diseases [3-4]. Early HIV models [3, 5-7] did not include the possibility of emergence of HIV strains that are resistant to ARVs. More recently, Wilson and colleagues have developed HIV models that included the emergence and transmission of drug-resistant strains [8-12]. Only very recently have models investigated the historical emergence of drug-resistant strains to multiple drug-classes [13]. This work has been an informative advancement of modelling of past trends in drug resistance but it is still a large abstraction from reality in that individual drug regimens are not explicitly included. Further, no prior study internationally has attempted to simulate significant and diverse clinical morbidities to HIV-infected populations at a population level. This study aims not only to map the current situation but to forecast the future demands to assist in the preparation of the care and management of Australia's HIV-infected population. The study significantly advances previous mathematical models of HIV epidemics in Australia [14-23] and is the first study internationally to simulate specific treatment pathways and significant co-morbidities of HIV-infected populations as well as forecast their detailed national geographical distribution. The mathematical computer model simulates Australia's population of HIV-infected people as they progress through antiretroviral treatment. Expected future clinical demands are forecasted over the next 10 years. Future versions of this study will extend this work to include other morbidities and mortality rates attached to these morbidites.

Overview of data used

This study directly uses national HIV surveillance data from Australia's National HIV Registry. All reported HIV diagnoses in Australia are used for describing the size of Australia's HIV-infected population and stage of disease progression of the individuals who are infected. At diagnosis, demographic factors of HIV-infected people (such as age, gender etc), their CD4 count (an immunological marker of disease progression), and geographical location (post code) are recorded. These data are coupled with the Australian HIV Observational Database (AHOD) and the Medicare Pharmaceutical Benefits Scheme Section-100 Highly Specialised Drugs Program in order to simulate the treatment pathways over time of Australia's HIV-infected population. Australian Census Data (2001 and 2006) from the Australian Bureau of Statistics are used to determine specific movement patterns across Statistical Local Areas (SLAs) to simulate geographical migration. The international peer-reviewed literature was systematically reviewed to determine associations between patient variables and morbidities. These results, in combination with model-based output descriptions of individuals in Australia's HIV-infected population, were used to simulate the expected clinical outcomes over time and space in Australia. Model-simulated results were compared with summary outputs from the 'HIV Futures Six' and 'Bettering the Evaluation And Care of Health (BEACH)' studies to ensure that the model accurately reflects available descriptions of Australia's HIV population and clinical care as consistently as possible.

The Australian HIV registry collects data on all HIV notifications in Australia. HIV/AIDS surveillance activities are conducted in collaboration with the Australian Commonwealth Government Department of Health and Ageing, State and Territory health authorities and collaborating networks. Summary data are published in the 'HIV, viral hepatitis and sexually transmissible infections in Australia Annual Surveillance Report' [24].

The Australian HIV Observational Database (AHOD) [25-26] is a clinical database of over 2700 people living with HIV at 27 sites around Australia, representing approximately 15% of the diagnosed HIV-infected population in Australia. The AHOD has been running for over 10 years and collects detailed data of treatment pathways experienced by people living with HIV in Australia. AHOD provides unique data, specific to the Australian context, on the rate of treatment failure and switching of regimens, and the impact of specific antiretroviral regimens on morbidities and mortality.

The Australian Bureau of Statistics (ABS) collects data from national censuses, including the number of people residing in each ABS-defined Statistical Local Area (SLA) at each census and the number that moved within and between all pairings of SLAs between censuses. Data from 2001 and 2006 censuses are used in this study.

The HIV Futures Survey is a periodic survey completed anonymously by approximately 1,000 (random) HIV-infected people across Australia. These data provide current and past treatment experiences and associations with the context of living with HIV (e.g. socio-economic factors).

Trends in use of antiretroviral therapies

Australia has a relatively long history of using ARVs and has one of the highest HIV treatment rates in the world. The history of HIV therapy can be described by three clearly defined eras: mono-therapy using Nucleoside Reverse Transcriptase Inhibitors (NRTIs) and beginning in 1987, dual-therapy using two NRTIs and beginning in 1992, and triple-therapy using drugs from at least two classes (this began in 1996 when both Non-Nucleoside Reverse Transcriptase Inhibitors (NNRTIs) and Protease Inhibitors (PIs) were introduced). The current standard of care is triple-therapy with drugs from at least two classes [1]. Recently, other classes of ARVs have become available, including fusion inhibitors, integrase inhibitors and co-receptor inhibitors [27].

Drug resistance is a major obstacle to the success of therapy. Persons infected with drug-resistant HIV have reduced therapeutic options for their survival [28]. Virus strains with reduced sensitivity to zidovudine (AZT), the first drug used against HIV, were detected in 1989, three years after it was introduced [29]. Subsequently, resistance to every currently licensed antiretroviral drug has been observed. Although drug resistance developed quickly to NRTI (due to poor viral suppression with mono/dual therapy), it emerged more slowly to NNRTIs and PIs when they were used in triple-therapy. Acquired resistance usually commences with resistance to a single ARV class, leading to treatment failure. Treated individuals can acquire multiple resistance mutations due to sequential failure of successive classes of ARVs [30-31]. The probability of these resistance mutations arising depends on the drug regimens that are used, patient adherence rates, clinician expertise, degree of immune suppression, viral replication rates, and HIV subtype. HIV-infected patients that have a history of being treated with the first type of (sub-optimal) ARVs (between 1987 and 1996) are most likely to have developed drug resistance to multiple classes of drugs. Thus, treatment options are now currently more limited and difficult decisions are required by clinicians in generating appropriate switch therapy regimens.

Drug-resistant HIV can also be transmitted when an uninfected individual acquires HIV by sexual contact or sharing needles (or vertically from mother to child) with an individual that is infected with drug-resistant strains. The first report of observed transmission of drug-resistant HIV was in 1993 [32]. Approximately 10% of all patients newly diagnosed with HIV in

Australia are infected with drug-resistant strains [33], however, there exists regional variation across Australia, ranging from 7-34% (0-9% for NRTI, 5-6% for NNRTI and 1.4-12% for PIs (unpublished data)).

In Australia, numerous ARVs are licensed for use and cover all treatment classes. Each combination of antiretroviral therapy is associated with a different rate of treatment failure. This study used data from the Australian HIV Observational Database (AHOD), which collects data on a cohort of over 2700 HIV-infected people in Australia and tracks lines of antiretroviral therapy (ART), their time on each regimen, time off any ART and whether treatment was ceased or the participant left the study. Patients used a wide variety of regimens that varied by the number of drugs used in the regimen, the classes of drugs and the specific drugs used in the regimens. In the current study, the AHOD data were organised by regimens and survival curves were produced for the duration of time on the regimen and the time on treatment breaks during regimen. Any change in treatment combination that involved only one drug change of the same class was not noted as a change in regimen. Regimens which were used by less than 10 people in the cohort were amalgamation with other regimens, grouped based on the class of drugs used in the therapy.

Estimation of the time until treatment failure

Treatment-failure was not recorded for each regimen for all people followed in the AHOD cohort (due to sustained virological suppression or loss to follow-up). To adjust for this right-censoring of the data, the Kaplan-Meier (Product-Limit) Estimator was used [34]. The standard Kaplan-Meier routine in the Matlab software, ecdf, was used to adjust the Kaplan-Meier curve and the variance about the curve using Greenwood's formula [35]. Inspection of the data suggested that the numbers of people stopping each regimen of treatment occurs at a constant rate proportional to the number of people remaining on the treatment; mathematically, this can be expressed as

$$\frac{dA}{dt} = -kA,$$

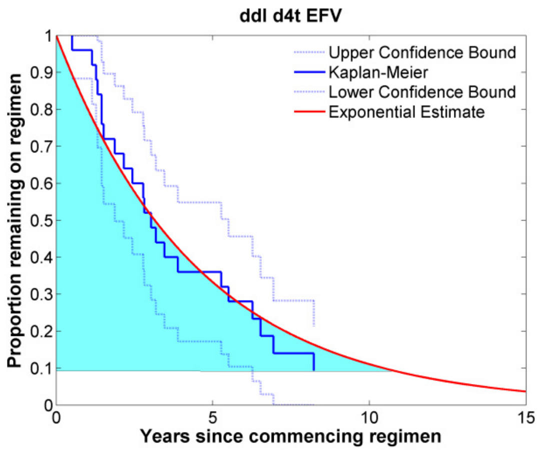
where k is the rate of ceasing the treatment regimen and A is the number of people remaining on the regimen as a proportion of those initiating the regimen. A simple survival equation was derived from the above equation, namely,

$$A = e^{-kt}.$$

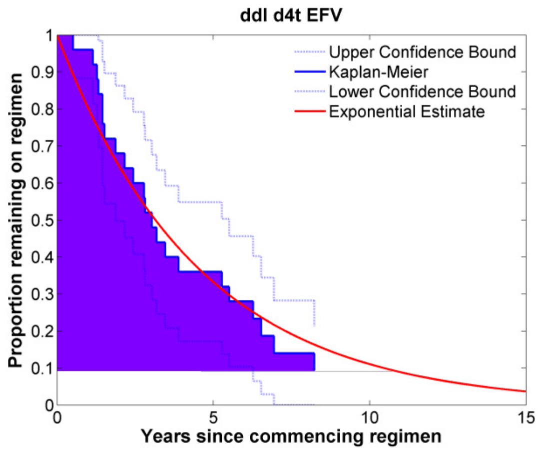
Hence an exponential curve was fitted to the graphs to make a smooth function from which the expected duration on treatment can be easily calculated. The rate of ceasing use of each regimen was calculated by equating the area under the Kaplan-Meier curve up to the last available datum point with the exponential function by adjusting the value of k (see Figure 1). This method allows sampling of the domain for which data exists and ensuring that the same average time on each regimen will be the same for simulations as with the empirical Kaplan-Meier curves.

Figure 1: A comparison of the area under a representative (a) Kaplan-Meier curve and (b) fitted exponential curve such that the area above each curve is equal.

a)

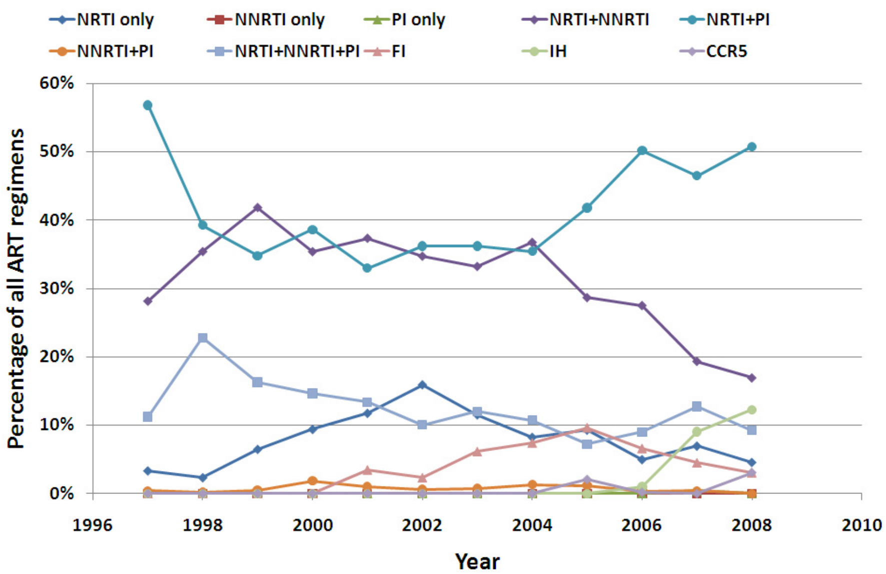


b)



The exponential function is particularly well suited to this application as it allows easy forward projection of the likely time on a drug regimen using right-censored data. This is particularly important when modelling the newer ARV regimens that are particularly effective but only have a relatively short period of observation with lower failure rates. The 'survival' times on each regimen are shown in Appendix A. The percentage of people who started each specific first-, second-, third- and fourth-line regimens over time is also indicated in Appendix A. However, trends in initiating ART regimens has changed over time (see Figure 2) and this is captured in the model.

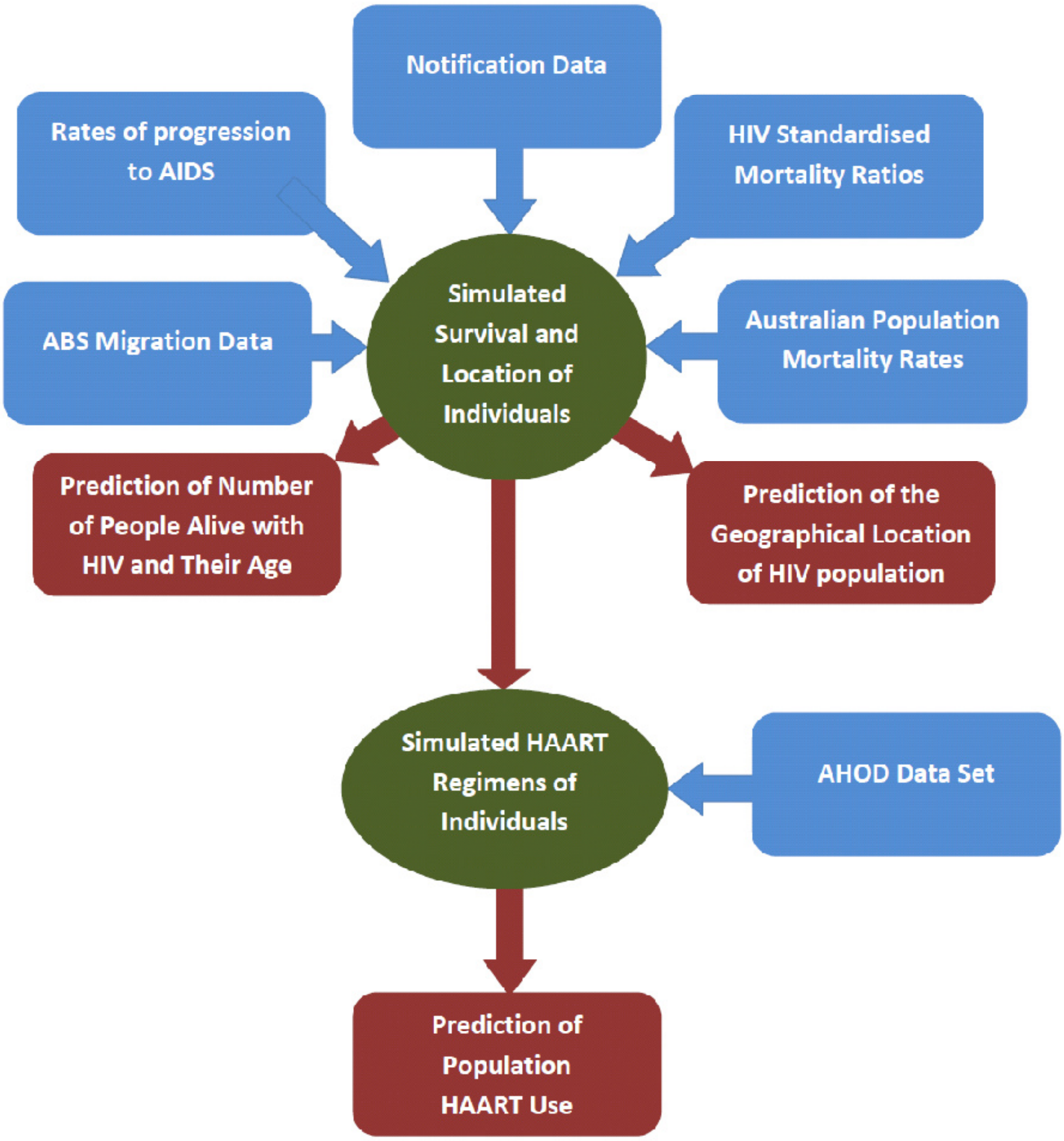
Figure 2: Trends over time in the use of different combinations of ART classes.



Basic Model Structure

The model has a number of components that simulate different elements of the medical history of the people living with diagnosed HIV in Australia (Figure 3).

Figure 3: Schematic diagram of the input data (blue), model modules (green) for processing data and simulating outcomes (red)



Overview of the Methods for Determining Location and Mortality

Movement of the HIV-infected population

Movement of the population of people living with HIV in Australia was simulated based on data sourced from the Australian 2001 and 2006 censuses collated by the Australian Bureau of Statistics (ABS). It was assumed that the HIV-positive population generally migrates in a similar manner to the general population when adjusted for age, sex and location of residence. Available data included the population in each Statistical Local Area (SLA, Australian Standard Geographical Classification) by age and gender for the years 2001 and 2006, including the number of people that moved from one SLA to another SLA in this five year period. Statistical Local Area boundaries were standardised to the 2006 Statistical Local Area boundaries. To ensure that the population movement rates indicated real movements and not just an artefact of changing boundaries, a method was devised to create a 2001 to 2006 SLA concordance file based on the households in the area. The core assumption of the method is that in groups of SLAs where boundaries have moved (and 2001 areas overlap with 2006 areas) the proportions of people in living in the area in will be approximately equal. The concordance file was then used to ascribe statistics of people in the 2001 census to 2006 Statistical Local Area boundaries. The comparison between the 2001 census data and the 2006 census data allows for a trend in migration to be established between the various areas based on age and current postcode. The model represents SLAs but results are presented according to ABS Statistical Regions due to the fine detail of SLAs.

Determining the lifespan of the HIV infected population

The national HIV/AIDS registry records reported AIDS-related deaths. As these records were incomplete, progression to AIDS was simulated using data on progression to AIDS based on CD4 count[36]. These data were used in the model along with mortality rates derived from a study by Nakhaee et al [37]. Nakhaee and colleagues investigated changes in mortality following HIV and AIDS in Australia through a linkage study between HIV/AIDS diagnoses and the National Death Index (NDI). Standardised Mortality Ratios (SMRs) were calculated for deaths following HIV infection in three periods of treatment: before antiretroviral therapy (pre-1989), pre- and early-HAART (1990–1996) and HAART (1997–2003).

For deaths following HIV without AIDS, the SMRs were 2.99 (2.49-3.58, 95% CI), 1.22 (1.12-1.33, 95% CI) and 1.61 (1.52-1.71, 95%CI) per 100 person-years during the periods before 1990, 1990–1996 and 1997–2003. For deaths after AIDS the SMRs were 137.84 (129.80-146.38, 95% CI), 28.64 (27.81-29.50, 95% CI) and 4.55 (4.31-4.80, 95% CI) in the respective periods. SMRs were also calculated according to age groups as shown in Table 1.

Table 1: Standardised mortality ratios for people living with HIV/AIDS by age-group and era

Age group (years)	≤ 1989		1990-1996		1997-2003	
	SMR (per 100-PYs)	95% CI	SMR (per 100-PYs)	95% CI	SMR (per 100-PYs)	95% CI
< 25	4.89	2.90-8.26	2.76	1.92-3.98	3.79	2.39-6.01
25-34	4.21	3.13-5.65	1.89	1.92-3.98	2.69	2.35-3.07
35-44	4.04	2.97-5.51	1.52	1.63-2.19	2.16	1.96-2.38
45-54	1.15	0.58-2.32	1.08	0.89-1.31	1.56	1.39-1.76
55-64	1.36	0.65-2.86	0.46	0.33-0.65	1.05	0.89-1.24
≥ 65	0.83	0.27-2.58	0.49	0.34-0.72	0.68	0.54-0.84

The HIV-CAUSAL Collaboration is a US-Europe-UK-based study that investigated the reduction in the risk of mortality for people on HAART compared with people who were not on HAART [38]. Their findings, of the impact of HAART on mortality by CD4 count and viral load, are shown in Table 2: Summary of the HIV-CAUSAL Collaboration results on mortality rates and are consistent with the mortality rates used in the current model and will be used to inform future iterations of the model with more detail.

Table 2: Summary of the HIV-CAUSAL Collaboration results on mortality rates

Baseline characteristic	Mortality hazard ratio	95% CI
CD4 cell count (cells/μl)		
<100	0.29	(0.22–0.37)
100 to <200	0.33	(0.25–0.44)
200 to <350	0.38	(0.28–0.52)
350 to <500	0.55	(0.41–0.74)
>500	0.77	(0.58–1.01)
HIV RNA (copies/ml)		
<10 000	0.82	(0.64–1.05)
10 000–100 000	0.46	(0.36–0.60)
>100 000	0.36	(0.28–0.45)
Gender		
Female	0.32	(0.21–0.50)
Male	0.52	(0.44–0.62)
Age (years)		
<35	0.6	(0.46–0.78)
35–50	0.47	(0.36–0.60)
>50	0.41	(0.31–0.53)
Transmission group		
Heterosexual	0.31	(0.21–0.46)
Homo/bisexual	0.66	(0.50–0.89)
Injection drug use	0.45	(0.36–0.56)
Other/unknown	0.73	(0.45–1.18)

Detailed Description of the Methods for Determining Location and Mortality

Initial Manipulation of Data

The demographics of the population were obtained from the Australian National HIV Registry, which provided information on the year of birth, location, sex, CD4 count and date of diagnosis for each individual in the population diagnosed with HIV.

Many of the records in the database had fields missing such as year of birth, postcode, and CD4 count. Those records had to be complete in order for the simulation to determine the outcome of the individuals. To do this, empty fields were filled by randomly sampling from the distributions of the completed fields of the other records in the database.

If a record did not have a year of birth, this number was chosen at random from other records that were diagnosed in the same year. If a record did not have a postcode for the individual, a postcode was chosen at random from other records from the same state and year of diagnosis. If initial CD4 levels were not present in the database, a CD4 level was chosen at random from the other records that had similar ages at the time of diagnosis.

Data cleaning took place to ensure that information on postcodes existed and represented real places. If a postcode was found to not exist, it was replaced by a random postcode as described above. All postcodes were converted to Statistical Local Area (SLA) format. Where postcodes covered more than one SLA, the SLA with the largest area in that postcode was the chosen SLA.

Methods for Determining Location

The Australian Bureau of Statistics provided data on the numbers of people present in each SLA by age and gender. The ABS also provided the numbers of people who moved between each SLA in each state/territory, as well as the total number of people who moved into each SLA from another state/territory. A probability matrix was created for each state/territory from these data which showed the probability that a person would move in a five-year period. The matrices presented a unique probability that an individual would move from one SLA to another within the state/territory. It was assumed (through limitations on available data) that each person in a state/territory had an equal probability to move to another state/territory based on available ABS data.

The simulations progressed in 5 year steps, determining at each step if movement occurred or not for each individual. The first stage of the simulation algorithm determined the current location of each individual, and the appropriate probabilities of movement related to that SLA. Whether the person moved or not, and the location to which they moved was then determined by random probability based on the probability matrix. If it was determined that a movement should occur in the following 5 years, then a time was chosen at random between 0 and 5 years into the future.

Methods for Determining Mortality

The simulation of mortality consisted of two main steps. The first step was the simulation of progression to AIDS. The second step was determining the rate of mortality based on general population rates, time until AIDS and standardised mortality ratios for those people living with HIV or those people who have an AIDS-defining condition.

Determining AIDS Progression

The progression of each case from HIV to AIDS was simulated using initial CD4 counts and rates of progression determined by using results from Mellors et al. [36]. The Mellors study created Kaplan-Meier curves of the time until AIDS based on CD4 count. The following function was fitted to those curves:

$$Distribution\ of\ time\ until\ AIDS = e^{at^{b}}$$

where t is the time until progression to AIDS. This function was chosen as it had the desirable qualities of being continuous, monotonically decreasing, being easily invertible and, depending on the selection of a and b, had a similar shape to the distributions available in the Mellors paper. The parameters, *a* and *b,* were selected by using a variable step size random walk minimisation algorithm.

Using the calculated distributions and the CD4 counts at diagnosis provided in the National HIV Registry, each individual was assigned a random time until AIDS, in the absence of antiretroviral therapies.

Determining Mortality

General population mortality rates were sourced from ABS mortality data. The ABS mortality data contained death rates by state, gender and age for the years from 1998 to 2008. When calculating deaths prior to 1998, the 1998 death was used. When calculating the post 2008 deaths, the 2008 death rate was used. At each year in the simulation, each individual had a probability of mortality occurring based on age, gender, current state/territory location, AIDS status and current year.

Current year, age and AIDS status were used to determine the appropriate standardised mortality ratio to use, as calculated by Nakhaee et al. [39]. Gender, age and state/territory location were used in determining the general population mortality rate to be selected. The standardised mortality ratio and mortality rate were then multiplied to create a unique probability of mortality for each individual in each year. Mortality was determined to occur by random selection based on the calculated probability of mortality.

Results for estimated size of population living with diagnosed HIV and location in Australia

The population of people living with diagnosed HIV in Australia has changed substantially from the early 1980s to today. In the early years of the epidemic, diagnosis rates were much higher than death rates. This lead to a rapid expansion in the numbers of people living with diagnosed HIV. In the early to mid 1990's, diagnosis rates roughly matched death rates, leading to a levelling off to around 12,500 people living with diagnosed HIV (PLWDH). After 1996, the number of people being diagnosed with HIV was greater than the numbers of people diagnosed with HIV who were dying. This was due to the change in mortality rates between the pre-HAART and HAART eras [39]. In the model, this trend is expected to continue into the future, with roughly stable new cases per year, but with a high rate of survival. The estimated number of PLWDH in Australia and each state/territory over the past and forecasted number over the next 10 years is shown in Figure 4 and Figure 5.

Figure 4: Number of people living with diagnosed HIV by state, indicating the proportions in each state/territory

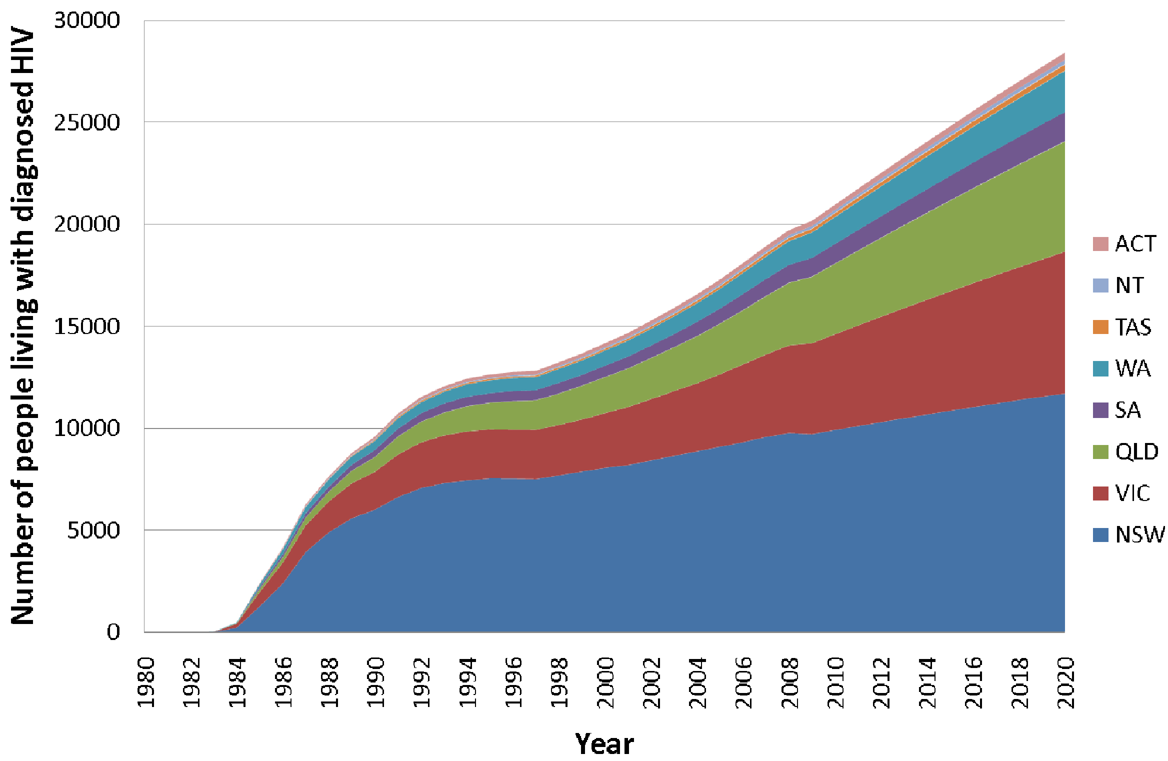
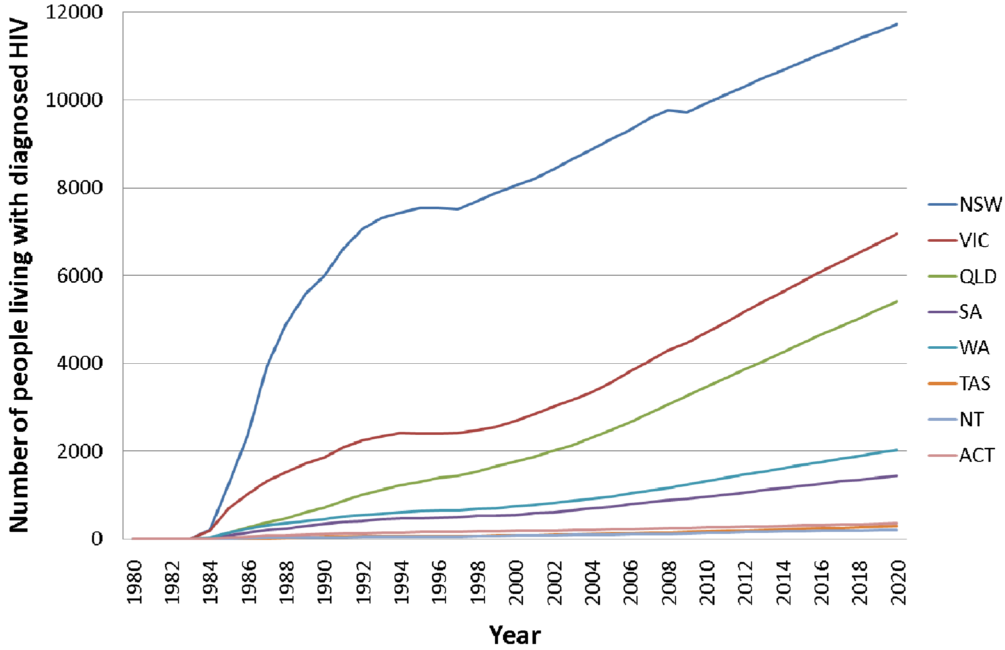


Figure 5: Estimated number of people in each state/territory by year



NSW was the first state affected largely by the HIV epidemic (Figure 5). In Table 3 the estimated number of people in each Australian state/territory by year is presented for past and future projections. NSW has remained as the jurisdiction with the greatest number of PLWDH. In 2010, NSW accounted for an estimated 9,924 of the 20,956 people living with diagnosed HIV in Australia.

The estimated past and future percentage increases in numbers of PLWDH is shown in

Table 4 for all states and territories. New South Wales is expected to have the lowest 10 year estimated percentage increase in the number of PLWDH over the next decade; however the significant size of the initial population of NSW contributes to the lower percentage increases.

National percentage increases from 1990 to 2000 and 2000 to 2010 were estimated to be about 48% nationwide. However, the increase over the next 10 years, from 2010 to 2020, is expected to be 35.6%. This increase is lower than the previous two 10-year increases. This suggests that although the number of people living with HIV is still increasing, the rate at which it is increasing is not exponential. That is, it appears that there will not be an epidemic outbreak in the number of people living with HIV in Australia; rather, HIV-infected people are staying alive for longer but the number of newly acquired infections and diagnoses is not decreasing. Over recent decades Queensland has experienced a relatively high percentage increase in the population of PLWDH. From 1990 to 2000 there was a large 145.7% percent increase in the population size.

Table 3: Estimated number of people in each state/territory by year

Year	*Australia*	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
1980	*1*	1	0	0	0	0	0	0	0
1981	*2*	2	0	0	0	0	0	0	0
1982	*1*	1	0	0	0	0	0	0	0
1983	*14*	3	4	0	1	6	0	0	0
1984	*462*	211	191	24	2	32	2	0	0
1985	*2389*	1254	707	150	91	138	7	9	32
1986	*4136*	2372	1025	267	147	240	8	17	60
1987	*6257*	3926	1317	376	203	312	13	30	79
1988	*7627*	4892	1517	476	242	363	17	32	88
1989	*8787*	5587	1721	610	298	407	34	34	95
1990	*9580*	6001	1862	720	345	450	49	40	113
1991	*10707*	6621	2088	878	388	511	56	44	122
1992	*11524*	7067	2243	1010	413	543	64	48	137
1993	*12047*	7315	2336	1112	454	570	63	54	142
1994	*12433*	7442	2410	1232	463	614	64	56	152
1995	*12639*	7548	2403	1303	471	634	67	53	160
1996	*12758*	7539	2400	1394	490	656	69	52	158
1997	*12810*	7513	2417	1445	497	648	69	59	162
1998	*13229*	7694	2474	1539	525	682	74	70	171
1999	*13663*	7885	2554	1652	533	708	77	75	179
2000	*14161*	8059	2689	1769	550	745	81	79	190
2001	*14670*	8205	2845	1879	591	785	89	82	194
2002	*15270*	8422	3013	2014	615	824	96	88	198
2003	*15895*	8657	3176	2141	651	870	101	92	206
2004	*16559*	8874	3340	2308	700	913	113	98	213
2005	*17287*	9098	3562	2478	740	965	122	99	222
2006	*18095*	9325	3814	2657	796	1035	132	108	228
2007	*18925*	9579	4050	2858	842	1104	139	112	240
2008	*19713*	9772	4305	3064	883	1169	146	122	251
2009	*20172*	9715	4467	3260	925	1247	165	135	257
2010	*20956*	9924	4702	3459	964	1322	176	144	265
2011	*21739*	10117	4939	3663	1013	1396	187	151	273
2012	*22513*	10311	5176	3862	1061	1467	198	157	281
2013	*23285*	10502	5408	4060	1111	1540	210	165	291
2014	*24047*	10685	5632	4258	1162	1616	222	173	299
2015	*24803*	10867	5858	4454	1211	1687	236	180	309
2016	*25554*	11047	6085	4648	1263	1758	249	188	317
2017	*26289*	11223	6308	4839	1313	1827	259	196	326
2018	*27009*	11399	6523	5030	1357	1893	271	199	336
2019	*27721*	11561	6743	5219	1404	1961	282	205	345
2020	*28422*	11721	6959	5408	1449	2026	294	210	355

Table 4: Estimated 10 year percentage increase in number of people living with diagnosed HIV by state/territory

	Percent increase year to year		
Year	**1990 to 2000**	**2000 to 2010**	**2010 to 2020**
Australia	47.8%	48.0%	35.6%
New South Wales	34.3%	23.1%	18.1%
Victoria	44.4%	74.9%	48.0%
Queensland	145.7%	95.6%	56.3%
South Australia	59.4%	75.2%	50.3%
Western Australia	65.6%	77.4%	53.3%
Tasmania	65.5%	116.2%	66.9%
Northern Territory	98.8%	82.7%	46.2%
Australian Capital Territory	67.4%	39.6%	34.2%

Population changes at the statistical region level

Our model forecasts that the total numbers of people living with diagnosed HIV across all statistical regions have consistently increased. Sydney remains the capital city with the largest number of people living with diagnosed HIV (PLWDH), with 7,852 estimated to be in the greater Sydney region by the end of 2010. Within Sydney, the statistical region with the greatest number of PLWDH is Inner Sydney, with an estimated 2,268 people by the end of 2010. The next largest population of PLWDH is in the Sydney Eastern Suburbs statistical region with 1,036, followed by Inner Melbourne (977) and Brisbane City Inner Ring (739) (Table 5).

Table 5: Number of people living with diagnosed HIV by statistical region and year

	Year			
	1990	**2000**	**2010**	**2020**
Australia (Total)	**9580**	**14161**	**20956**	**28422**
NSW	**6001**	**8059**	**9924**	**11721**
Sydney	**4863**	**6485**	**7852**	**9082**
Inner Sydney	1398	1953	2268	2471
Eastern Suburbs	596	954	1036	1099
St George-Sutherland	445	505	611	730
Canterbury-Bankstown	264	318	423	507
Fairfield-Liverpool	162	276	335	371
Outer South Western Sydney	78	132	169	216
Inner Western Sydney	393	354	414	481
Central Western Sydney	386	370	427	483
North Western Sydney	454	467	554	681
Lower Northern Sydney	245	428	568	680
Central Northern Sydney	174	314	461	601
Northern Beaches	117	191	289	383
Gosford-Wyong	151	222	296	380
NSW Rural	**1138**	**1574**	**2072**	**2638**
Hunter	335	433	542	681
Illawarra	167	267	342	423
South Eastern	47	92	145	211
Richmond-Tweed	186	240	300	368
Mid-North Coast	187	220	286	351
Northern	34	66	109	146
Far West-North Western	29	47	63	85
Central West	97	118	135	159
Murray-Murrumbidgee	56	92	149	214
Victoria	**1862**	**2689**	**4702**	**6959**
Melbourne	**1609**	**2299**	**3998**	**5841**
Outer Western Melbourne	189	317	679	1076
North Western Melbourne	78	166	272	400
Inner Melbourne	535	631	977	1261
North Eastern Melbourne	198	257	426	619
Inner Eastern Melbourne	261	333	527	754
Southern Melbourne	180	285	524	793
Outer Eastern Melbourne	91	132	204	299
South Eastern Melbourne	47	105	235	392
Mornington Peninsula	30	74	155	247
Rural Victoria	**253**	**389**	**704**	**1118**
Barwon-Western District	79	100	179	279
Central Highlands-Wimmera	39	60	94	155
Loddon-Mallee	38	61	146	241
Goulburn-Ovens-Murray	60	98	171	262
All Gippsland	37	70	114	181

	Year			
	1990	**2000**	**2010**	**2020**
Queensland	**720**	**1769**	**3459**	**5408**
Brisbane	**383**	**868**	**1742**	**2697**
Brisbane City Inner Ring	228	382	739	1048
Brisbane City Outer Ring	77	229	471	754
South and East BSD Balance	34	116	217	353
North BSD Balance	34	103	230	399
Ipswich City	9	37	86	143
Rural Queensland	**337**	**901**	**1717**	**2710**
Gold Coast	135	332	582	860
Sunshine Coast	60	134	227	357
West Moreton	5	17	36	65
Wide Bay-Burnett	20	66	144	249
Darling Downs-South West	14	48	112	188
Mackay-Fitzroy-Central West	21	75	167	278
Northern-North West	29	75	130	215
Far North	53	155	319	499
South Australia	**345**	**550**	**964**	**1449**
Adelaide	**313**	**466**	**812**	**1218**
Northern Adelaide	56	85	200	332
Western Adelaide	97	120	195	278
Eastern Adelaide	149	210	297	413
Southern Adelaide	10	51	121	195
Rural South Australia	**32**	**84**	**152**	**231**
Northern and Western SA	2	23	52	75
Southern and Eastern SA	30	61	100	156
Western Australia	**450**	**745**	**1322**	**2026**
Perth	**417**	**636**	**1091**	**1623**
Central Metropolitan	132	127	168	226
East Metropolitan	61	109	191	284
North Metropolitan	101	175	312	467
South West Metropolitan	51	98	177	272
South East Metropolitan	71	127	243	375
Rural Western Australia	**33**	**109**	**231**	**403**
Lower Western WA	18	45	101	186
Remainder - Balance WA	15	64	130	217
Tasmania	**49**	**81**	**176**	**294**
Northern Territory	**40**	**79**	**144**	**210**
Australian Capital Territory	**113**	**190**	**265**	**355**

In Table 6 we present the top 10 statistical regions by increase in the estimated number of people living with diagnosed HIV between 2000 and 2010. The largest increases have occurred in statistical regions in Victoria, Queensland and New South Wales (Table 6). These statistical regions are locations in major metropolitan areas and traditional hubs of HIV. Over the same period, other regions have been affected by relatively large percentage increases in the number of PLWDH (Table 7); these statistical regions are largely located on the fringe of large metropolitan areas in Queensland, South Australia, Western Australia and Victoria.

Table 6: Top 10 statistical regions by increase in population living with diagnosed HIV (from 2000 to 2010)

Statistical Region	State	Estimated Population in 2000	Estimated Population in 2010	Estimated Increase in Population
Outer Western Melbourne	VIC	317	679	361
Brisbane City Inner Ring	QLD	382	739	357
Inner Melbourne	VIC	631	977	345
Inner Sydney	NSW	1953	2268	315
Gold Coast	QLD	332	582	249
Brisbane City Outer Ring	QLD	229	471	243
Southern Melbourne	VIC	285	524	240
Inner Eastern Melbourne	VIC	333	527	194
North Eastern Melbourne	VIC	257	426	169
Far North	QLD	155	319	164

Table 7: Top 10 statistical regions by percentage increase in population living with diagnosed HIV (from 2000 to 2010)

Statistical Region	State	Estimated Population in 2000	Estimated Population in 2010	Percent Change
Loddon-Mallee	VIC	61	146	139.2%
Southern Adelaide	SA	51	121	136.8%
Northern Adelaide	SA	85	200	135.6%
Darling Downs-South West	QLD	48	112	134.0%
Ipswich City	QLD	37	86	130.8%
Northern and Western SA	SA	23	52	126.1%
South Eastern Melbourne	VIC	105	235	124.7%
Lower Western WA	WA	45	101	124.5%
North BSD Balance	QLD	103	230	122.6%
Mackay-Fitzroy-Central West	QLD	75	167	122.2%

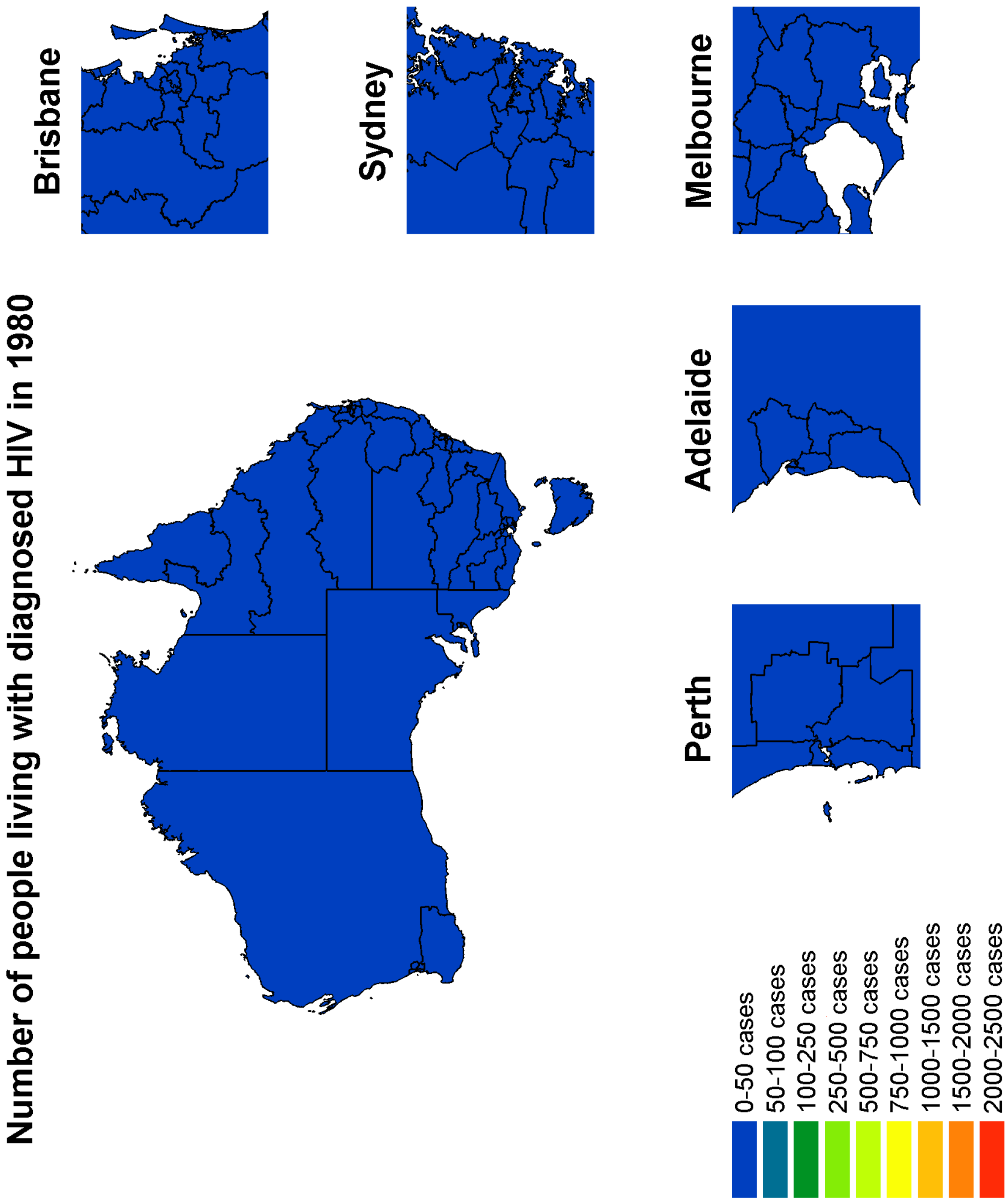
Discussion of Maps

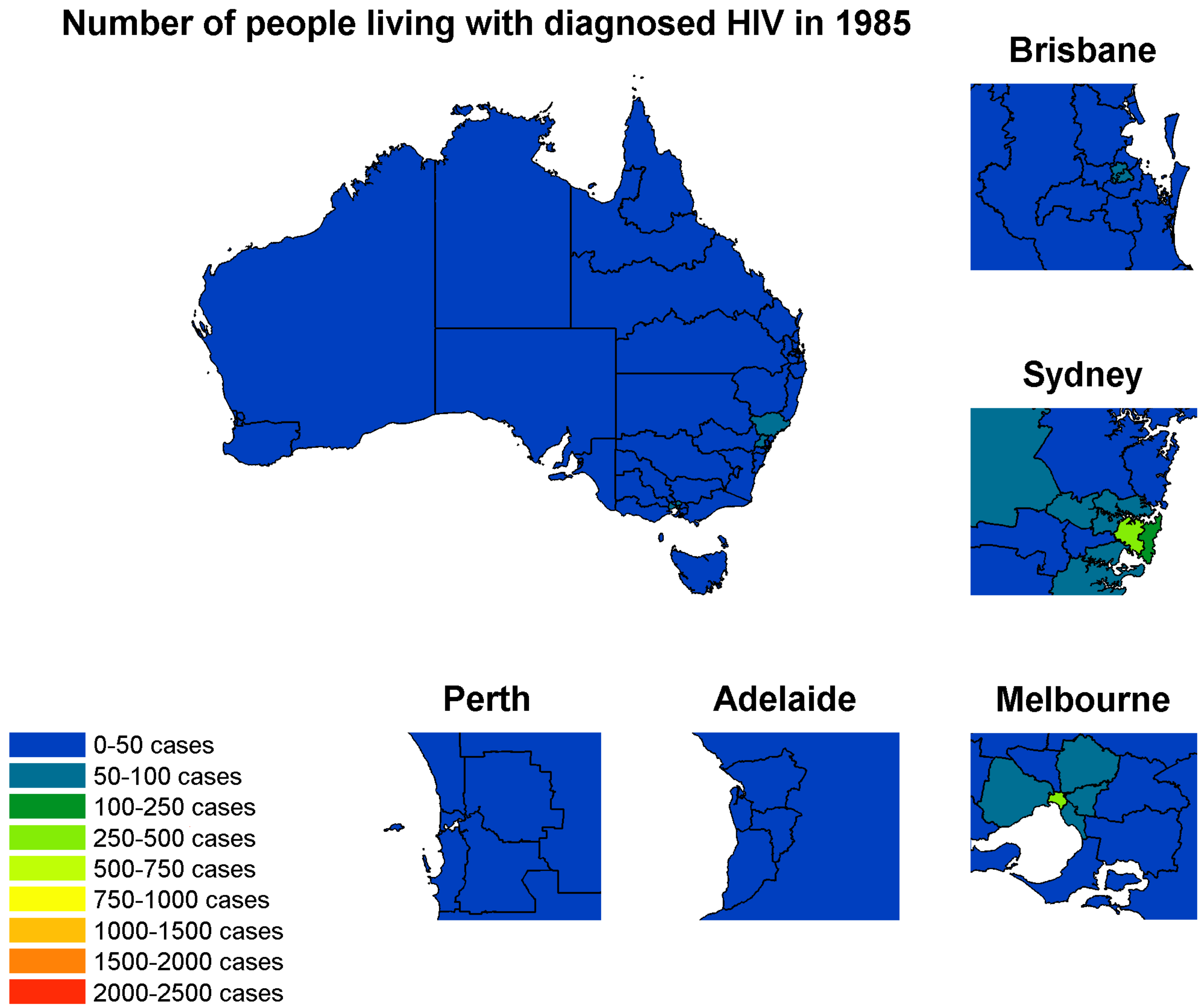
The following section contains maps that have been generated from output of the model. The first set of maps show the total (raw) number of infected individuals at 5 year intervals from 1985 to 2020 as estimated by the model. The second set of maps show the prevalence of individuals living with diagnosed HIV per 100 000 people at 5 year intervals from 1985 to 2020 as estimated by the model.

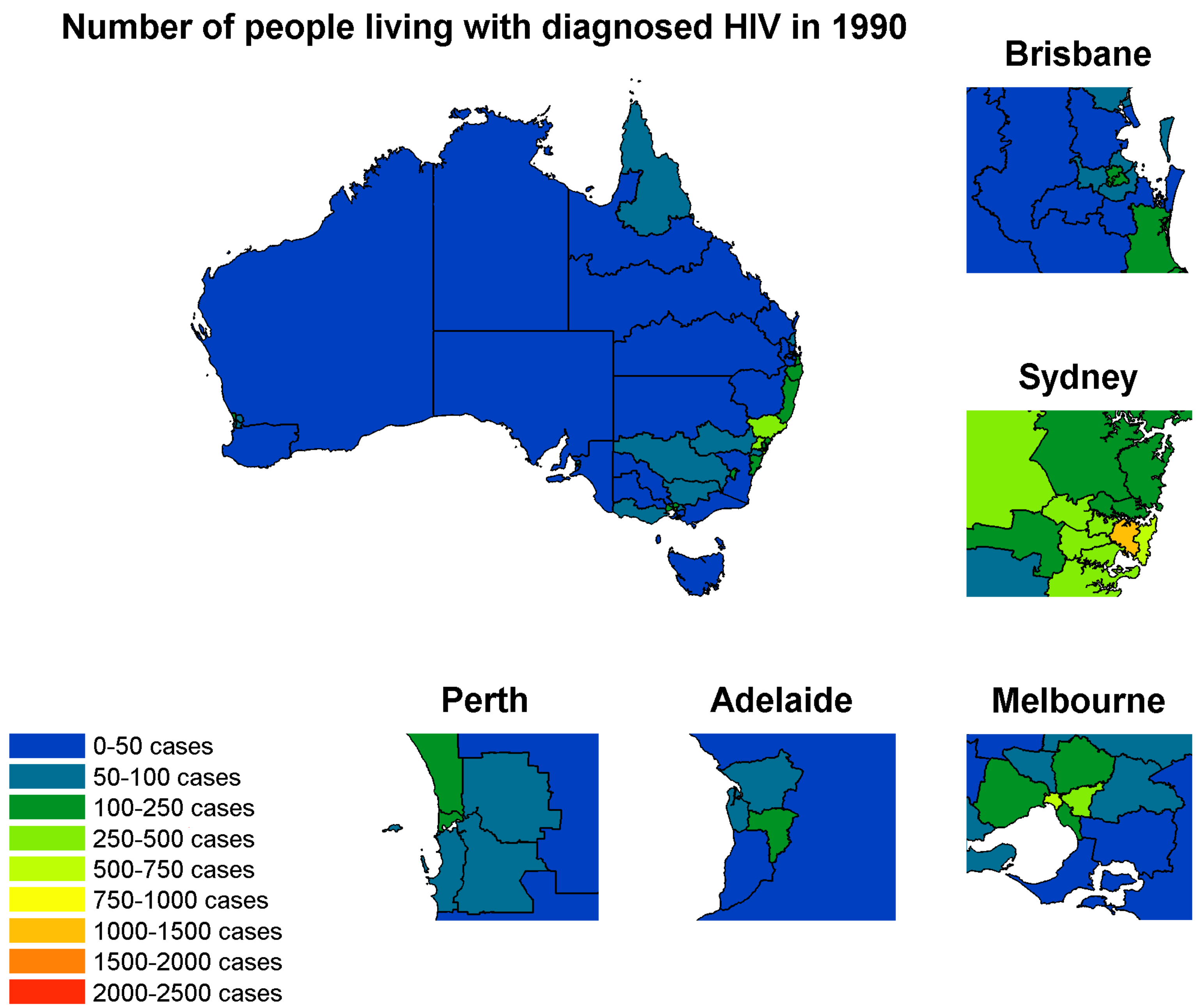
As shown in the maps, the majority of people living with diagnosed HIV are calculated to be living in the central areas of the 3 largest capital cities, namely, Sydney, Melbourne and Brisbane. In the early years, PLWDH lived almost exclusively in those areas. Into the mid-1990s, the number of PLWDH in the other capital cities started to increase. Of particular note is Far North Queensland and the coastline between Sydney and Brisbane. These areas have populations of PLWDH much higher than the other non-capital city areas. The model predicts that in the future there will be increases in diagnoses outside of capital cities, together with dispersion of people away from capital cities, resulting in greater populations of PLWDH in more rural areas.

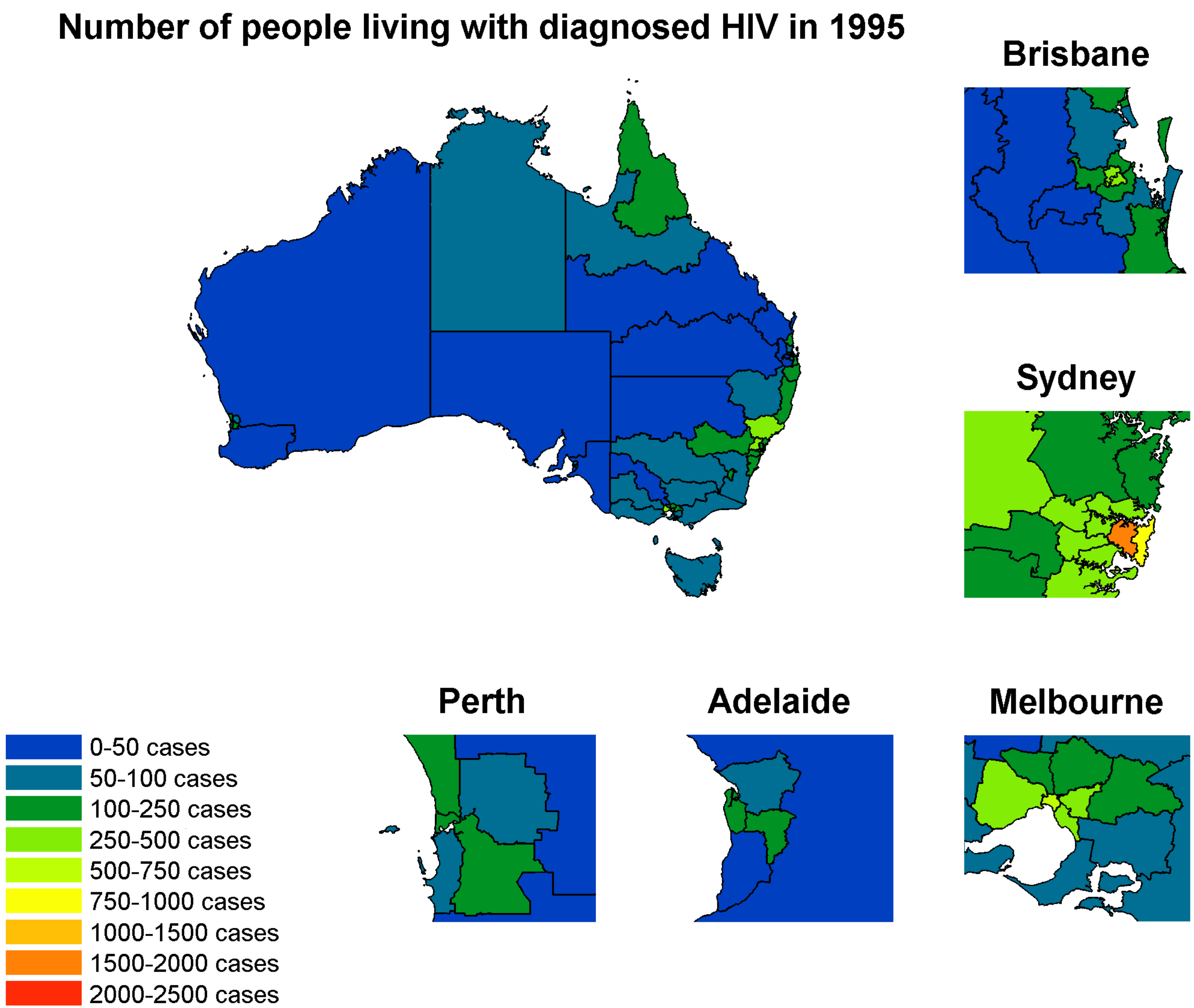
The prevalence maps appear to be slightly different to the maps showing the raw numbers. This is due to differences in the number of people in the general population in each of the statistical regions.

Maps of numbers of people with diagnosed HIV in Australia

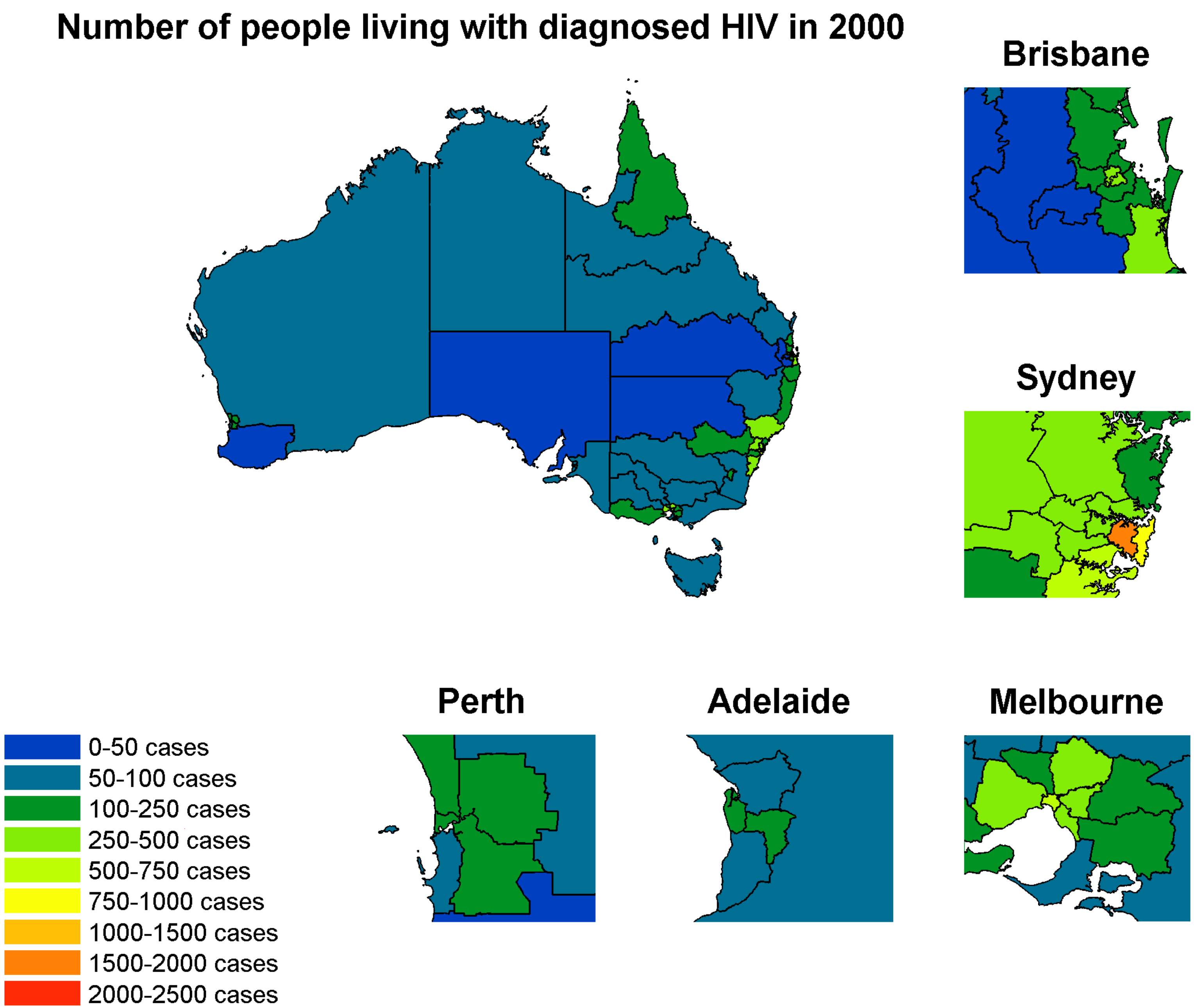



Number of people living with diagnosed HIV in 1985
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-50 cases
50-100 cases
100-250 cases
250-500 cases
500-750 cases
750-1000 cases
1000-1500 cases
1500-2000 cases
2000-2500 cases

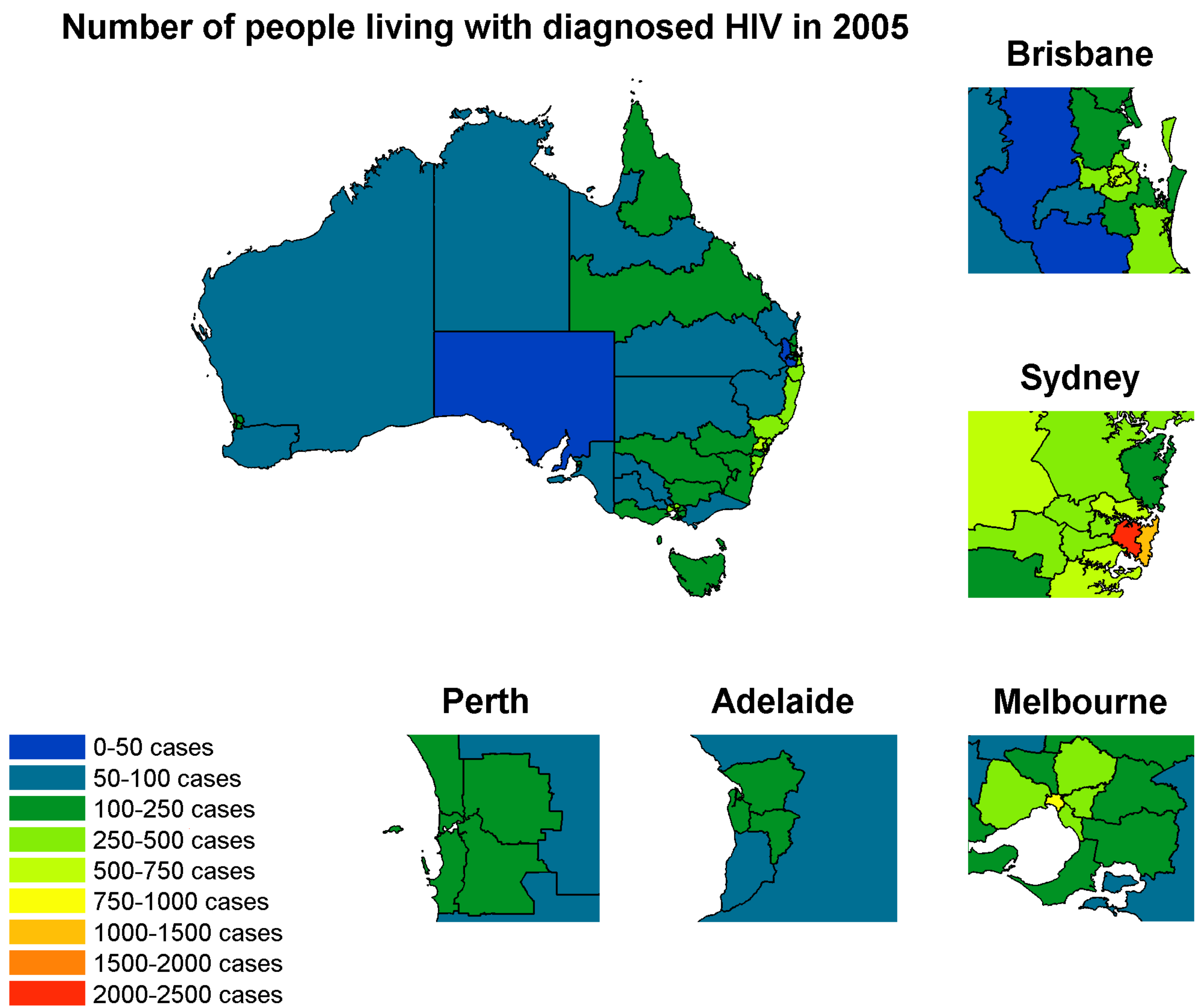

Number of people living with diagnosed HIV in 1990
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-50 cases
50-100 cases
100-250 cases
250-500 cases
500-750 cases
750-1000 cases
1000-1500 cases
1500-2000 cases
2000-2500 cases

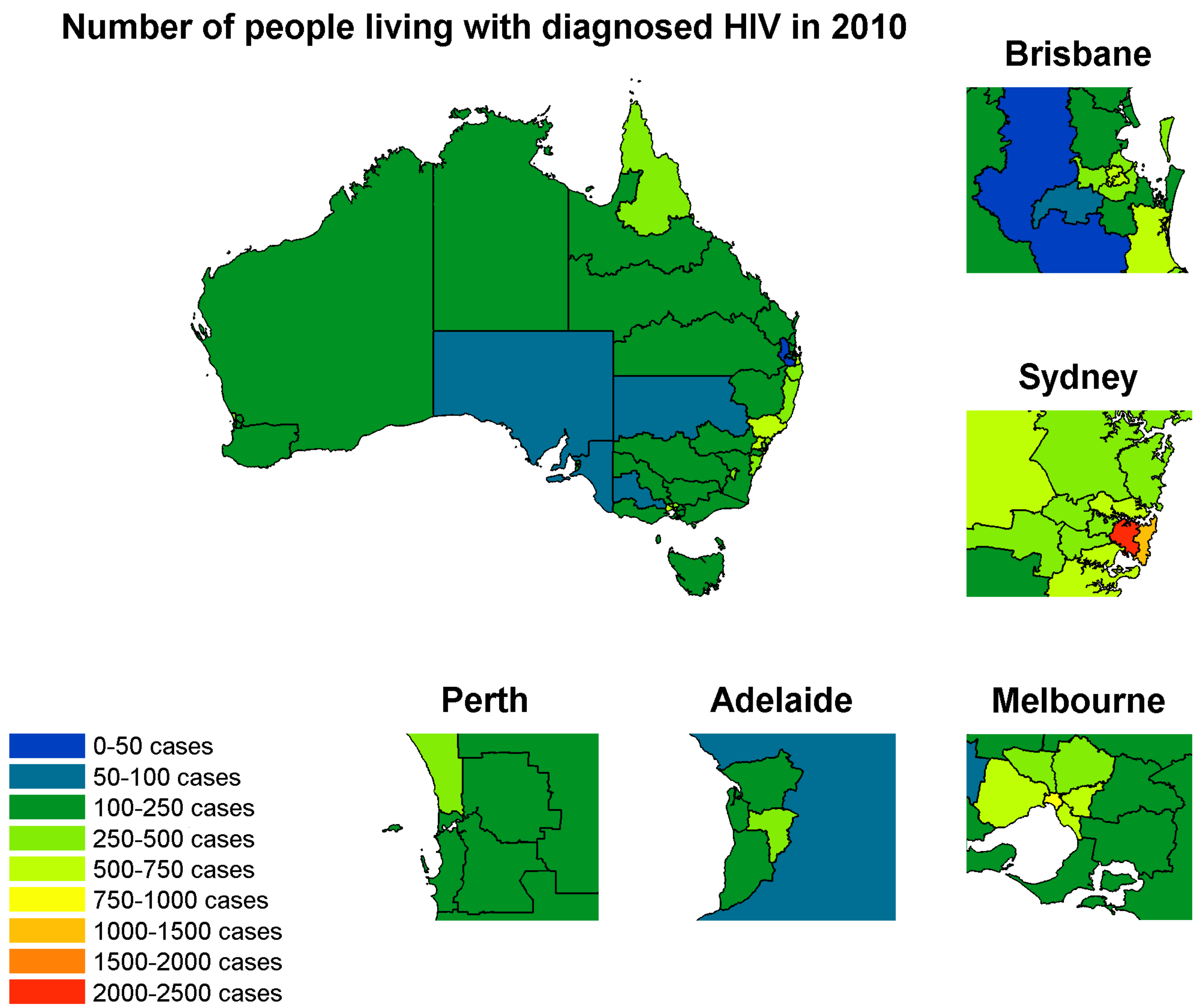


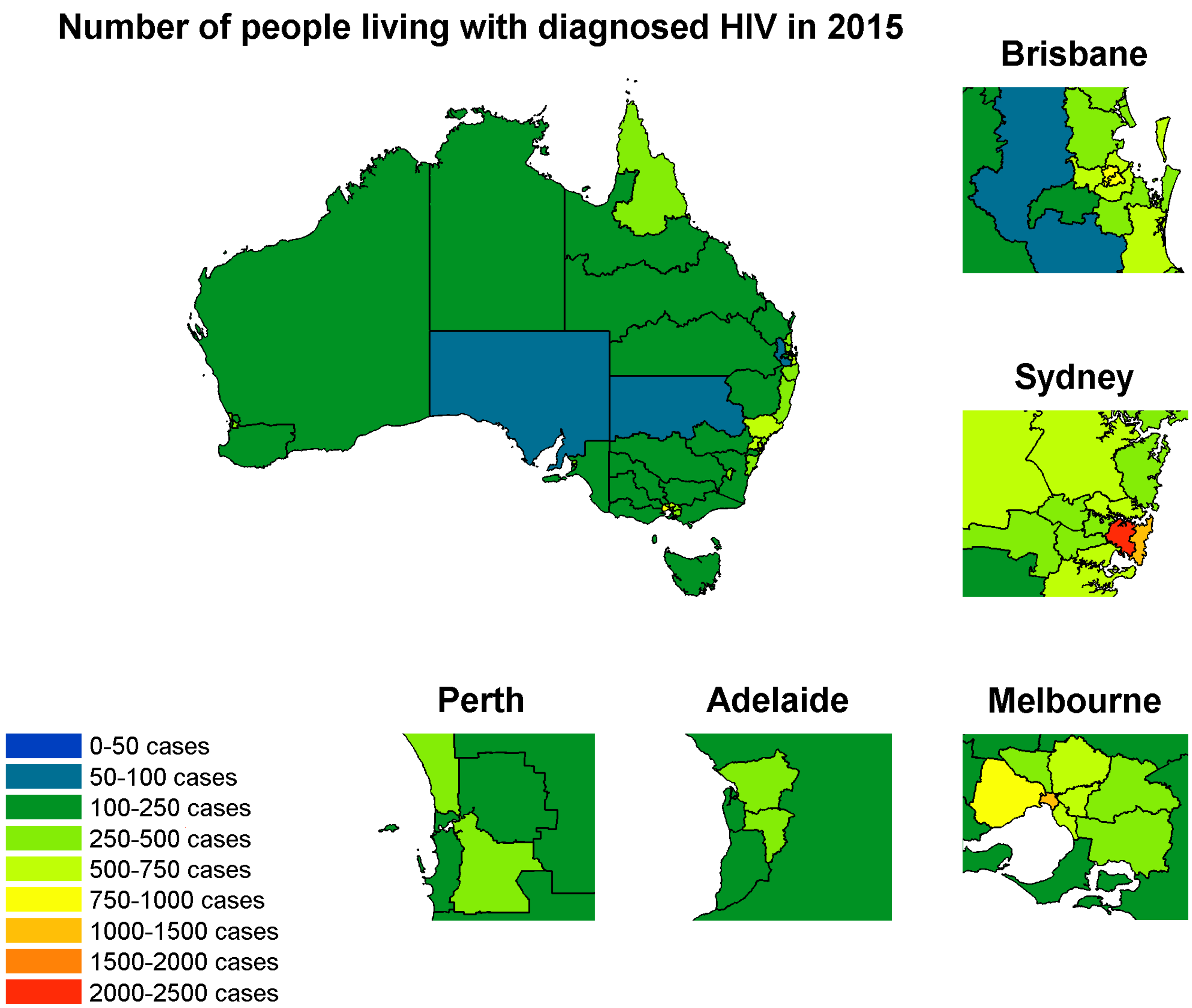
Number of people living with diagnosed HIV in 1995
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-50 cases
50-100 cases
100-250 cases
250-500 cases
500-750 cases
750-1000 cases
1000-1500 cases
1500-2000 cases
2000-2500 cases



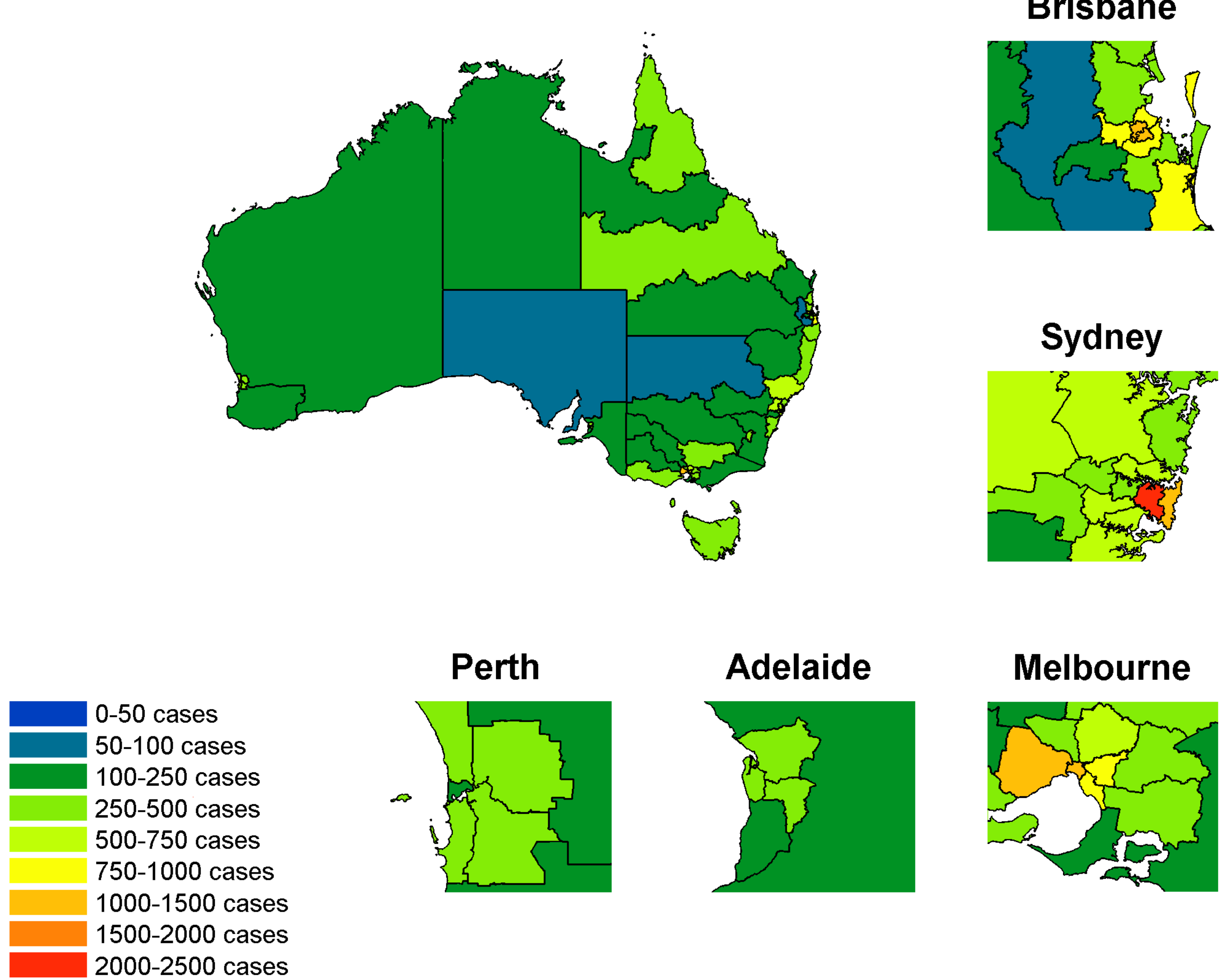
Number of people living with diagnosed HIV in 2000
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-50 cases
50-100 cases
100-250 cases
250-500 cases
500-750 cases
750-1000 cases
1000-1500 cases
1500-2000 cases
2000-2500 cases


Number of people living with diagnosed HIV in 2005
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-50 cases
50-100 cases
100-250 cases
250-500 cases
500-750 cases
750-1000 cases
1000-1500 cases
1500-2000 cases
2000-2500 cases

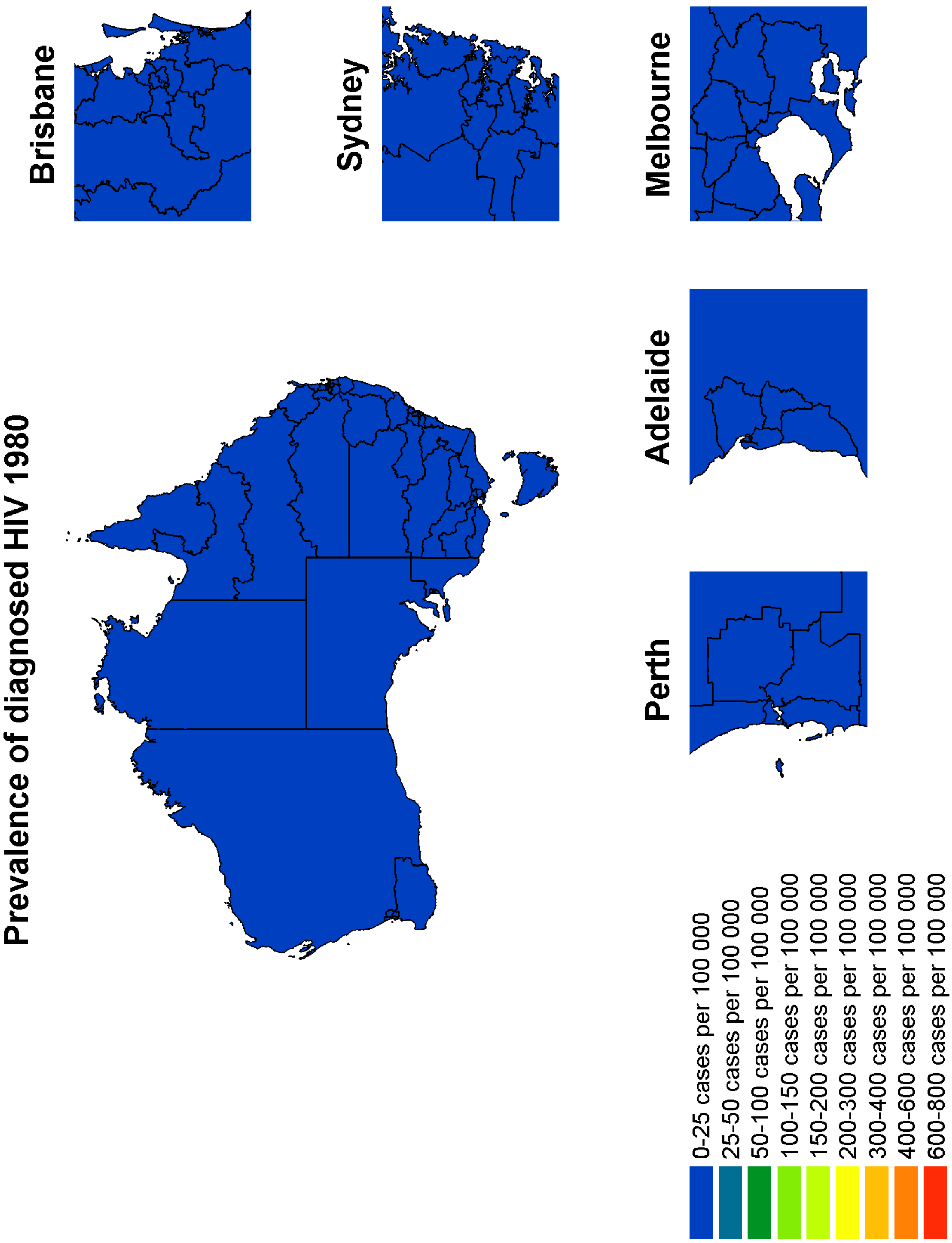

Number of people living with diagnosed HIV in 2010
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-50 cases
50-100 cases
100-250 cases
250-500 cases
500-750 cases
750-1000 cases
1000-1500 cases
1500-2000 cases
2000-2500 cases

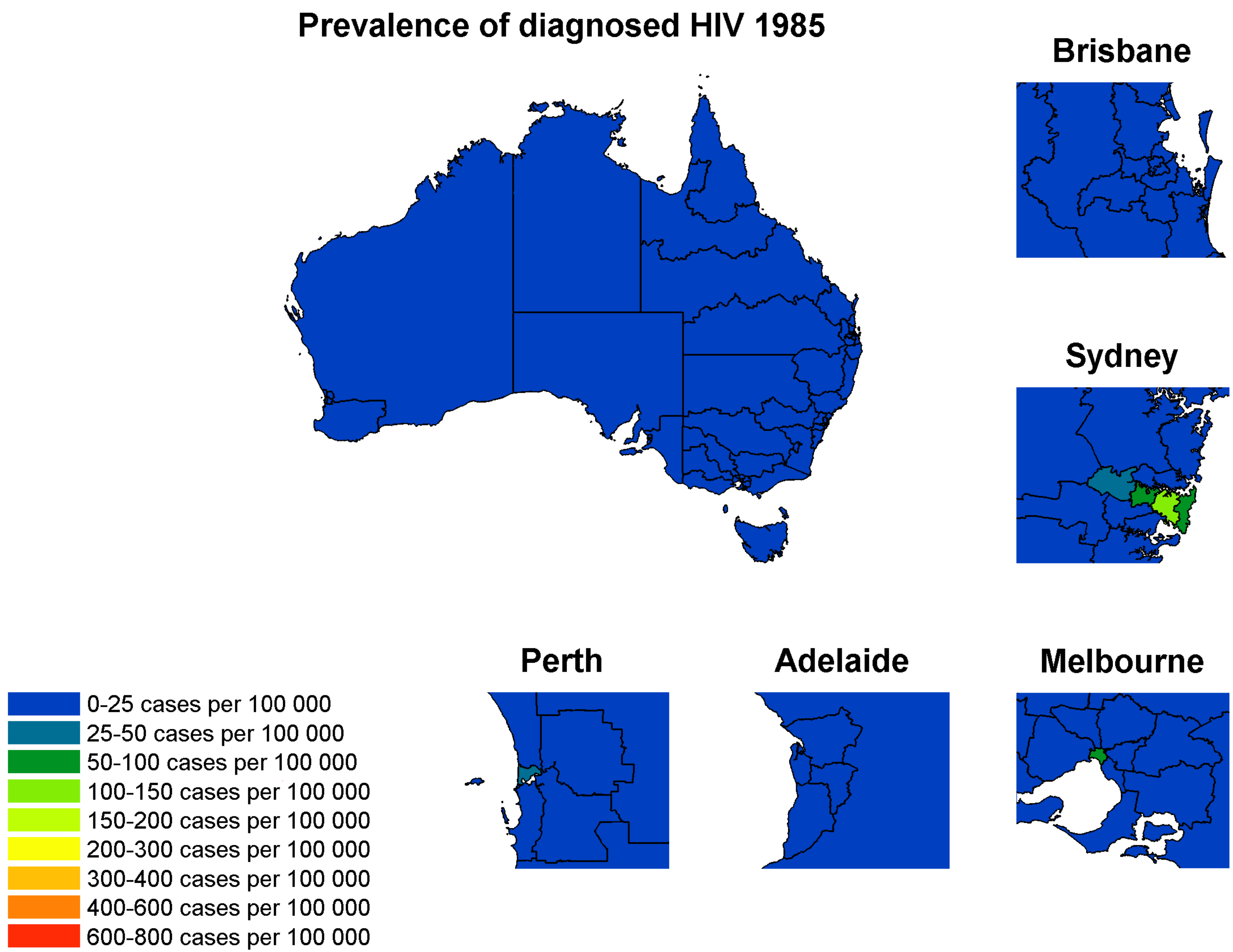

Number of people living with diagnosed HIV in 2015
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-50 cases
50-100 cases
100-250 cases
250-500 cases
500-750 cases
750-1000 cases
1000-1500 cases
1500-2000 cases
2000-2500 cases

Number of people living with diagnosed HIV in 2020



Prevalence of HIV maps




Prevalence of diagnosed HIV 1985
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-25 cases per 100 000
25-50 cases per 100 000
50-100 cases per 100 000
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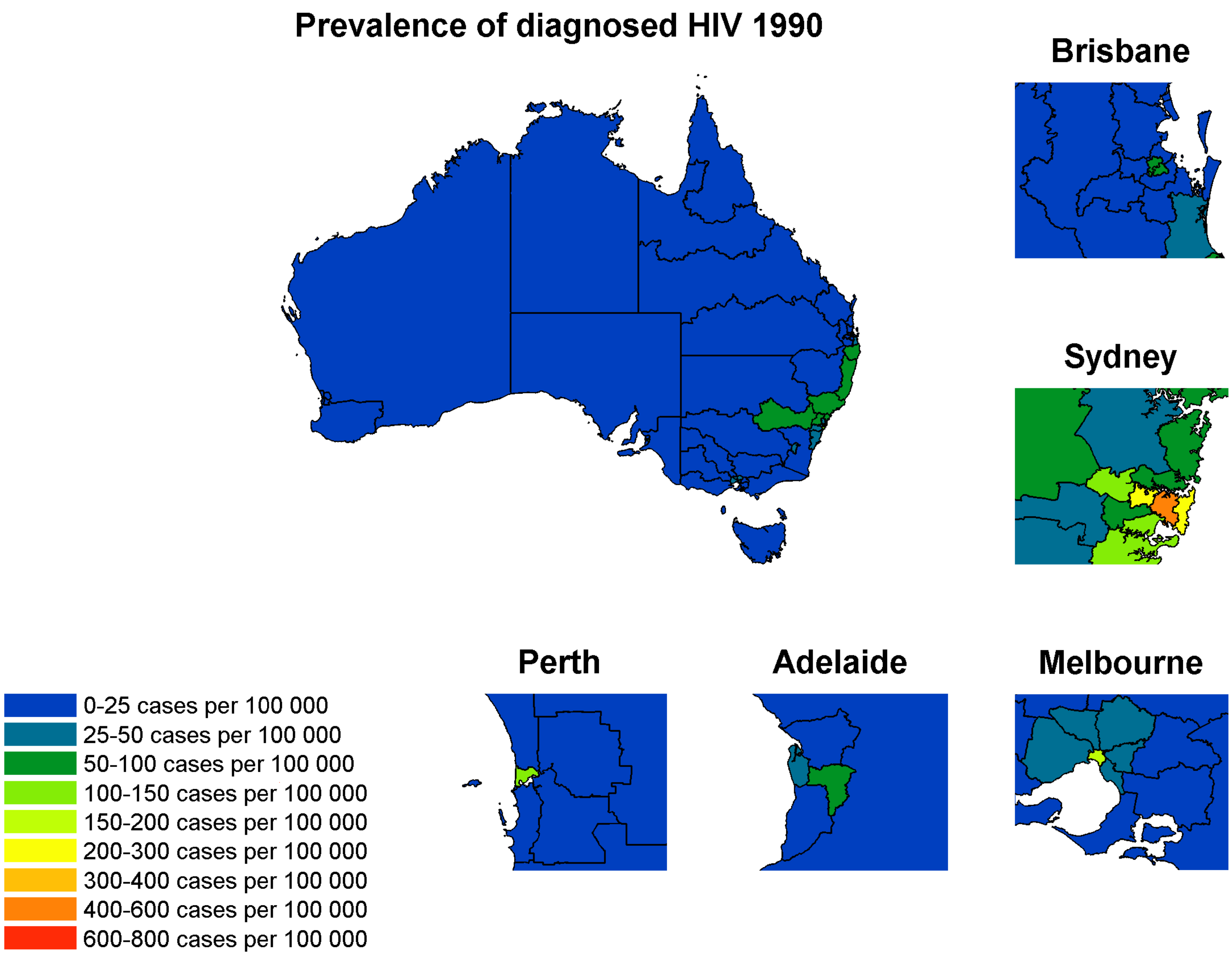
150-200 cases per 100 000
200-300 cases per 100 000
300-400 cases per 100 000
400-600 cases per 100 000
600-800 cases per 100 000


Prevalence of diagnosed HIV 1990
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-25 cases per 100 000
25-50 cases per 100 000
50-100 cases per 100 000
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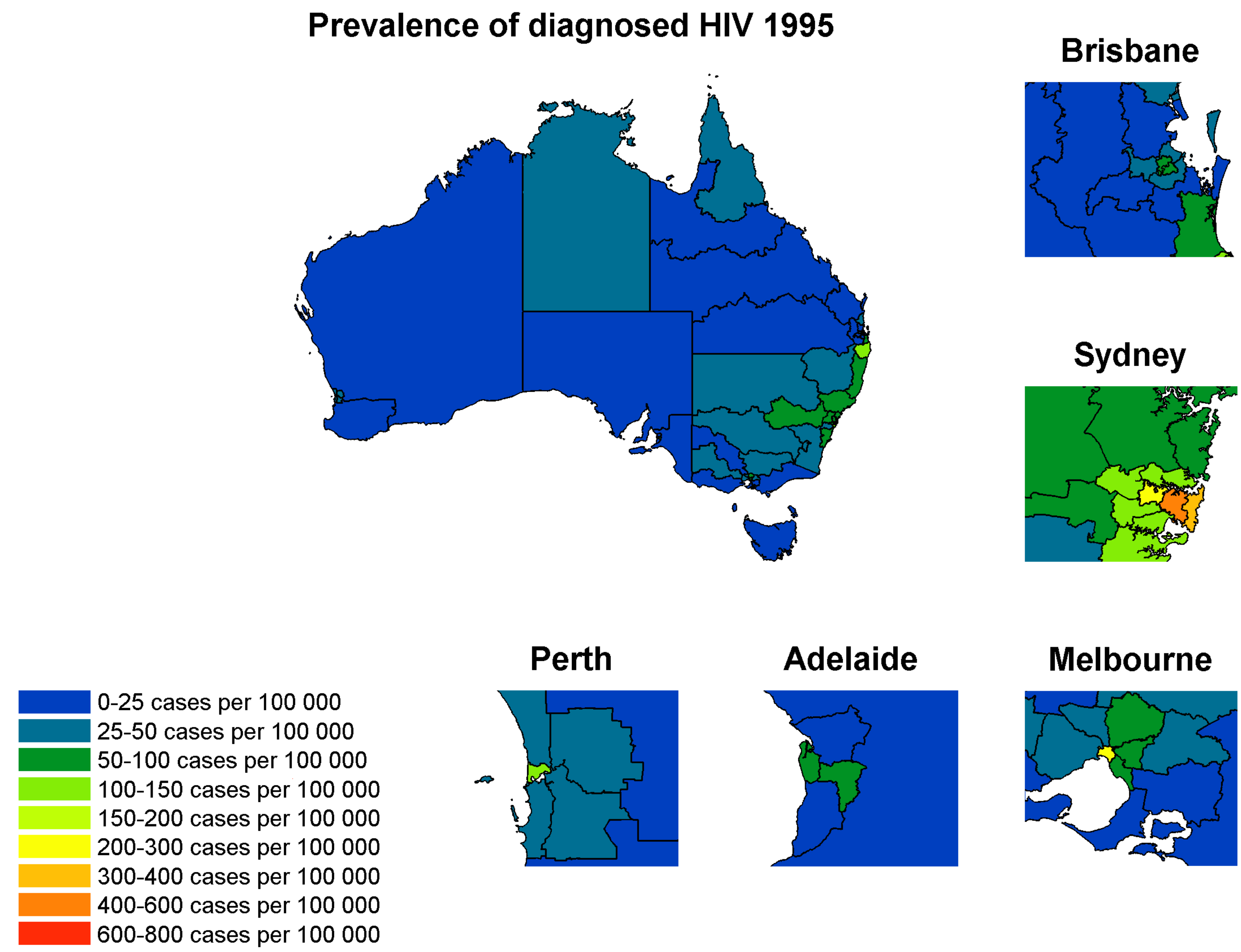
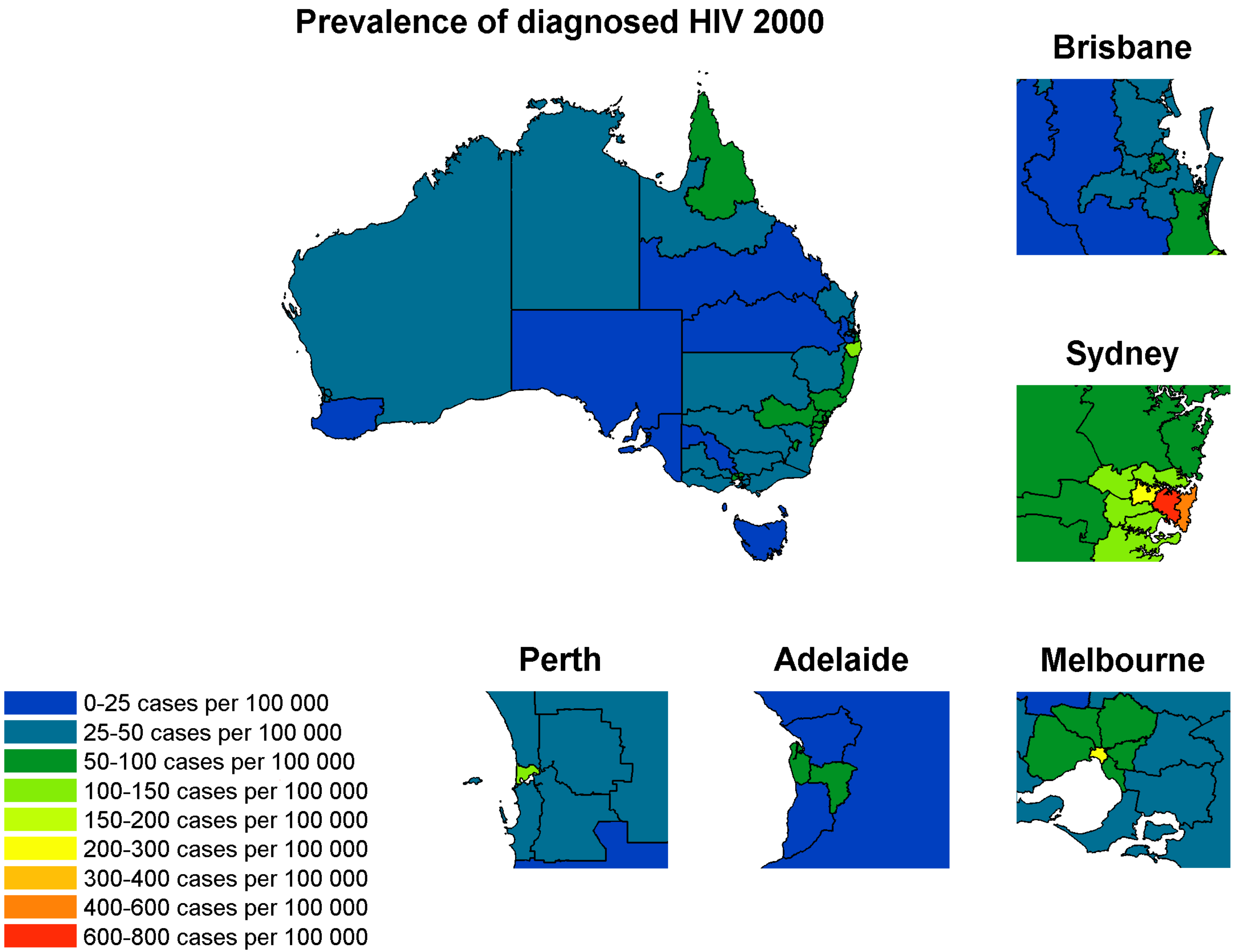
150-200 cases per 100 000
200-300 cases per 100 000
300-400 cases per 100 000
400-600 cases per 100 000
600-800 cases per 100 000



Prevalence of diagnosed HIV 1995
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-25 cases per 100 000
25-50 cases per 100 000
50-100 cases per 100 000
100-150 cases per 100 000
150-200 cases per 100 000
200-300 cases per 100 000
300-400 cases per 100 000
400-600 cases per 100 000
600-800 cases per 100 000


Prevalence of diagnosed HIV 2000
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-25 cases per 100 000
25-50 cases per 100 000
50-100 cases per 100 000
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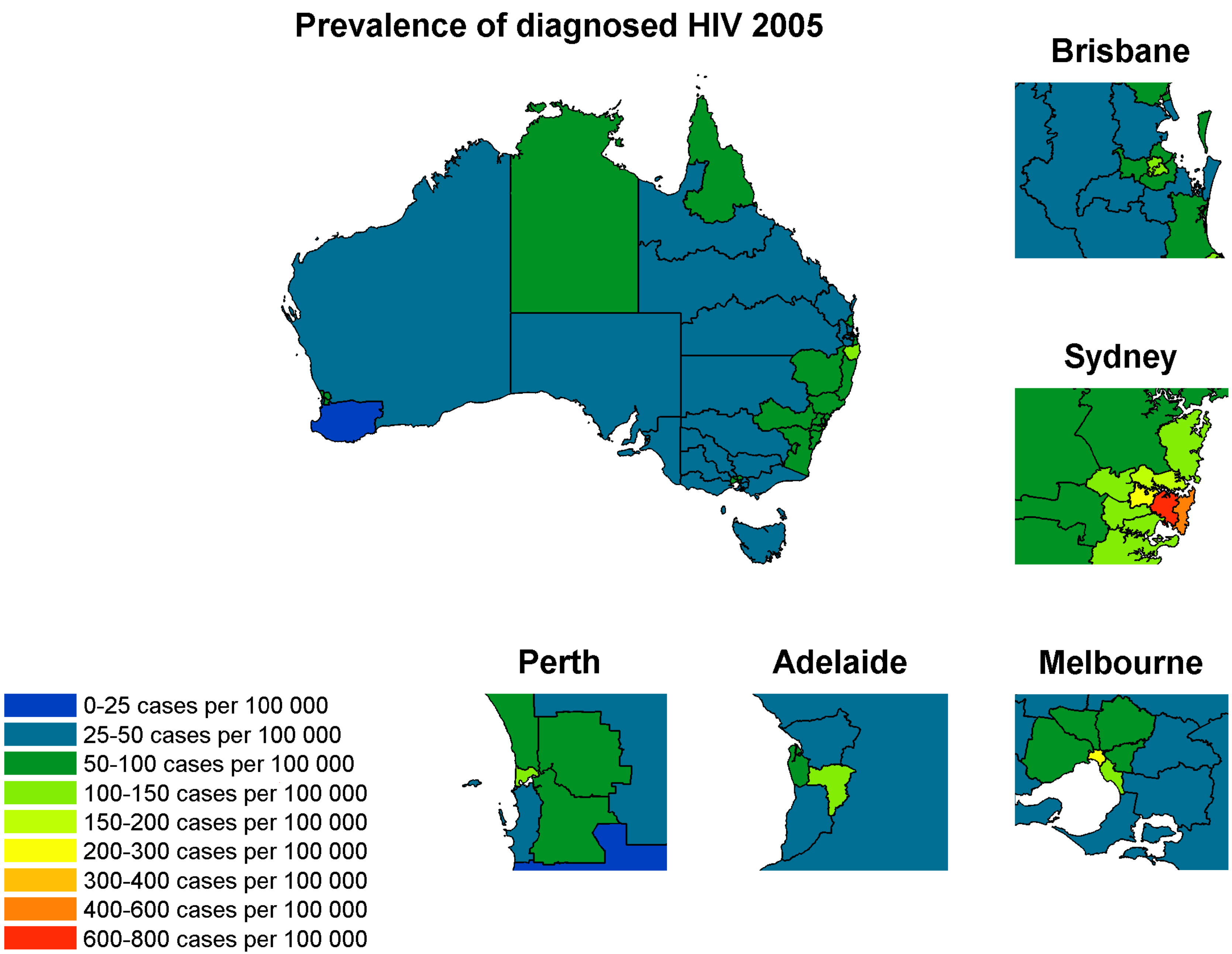
300-400 cases per 100 000
400-600 cases per 100 000
600-800 cases per 100 000


Prevalence of diagnosed HIV 2005
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-25 cases per 100 000
25-50 cases per 100 000
50-100 cases per 100 000
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150-200 cases per 100 000
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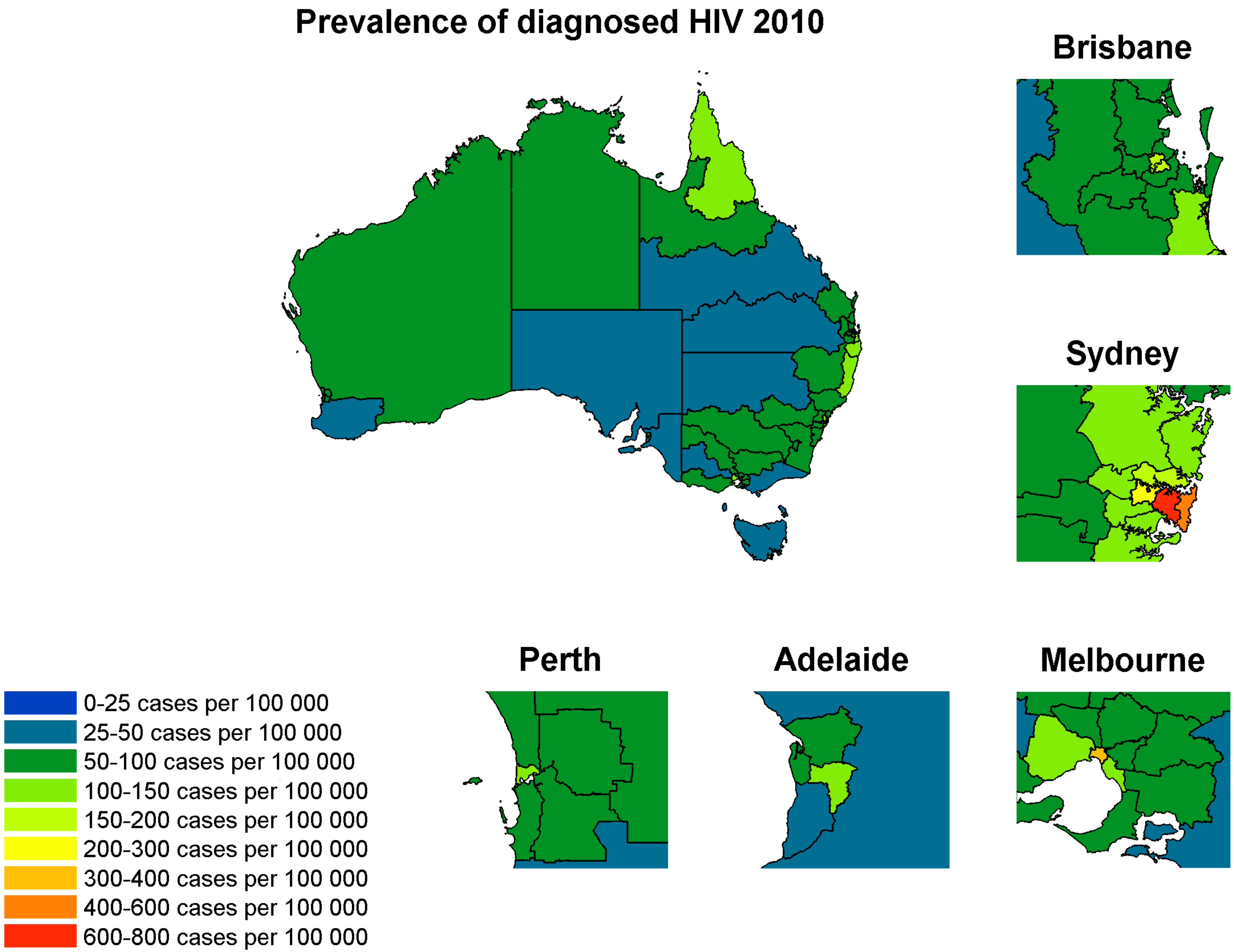
400-600 cases per 100 000
600-800 cases per 100 000


Prevalence of diagnosed HIV 2010
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-25 cases per 100 000
25-50 cases per 100 000
50-100 cases per 100 000
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150-200 cases per 100 000
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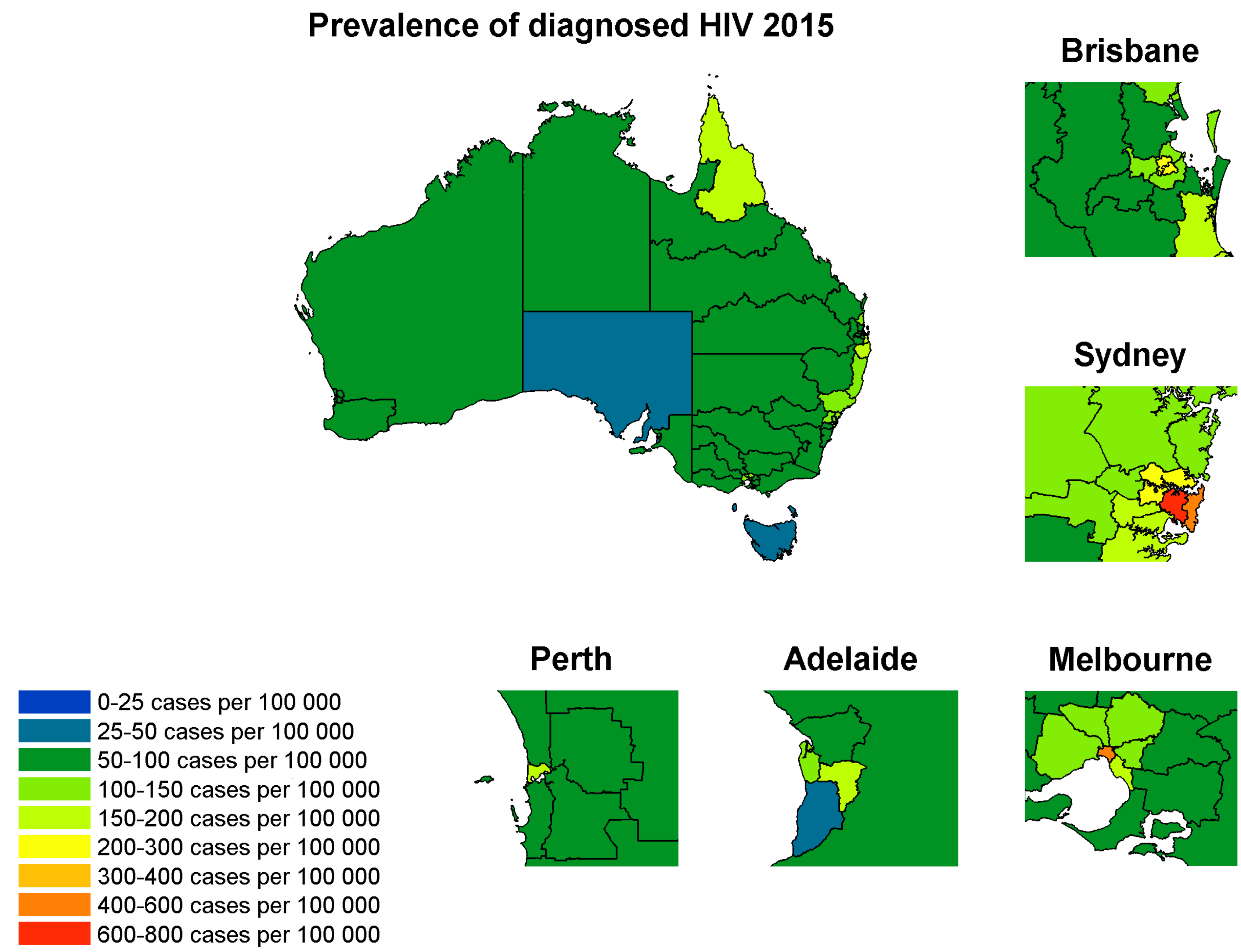
300-400 cases per 100 000
400-600 cases per 100 000
600-800 cases per 100 000


Prevalence of diagnosed HIV 2015
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-25 cases per 100 000
25-50 cases per 100 000
50-100 cases per 100 000
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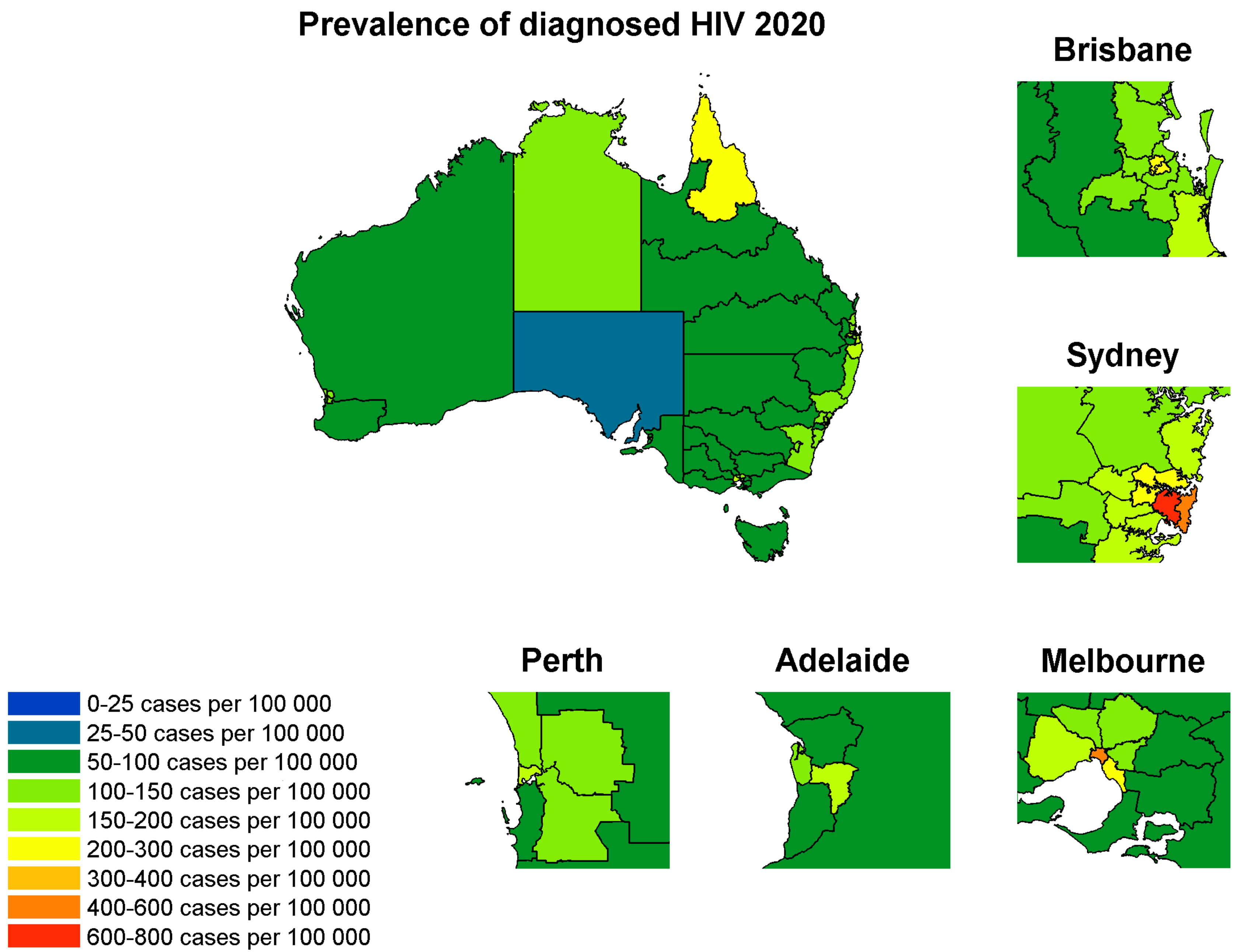
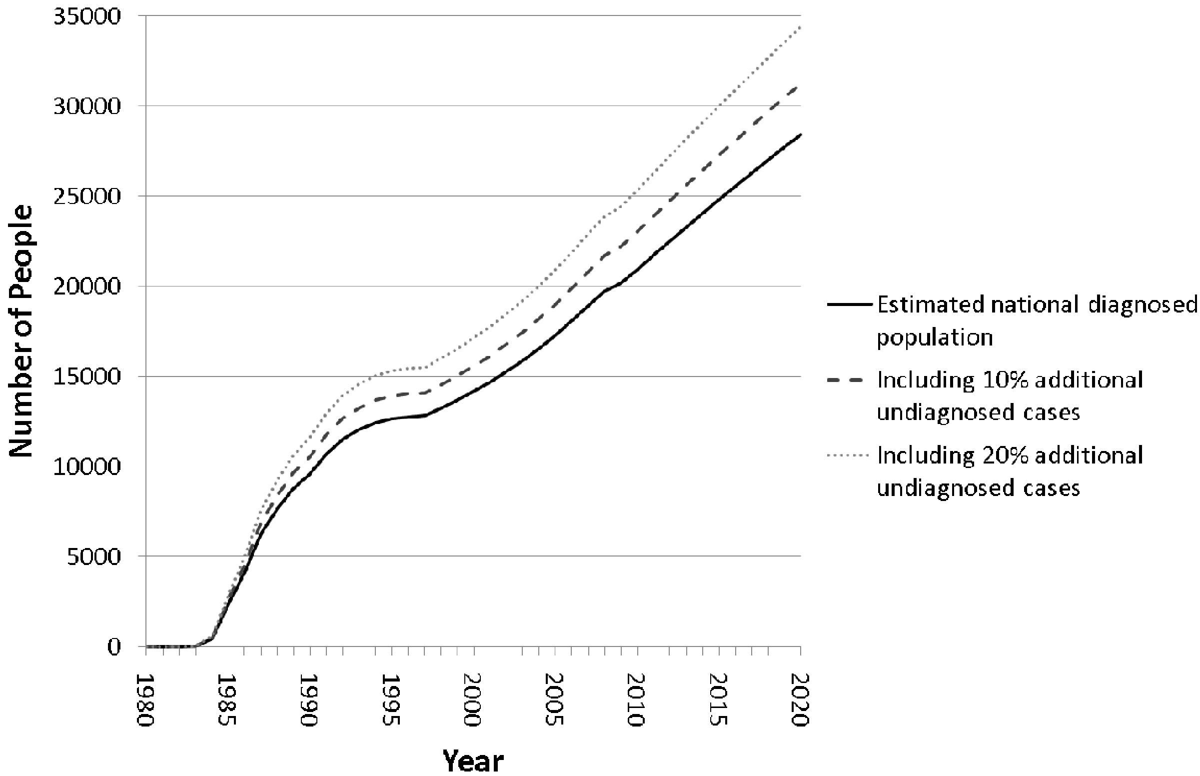
600-800 cases per 100 000


Prevalence of diagnosed HIV 2020
Brisbane
Sydney
Perth
Adelaide
Melbourne
0-25 cases per 100 000
25-50 cases per 100 000
50-100 cases per 100 000
100-150 cases per 100 000
150-200 cases per 100 000
200-300 cases per 100 000
300-400 cases per 100 000
400-600 cases per 100 000
600-800 cases per 100 000

Prevalence of HIV in Australia

The numbers predicted in this model represent the numbers of people we would expect who have diagnosed HIV. It has been predicted that undiagnosed cases of HIV may make up somewhere between 10-20% of cases of HIV in Australia [23, 40]. Based on these estimates, the total number of people living with HIV in Australia would be ~23,284-26,195 in 2010 and forecasted to be ~31,580-35,528 in 2020 (Figure 6).

Figure 6: Estimated number of people living with diagnosed HIV over time and estimated number of people living with HIV, adjusting for estimates of the undiagnosed population



Trends in HIV and gender

HIV in Australia has tended to predominantly affect males. The epidemic in Australia is characterised by transmission mainly through unprotected anal intercourse among men who have sex with men [24]. However, females are increasingly being affected by the HIV epidemic (Figure 7, Figure 8, Table 8). In the period from 2000 to 2010, the estimated increase in the number of male cases living with diagnosed HIV was 44.7%. In comparison, the estimated increase in the number of females was 104.8%. From 2010 to 2020 the number of male cases living with HIV is expected to rise by 33.7%. In comparison, the number of female cases is expected to rise by 58.6%.

Figure 7 Number of males and females living with diagnosed HIV in Australia by year

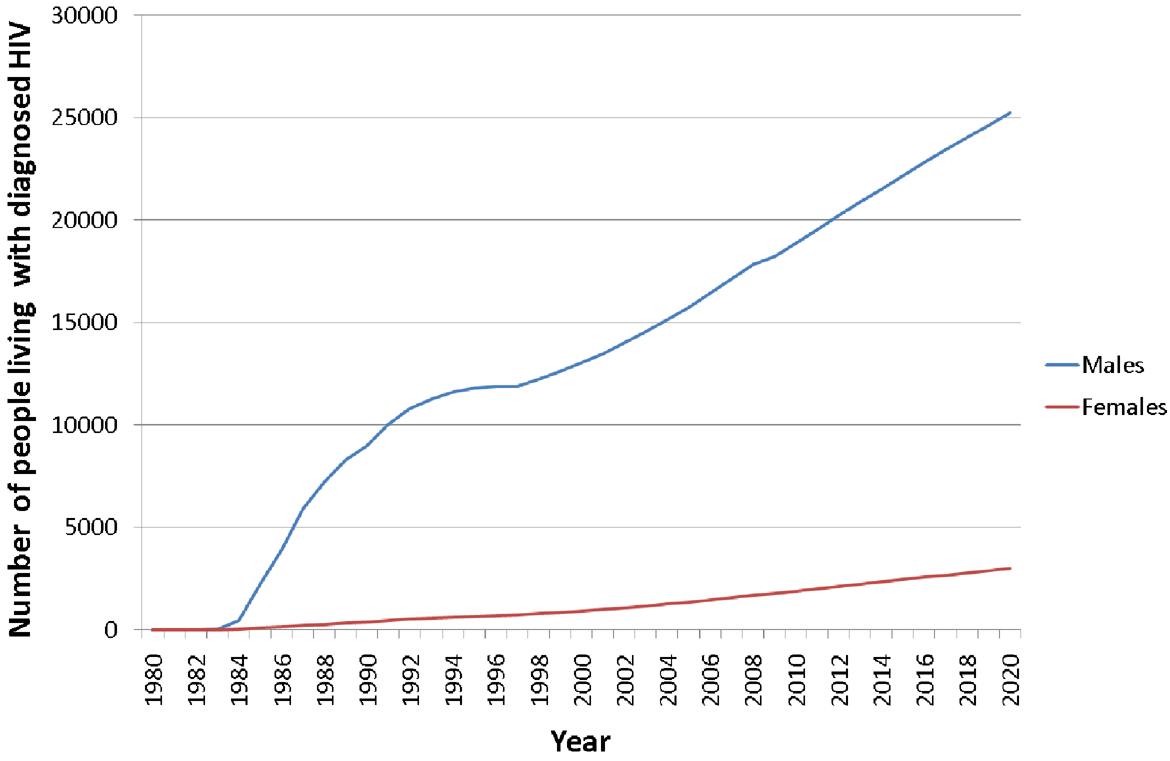


Figure 8 Number of females living with diagnosed HIV in Australia by year

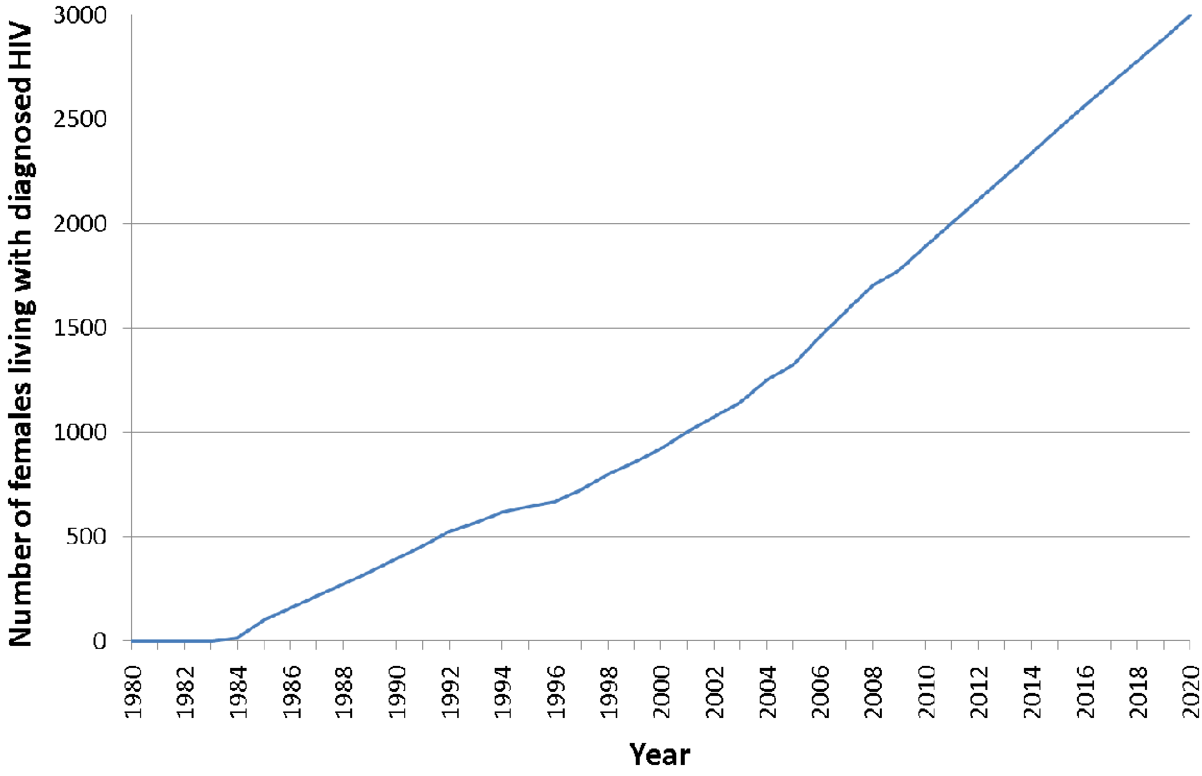


Table 8 Number of males and females living with diagnosed HIV in Australia by year

Year	Males	Females
1985	2243	99
1990	8995	393
1995	11793	643
2000	13040	923
2005	15760	1324
2010	18869	1890
2015	22156	2451
2020	25235	2997

Gender and location

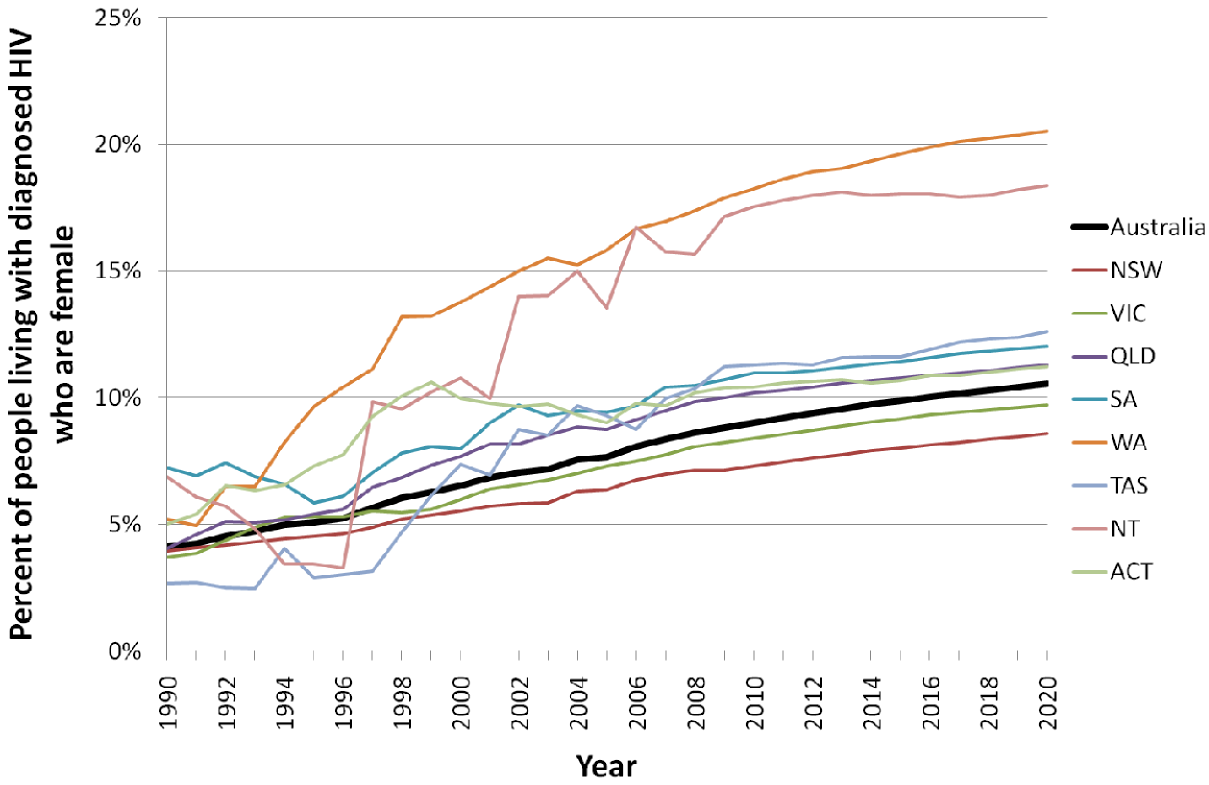
The proportion of the PLWDH population that is female varies significantly between jurisdictions. There has been a consistent increase in the estimated number of females living with diagnosed HIV as a proportion of the population in all states/territories from 1990 until 2010. The proportions of females are also expected to increase from 2010 to 2020 for each state (Figure 8).

The number of females living with HIV is lowest in New South Wales in 2010, where only 7.3% of the PLWDH are female. Western Australia and the Northern Territory are jurisdictions which have the highest numbers of the female population as a percentage of the diagnosed HIV population, being 18.2 % and 17.5% respectively. This would indicate that population trends are reflecting HIV risk behaviour within heterosexual populations within these locations.

Table 9: 10-year percentage change in female population living with diagnosed HIV by state/territory

Year	1990	2000	2010	2020
Australia	4.1%	6.5%	9.0%	10.5%
NSW	4.0%	5.5%	7.3%	8.6%
VIC	3.7%	6.0%	8.4%	9.7%
QLD	4.0%	7.7%	10.2%	11.3%
SA	7.2%	8.0%	11.0%	12.0%
WA	5.2%	13.8%	18.2%	20.5%
TAS	2.7%	7.4%	11.3%	12.6%
NT	6.9%	10.8%	17.5%	18.4%
ACT	5.0%	10.0%	10.4%	11.2%

Figure 9: Percent of the population living with diagnosed HIV who are female by year



The number of women as a proportion of the entire HIV-infected population is generally higher outside the capital cities than inside them. With the exception of South Australia, all states/territories which have multiple statistical regions have a higher proportion women among the population living with HIV outside of the capital cities than inside them. Western Australia has the highest proportion of women with HIV in rural areas, at 28.3% of the HIV-infected population (Table 10).

Table 10: Percent of the population living with diagnosed HIV that is female by geographical location

	State	Capital City	Non-Capital City
New South Wales	7.3%	7.0%	8.2%
Victoria	8.4%	8.2%	9.5%
Queensland	10.2%	10.0%	10.4%
South Australia	11.0%	11.0%	10.7%
Western Australia	18.2%	16.1%	28.3%
Tasmania	11.3%		
Northern Territory	17.5%		
Australian Capital Territory	10.4%		

Age distribution

The age of the population living with HIV is increasing. This is due in large part to the increased survival rates due to HAART [39]. The results of the model indicate that while the population of people living with diagnosed HIV is getting larger, the population is ageing into older age groups.

The distribution of ages can be seen in Figure 10. In 1985, the age group with the largest number of PLWDH was the 25-34 group. By 1995, the largest group was 35-34. By 2010, the largest group was the 45-54 group. Throughout the course of the epidemic, older ages groups have continually increased in size. Younger groups initially increased in size, and then slowly started to decrease.

Figure 10 Distribution of age groups of people living with diagnosed HIV by year

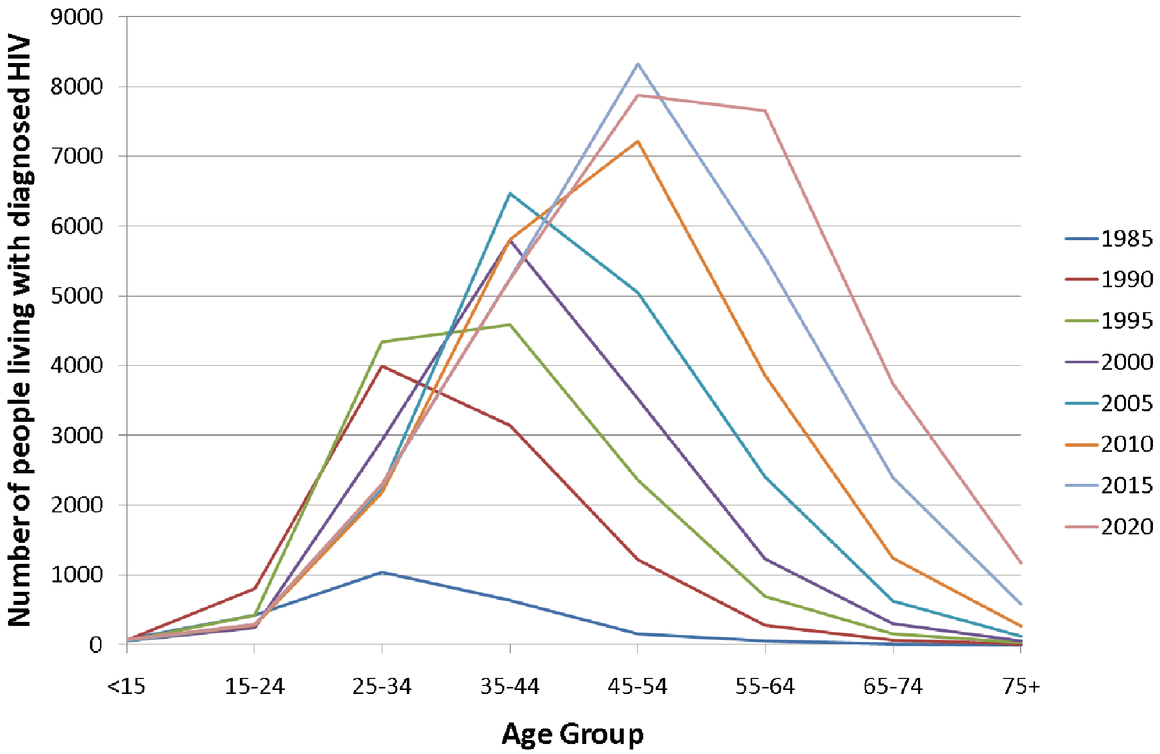
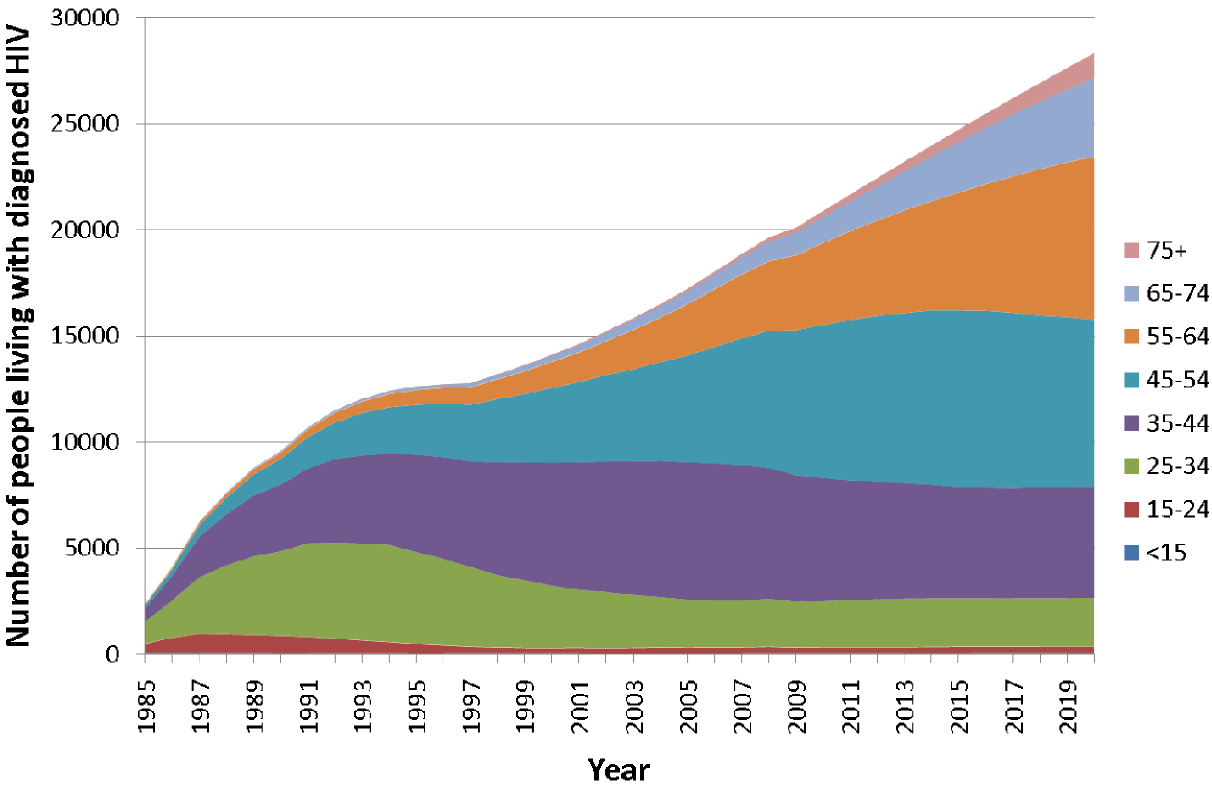


Figure 11 Numbers of people living with diagnosed HIV by age group and year



The age profile of PLWDH in Australia has clearly changed over time (Figure 11, Figure 12, Table 11). The proportions of people in the younger age groups have reduced significantly. In 1985, the proportion of the population living with diagnosed HIV in the 25-34 age group was 43.6%, and in the 15-24 age group it was 17.5%. In 2010 the proportions were 10.4% and 1.3%, respectively, with further expected decreases in the proportions by 2020 to 8.1% and 1.0%, respectively. In contrast, the proportion of PLWDH over 55 years of age has substantially increased. In 1985 the proportion of the population aged over 55 years was 2.7%. By 2000 it was 11.2%. In 2010, it was 25.7% and by 2020 it is expected to be 44.3%. If such a result were to eventuate then it would have significant implications for the national HIV response in Australia. Treatment and care approaches for the population of people living with HIV will need to be working across models of care and service delivery that can link preventative health, HIV specific clinical management, and referred management of other co-morbidities in a coordinated way across both primary care and specialist systems which support this ageing population.

Figure 12 Proportion of people living with diagnosed HIV by age group and year

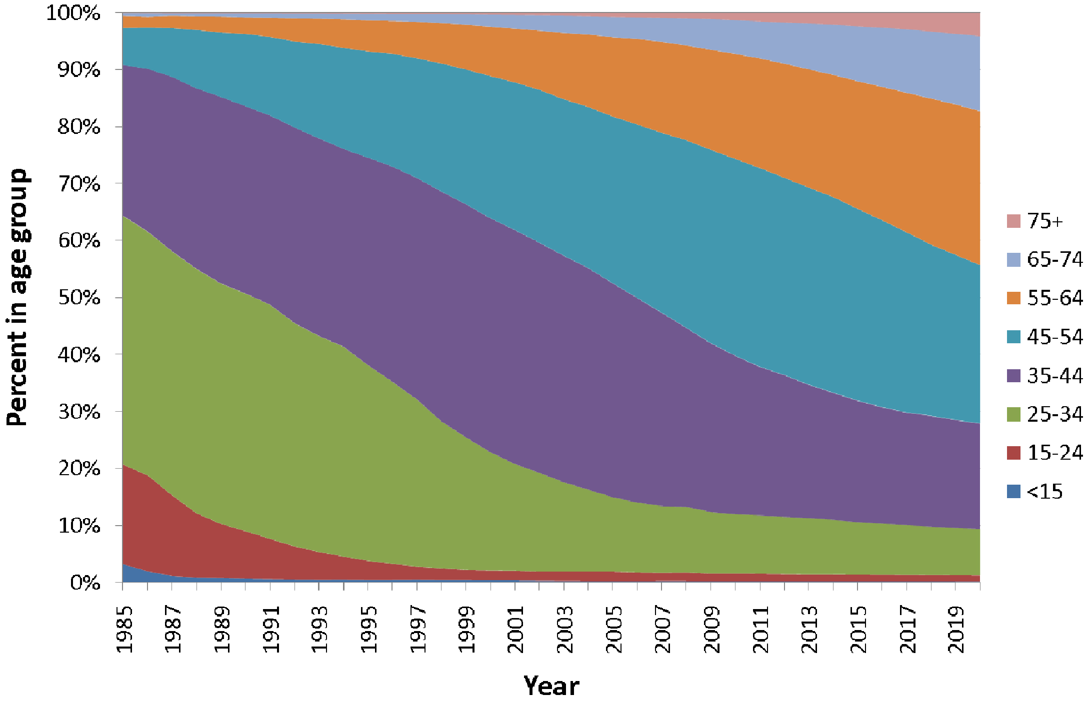


Table 11: Proportion of people living with diagnosed HIV by age group and year

	<15	15-24	25-34	35-44	45-54	55-64	65-74	75+
1985	3.2%	17.5%	43.6%	26.4%	6.5%	2.1%	0.5%	0.0%
1990	0.7%	8.4%	41.7%	32.8%	12.7%	2.9%	0.7%	0.1%
1995	0.4%	3.4%	34.4%	36.3%	18.7%	5.4%	1.2%	0.2%
2000	0.4%	1.7%	20.8%	41.0%	24.9%	8.7%	2.1%	0.4%
2005	0.3%	1.7%	13.1%	37.5%	29.3%	13.9%	3.6%	0.7%
2010	0.3%	1.3%	10.4%	27.8%	34.5%	18.5%	5.9%	1.3%
2015	0.3%	1.2%	9.2%	21.2%	33.7%	22.4%	9.7%	2.4%
2020	0.3%	1.0%	8.1%	18.5%	27.8%	27.0%	13.2%	4.1%

Table 12: Estimated number of people living with diagnosed HIV by age group and year

	<15	15-24	25-34	35-44	45-54	55-64	65-74	75+
1980	0	0	0	0	0	0	1	0
1981	0	0	0	1	0	0	1	0
1982	0	0	0	1	0	0	0	0
1983	0	0	8	4	2	0	0	0
1984	23	65	193	130	33	11	7	0
1985	76	418	1043	631	156	51	13	1
1986	82	696	1769	1180	300	79	27	3
1987	74	884	2677	1914	537	135	29	7
1988	69	857	3270	2414	783	183	42	8
1989	72	832	3706	2873	996	247	52	9
1990	64	801	3992	3144	1216	282	68	11
1991	63	758	4397	3549	1479	361	85	12
1992	60	672	4513	3951	1738	467	102	16
1993	57	590	4563	4169	1997	534	114	17
1994	61	509	4575	4309	2204	619	130	21
1995	56	425	4339	4590	2358	688	149	25
1996	58	361	4070	4809	2528	732	159	29
1997	62	293	3758	4962	2690	824	176	28
1998	57	271	3409	5323	2968	935	216	32
1999	58	245	3176	5573	3229	1069	257	37
2000	56	246	2935	5797	3525	1231	297	51
2001	57	249	2741	6005	3795	1380	352	60
2002	52	242	2645	6141	4088	1586	414	69
2003	49	257	2485	6299	4354	1847	486	81
2004	46	274	2376	6413	4668	2098	543	99
2005	47	286	2251	6465	5043	2404	625	120
2006	49	278	2214	6465	5493	2710	699	141
2007	57	273	2209	6393	5961	3012	808	164
2008	58	297	2264	6169	6468	3269	943	194
2009	57	260	2176	5953	6827	3529	1091	225
2010	59	275	2178	5806	7212	3861	1243	270
2011	58	279	2223	5647	7561	4171	1421	325
2012	61	278	2258	5577	7774	4495	1634	383
2013	63	275	2293	5429	8033	4825	1871	442
2014	64	283	2297	5347	8231	5140	2121	504
2015	65	290	2284	5249	8328	5544	2396	582
2016	69	287	2287	5198	8356	5967	2663	661
2017	72	287	2289	5170	8290	6416	2939	756
2018	71	289	2292	5225	8083	6910	3186	882
2019	72	288	2296	5229	8006	7293	3440	1025
2020	72	291	2306	5240	7873	7657	3741	1167

Summary of expected antiretroviral treatment demands in Australia

The model reproduced the past treatment demands in Australia and simulated the expected future demands over the next 10 years by ART regimen (see Appendix A). In Figure 13 and Figure 14 we present the estimated number of people living with diagnosed HIV who are treatment-naive, experienced first-, second-, or subsequent lines of antiretroviral therapy. It is anticipated that the number of PLWDH will remain constant, at approximately 2,500 (Figure 14), assuming treatment guidelines and clinical practice does not change substantially. The number of people on first-line regimens will also consistently remain steady, at approximately 6,000. However, there is expected to be an increase in the number of people requiring second-line regimens and a substantial increase in the number of people requiring third- and subsequent lines of therapy (Figure 13, Figure 14). Specifically, the estimated number of people requiring second-line and subsequent lines of therapies is expected to increase from 7,050 and 5,489 in 2010 to approximately 8,355 and 11,385 in 2020. Considered as a proportion, approximately 26% of all PLWDH in Australia are on third-/subsequent lines of therapy in 2010 and it is estimated this will increase to 40% by 2020 (Figure 15). The total potential demand for antiretroviral therapy in Australia is estimated to be 18,362 in 2010 and 25,580 in 2020. However, the actual number of people on antiretroviral therapy is likely to be less than this, since all people eligible for treatment do not immediately commence therapy.

Figure 13: Estimated number of people living with diagnosed HIV in Australia not on HAART or on first-, second-, or third- or subsequent lines of therapy

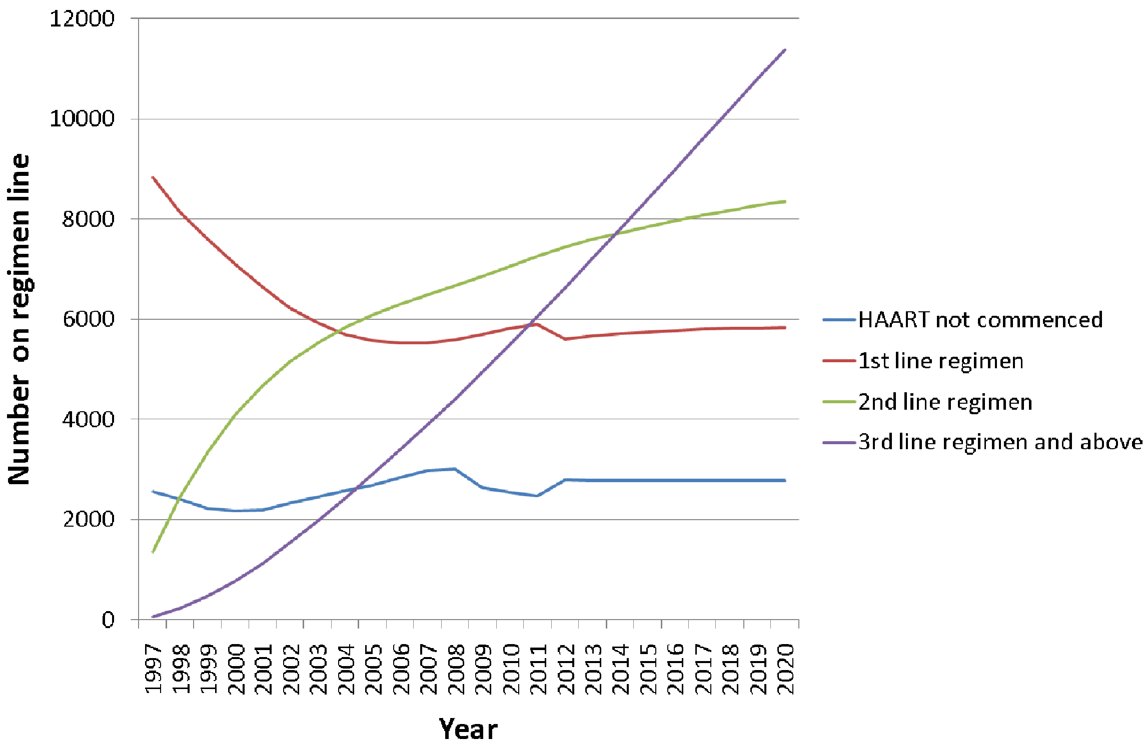


Figure 14: Estimated sum of people living with diagnosed HIV in Australia not on HAART or on first-, second-, or third- or subsequent lines of therapy

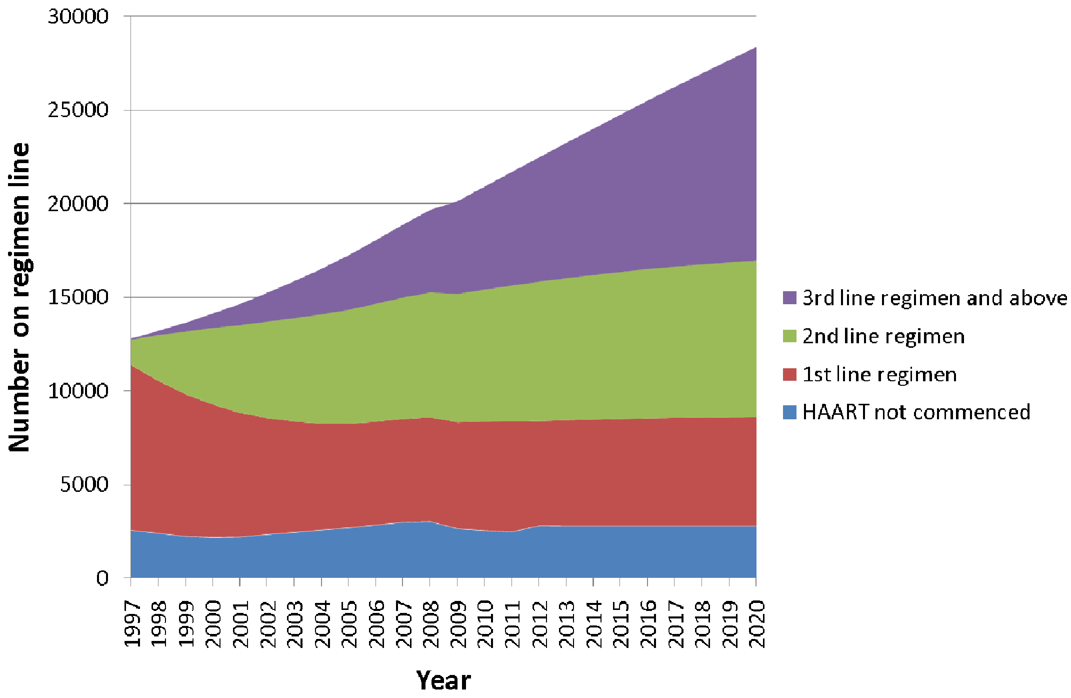
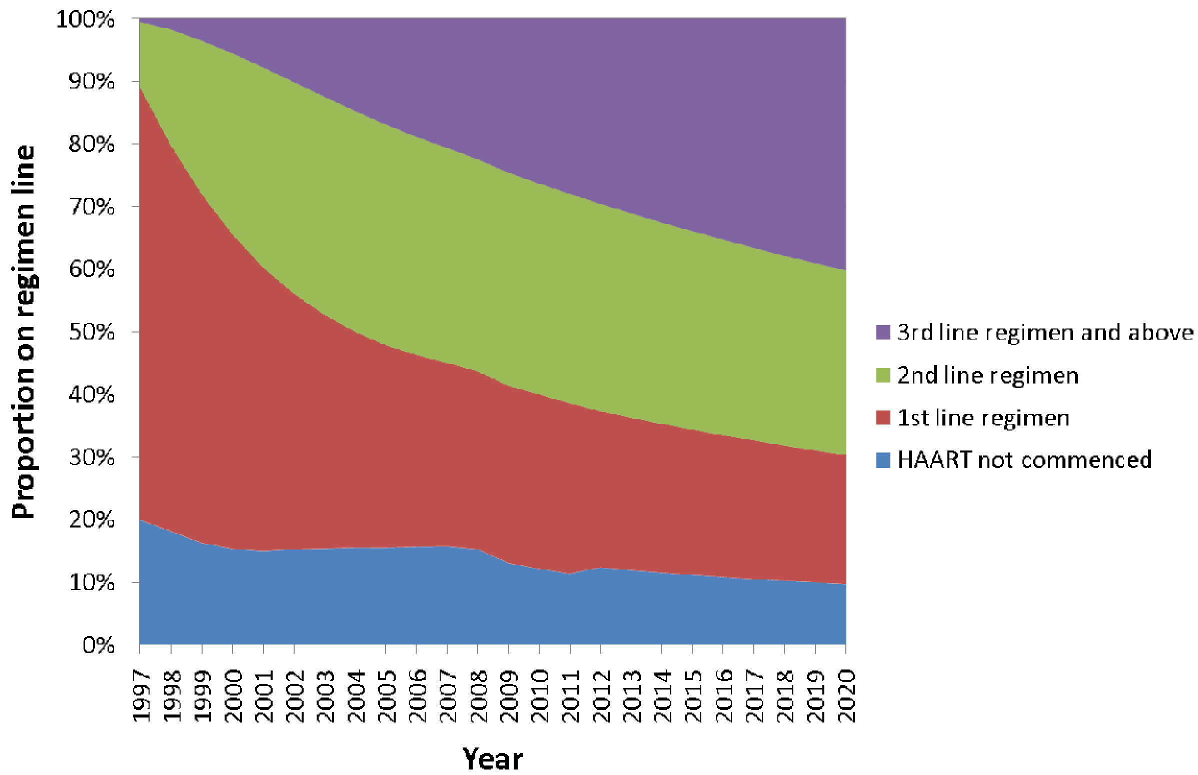


Figure 15: Estimated proportion of people living with diagnosed HIV in Australia not on HAART or on first-, second-, or third-/subsequent lines of therapy



Conclusions

Australia has an HIV-positive population that is surviving longer due to effective use of highly active antiretroviral therapy (HAART). This population is now ageing and will present unique challenges for the provision of health services to these patients. Understanding where these people will likely be and the conditions that they will present with will be pivotal to providing reliable health care in the future. This population is also increasing in size due to new infections. The extended lifetime together with new cases will result in an increase in the prevalence of HIV in the population, leading to an increased strain on the health system, and also the possibility of increased infection rates.

This report has provided detailed forecasts of the number of people living with HIV in Australia, by age, gender and geographical location. This report also provided estimates of the number of people requiring antiretroviral therapies, by first-, second-, and subsequent lines of therapies, along with estimates of the number of incident cases of cancers among people living with HIV in Australia. These forecasts are valuable for planning to care for the needs of people living with HIV in Australia, particularly those requiring complex case management that may be living in areas that currently do not have specialised HIV clinicians.

Future editions of this work should consider measures to validate the estimated geographical distribution of people living with HIV in Australia, include further details of CD4 counts and viral load as it relates to disease progression and mortality, improve accuracy of estimates of incidence of cancer, and incorporate other co-morbidities of importance to people living with HIV. It would also be valuable to link models that capture sexual and injecting behaviours related to HIV transmission and testing rates to the current model based on the National HIV Registry. Such a model could be used to examine how behavioural and biomedical interventions could lead to long-term implications on health systems. Health economic analyses could also be conducted to ensure the most effective and cost-effective programs are established. This model is expected to become an invaluable tool for evaluating the past epidemic trends of HIV in Australia, understanding the present state, forecasting the future burden and demand for clinical services, and determining how policies, programs and services should change in order to prevent disease burdens and improve the health of Australians at risk of or infected with HIV.

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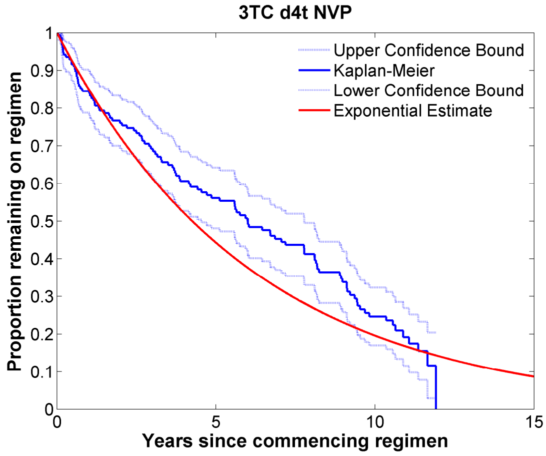
Appendix A: Rates of initiating and stopping treatment regimens

Rate of stopping first-line regimens

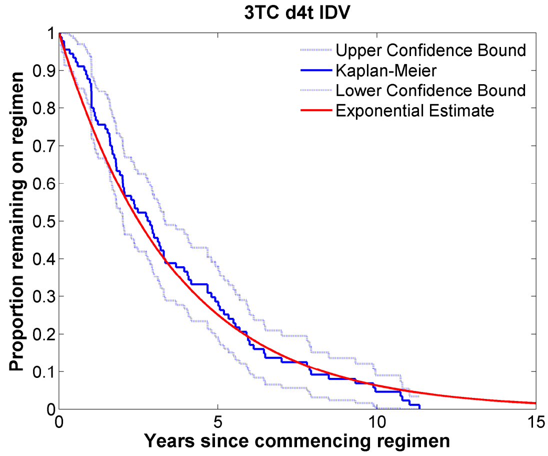
a)

3TC/d4t/NVP
(9.1% of first-line)
Median time on regimen
4.25 years (1.76-8.5 IQR)



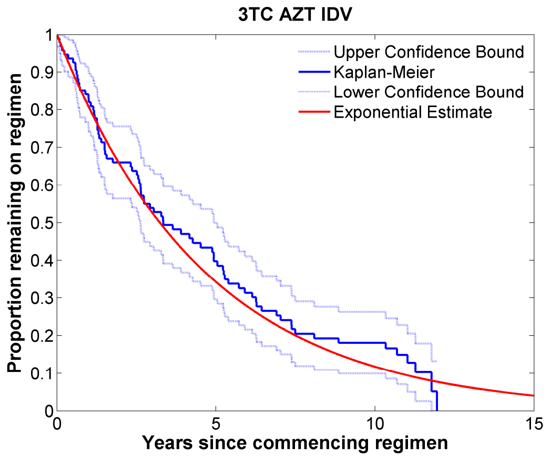
b)

3TC/d4t/IDV
(5.3% of first-line)
Median time on regimen
2.51 years (1.04-5.01 IQR)



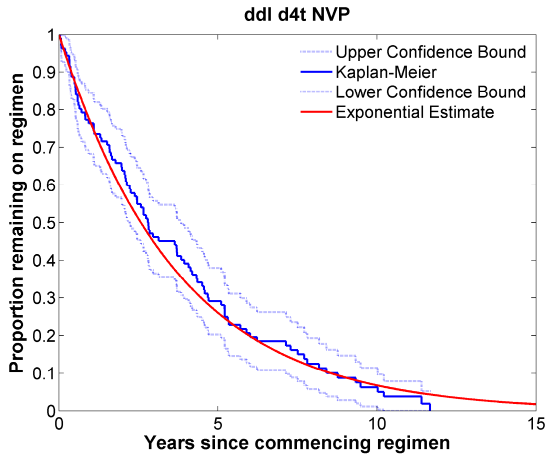
c)

3TC/AZT/IDV
(5.5% of first-line)
Median time on regimen
3.23 years (1.34-6.46 IQR)



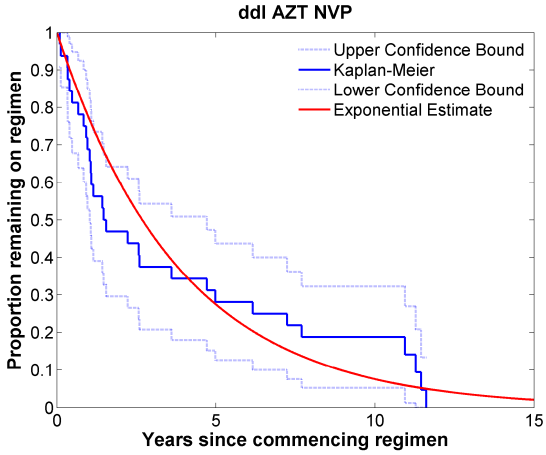
d)

ddI/d4t/NVP
(6.3% of first-line)
Median time on regimen
2.57 years (1.07-5.15 IQR)



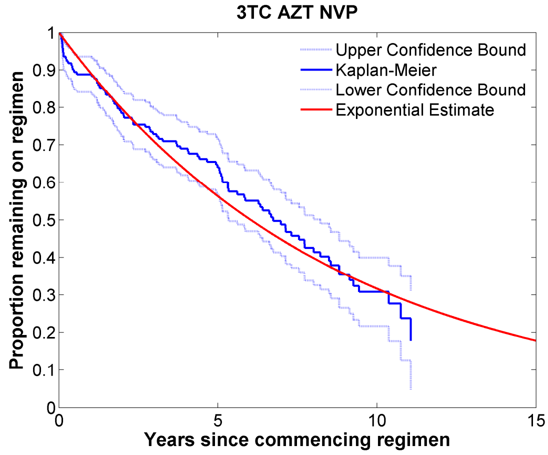
e)

ddI/AZT/NVP
(1.9% of first-line)
Median time on regimen
2.68 years (1.11-5.36 IQR)



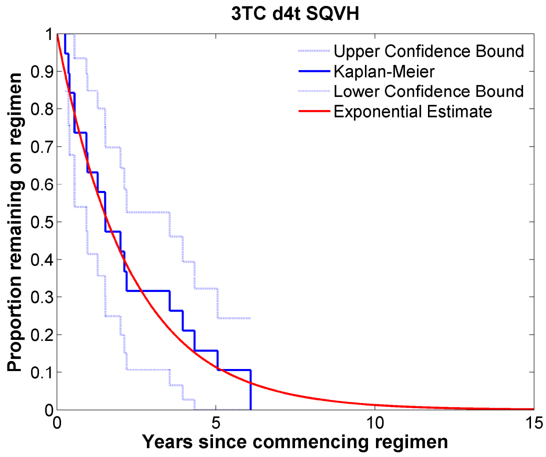
f)

3TC/AZT/NVP
(10.1% of first-line)
Median time on regimen
6.02 years (2.5-12.05 IQR)



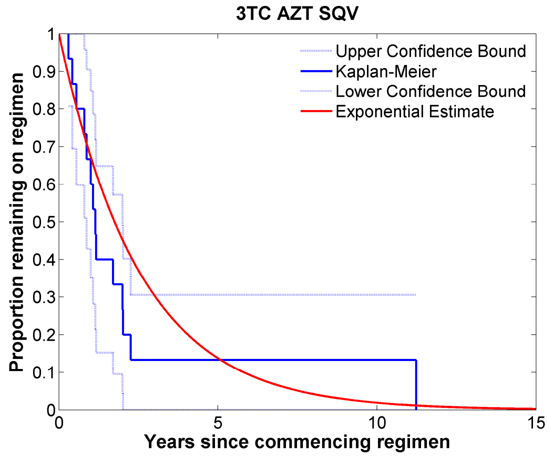
g)

3TC/d4t/SQVH
(1.1% of first-line)
Median time on regimen
1.6 years (0.66-3.19 IQR)



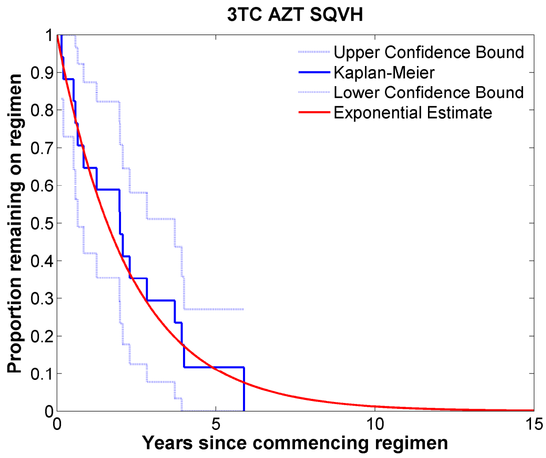
h)

3TC/AZT/SQV
(0.9% of first-line)
Median time on regimen
1.75 years (0.73-3.49 IQR)



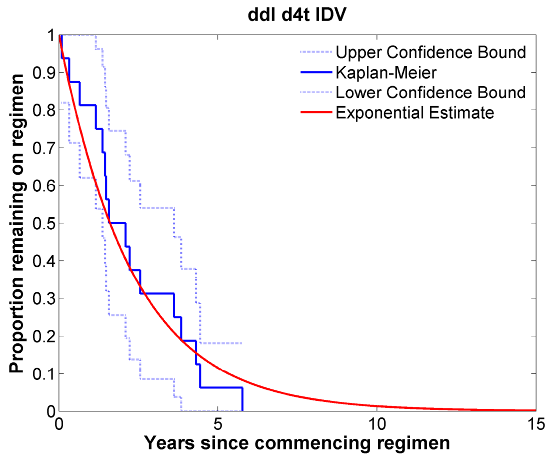
i)

3TC/AZT/SQVH
(1% of first-line)
Median time on regimen
1.58 years (0.66-3.16 IQR)



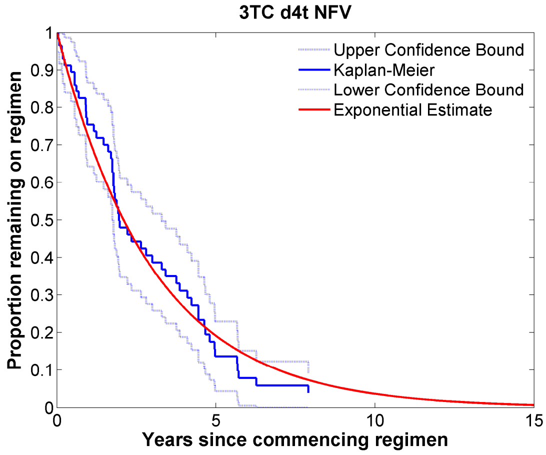
j)

ddI/d4t/IDV
(0.9% of first-line)
Median time on regimen
1.6 years (0.67-3.21 IQR)



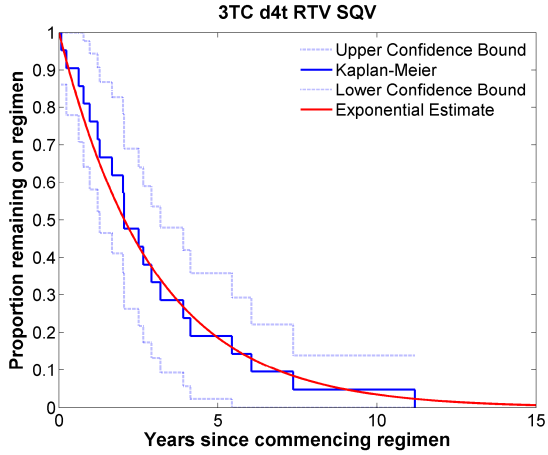
k)

3TC/d4t/NFV
(3.3% of first-line)
Median time on regimen
2.09 years (0.87-4.19 IQR)



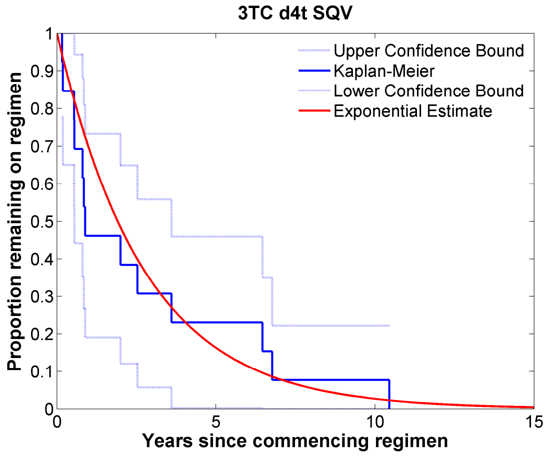
l)

3TC/d4t/RTV/SQV
(1.2% of first-line)
Median time on regimen
2.06 years (0.85-4.12 IQR)



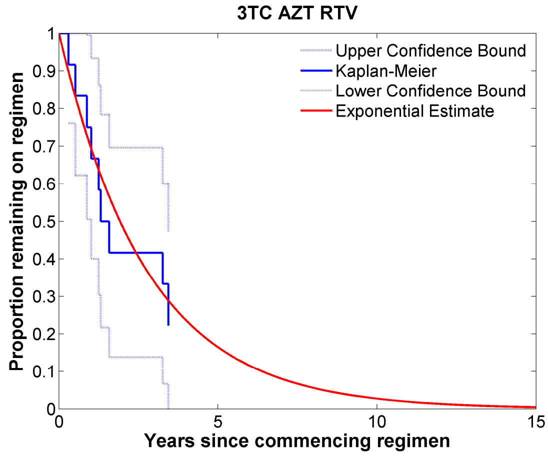
m)

3TC/d4t/SQV
(0.8% of first-line)
Median time on regimen
1.91 years (0.79-3.82 IQR)



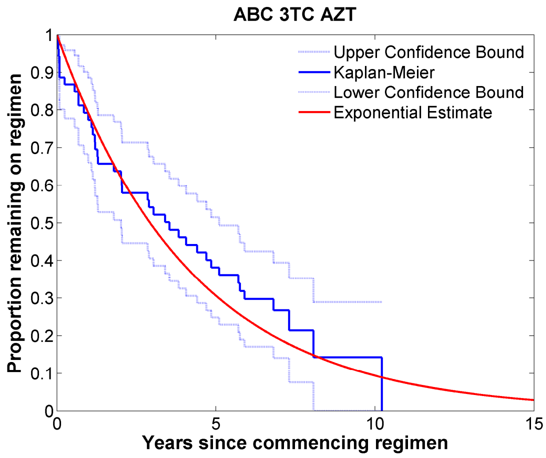
n)

3TC/AZT/RTV
(0.8% of first-line)
Median time on regimen
1.92 years (0.8-3.84 IQR)



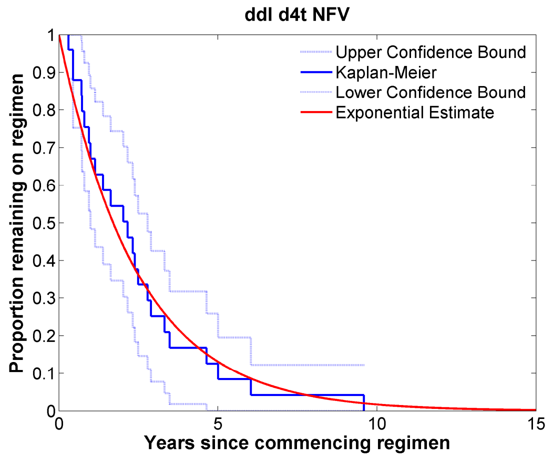
o)

ABC/3TC/AZT
(3.1% of first-line)
Median time on regimen
2.93 years (1.21-5.85 IQR)



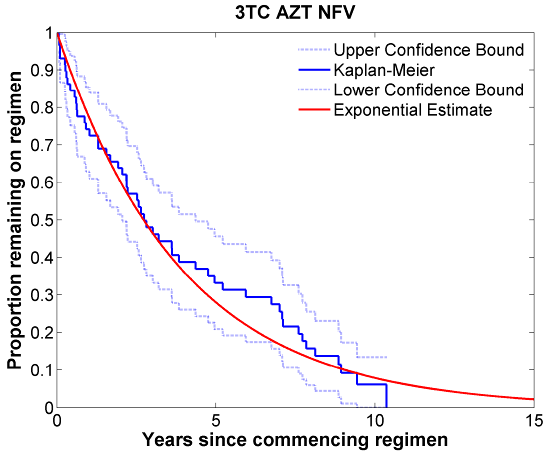
p)

ddI/d4t/NFV
(1.5% of first-line)
Median time on regimen
1.7 years (0.71-3.41 IQR)



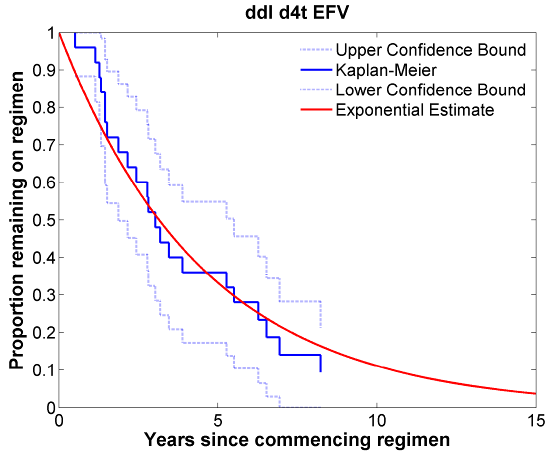
q)

3TC/AZT/NFV
(3.4% of first-line)
Median time on regimen
2.72 years (1.13-5.44 IQR)



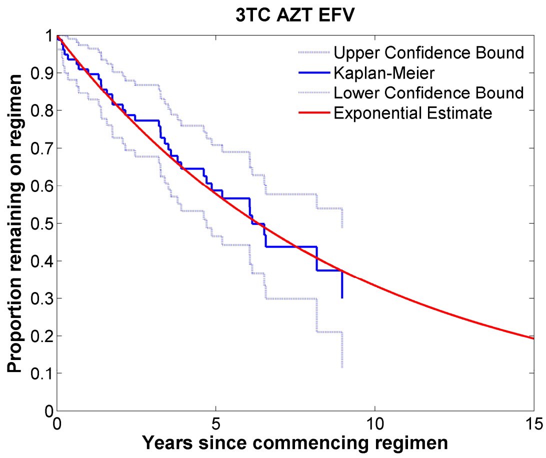
r)

ddI/d4t/EFV
(1.5% of first-line)
Median time on regimen
3.15 years (1.31-6.29 IQR)



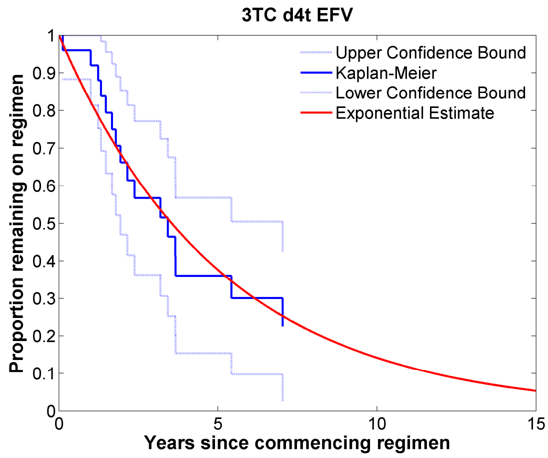
s)

3TC/AZT/EFV
(4.6% of first-line)
Median time on regimen
6.32 years (2.62-12.63 IQR)



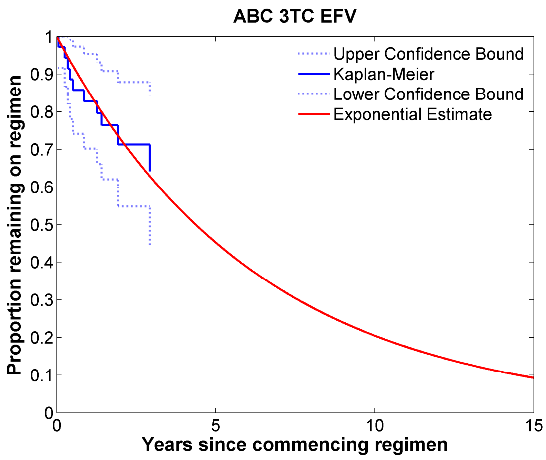
t)

3TC/d4t/EFV
(1.5% of first-line)
Median time on regimen
3.54 years (1.47-7.09 IQR)



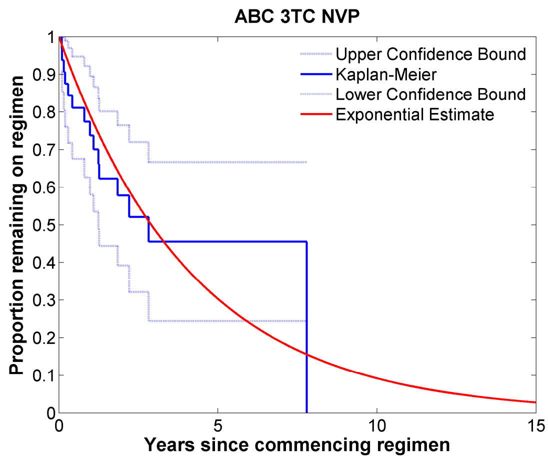
u)

ABC/3TC/EFV
(2.1% of first-line)
Median time on regimen
4.37 years (1.81-8.74 IQR)



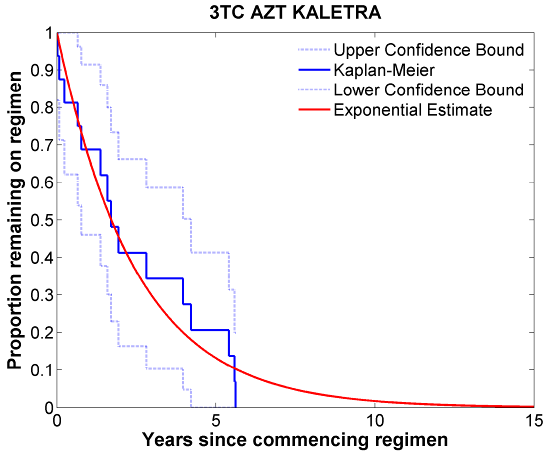
v)

ABC/3TC/NVP
(1.9% of first-line)
Median time on regimen
2.9 years (1.2-5.8 IQR)



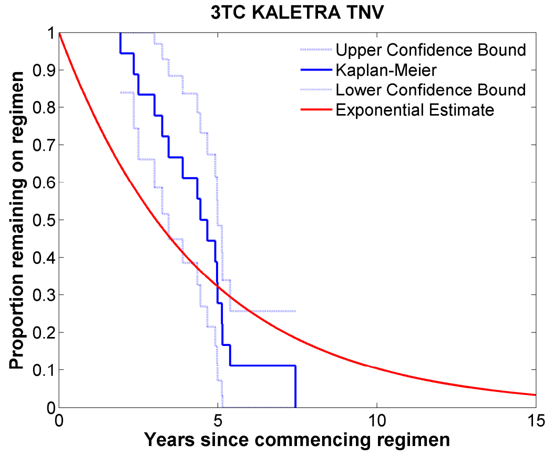
w)

3TC/AZT/KALETRA
(0.9% of first-line)
Median time on regimen
1.71 years (0.71-3.41 IQR)



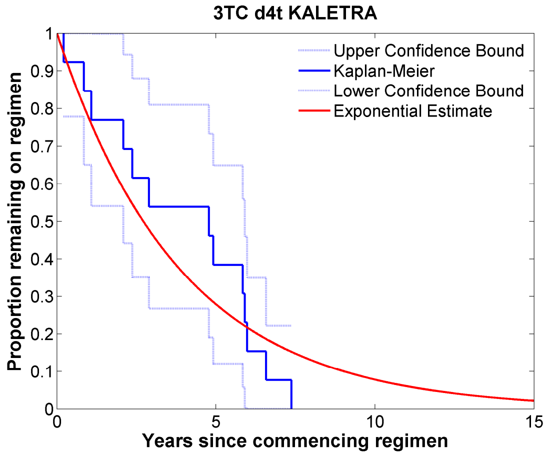
x)

3TC/KALETRA/TNV
(1.1% of first-line)
Median time on regimen
3.05 years (1.27-6.11 IQR)



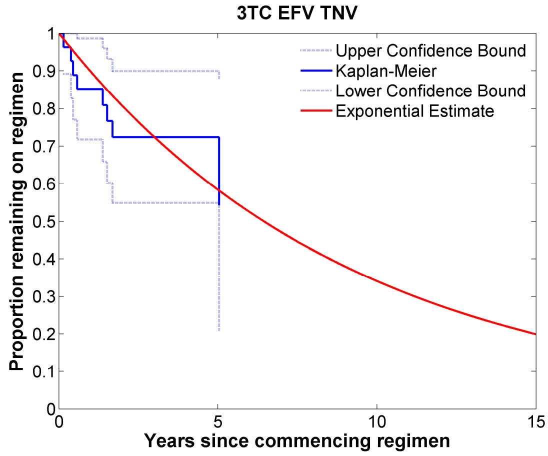
y)

3TC/d4t/KALETRA
(0.8% of first-line)
Median time on regimen
2.71 years (1.13-5.43 IQR)



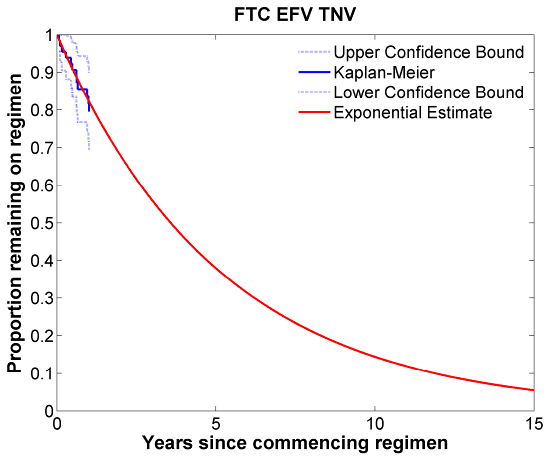
z)

3TC/EFV/TNV
(1.6% of first-line)
Median time on regimen
6.44 years (2.67-12.88 IQR)



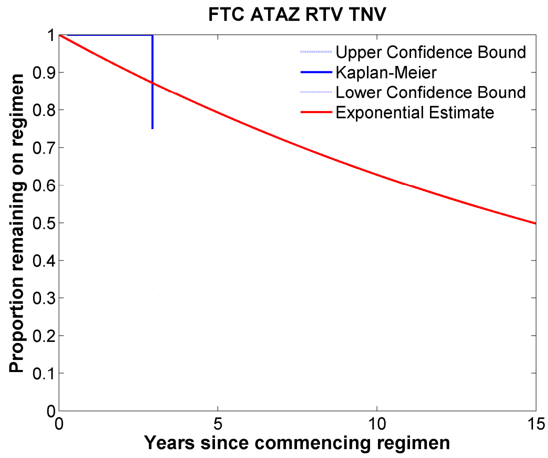
aa)

FTC/EFV/TNV
(4% of first-line)
Median time on regimen
3.57 years (1.48-7.15 IQR)



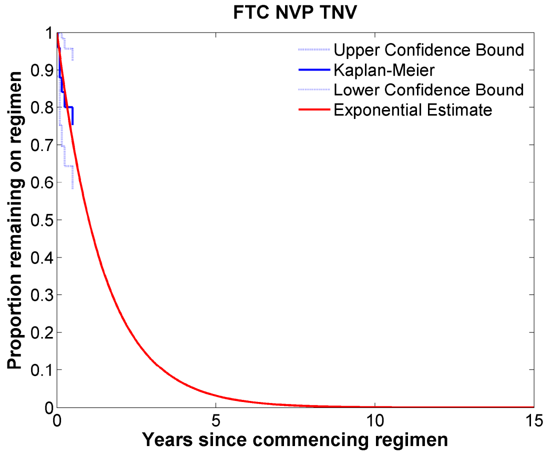
ab)

FTC/ATAZ/RTV/TNV
(0.8% of first-line)
Median time on regimen
14.91 years (6.19-29.81 IQR)



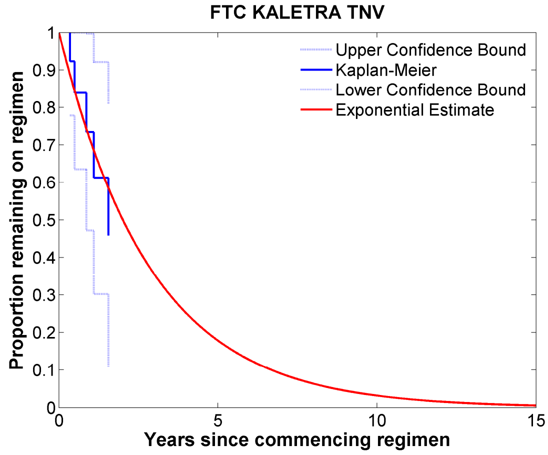
ac)

FTC/NVP/TNV
(1.5% of first-line)
Median time on regimen
1 years (0.42-2 IQR)



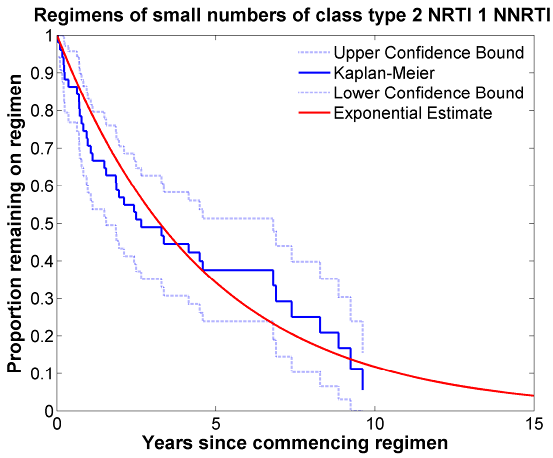
ad)

FTC/KALETRA/TNV
(0.8% of first-line)
Median time on regimen
2.01 years (0.83-4.02 IQR)



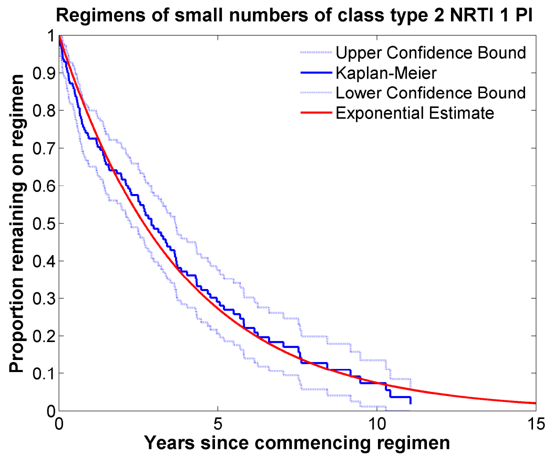
ae)

Other regimens: 2 NRTI+1 NNRTI
(3% of first-line)
Median time on regimen
3.23 years (1.34-6.46 IQR)



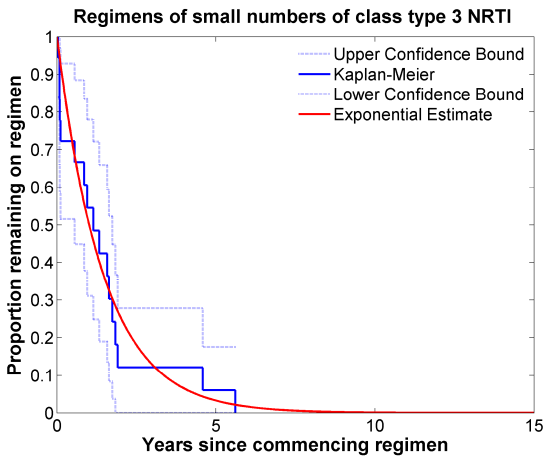
af)

Other regimens: 2 NRTI+1 PI
(8.4% of first-line)
Median time on regimen
2.67 years (1.11-5.33 IQR)



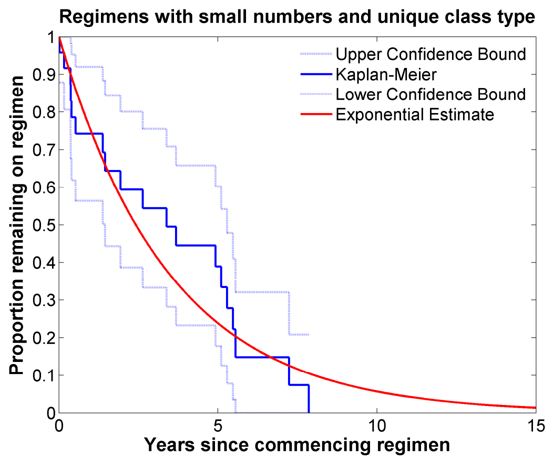
ag)

Other regimens: 3 NRTI
(1.1% of first-line)
Median time on regimen
1.01 years (0.42-2.02 IQR)



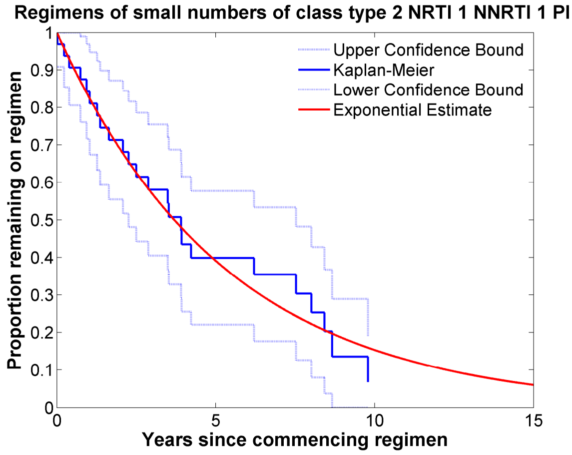
ah)

Other regimens
(1.4% of first-line)
Median time on regimen
2.42 years (1-4.83 IQR)



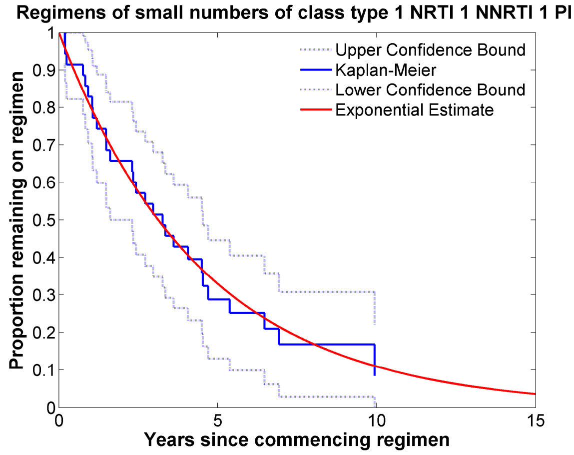
ai)

Other regimens: 2 NRTI + 1 NNRTI + 1 PI
(1.9% of first-line)
Median time on regimen
3.69 years (1.53-7.38 IQR)



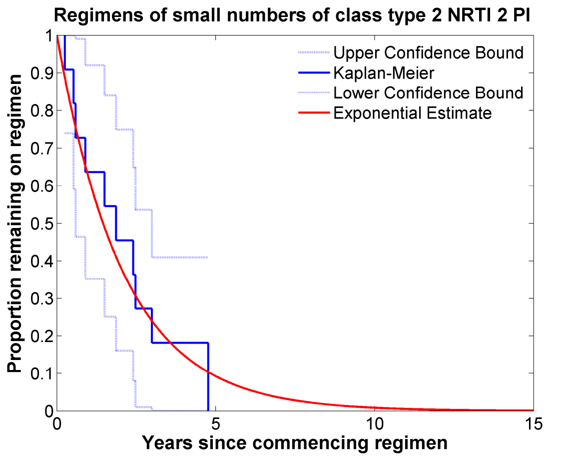
aj)

Other regimens: 1 NRTI + 1 NNRTI + 1 PI
(2.1% of first-line)
Median time on regimen
3.12 years (1.3-6.24 IQR)



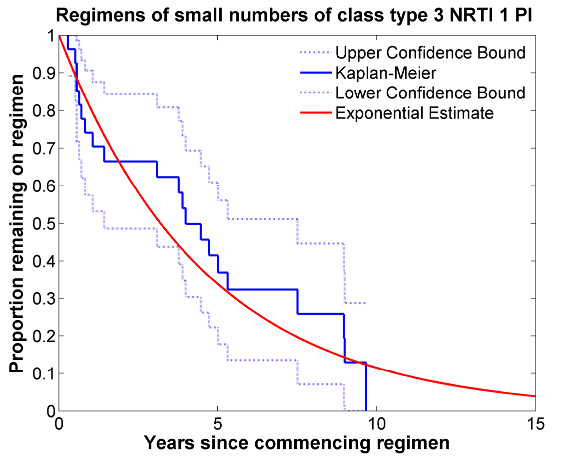
ak)

Other regimens: 2 NRTI + 2 PI
(0.6% of first-line)
Median time on regimen
1.45 years (0.6-2.9 IQR)



al)

Other regimens: 3 NRTI+ 1 PI
(1.6% of first-line)
Median time on regimen
3.2 years (1.33-6.4 IQR)



am)

Other regimens: 3 NRTI + 1 NNRTI
(0.8% of first-line)
Median time on regimen 2.79 years
(1.16-5.59 IQR)

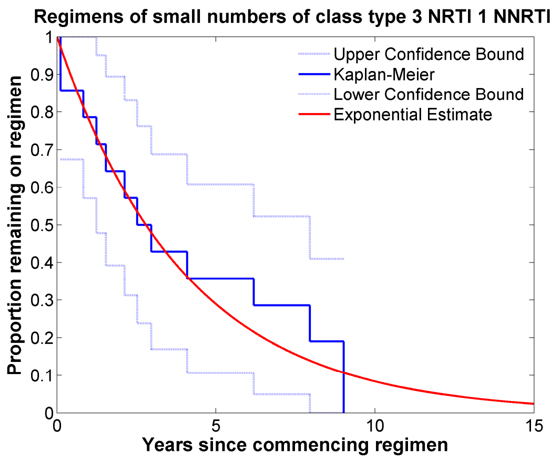
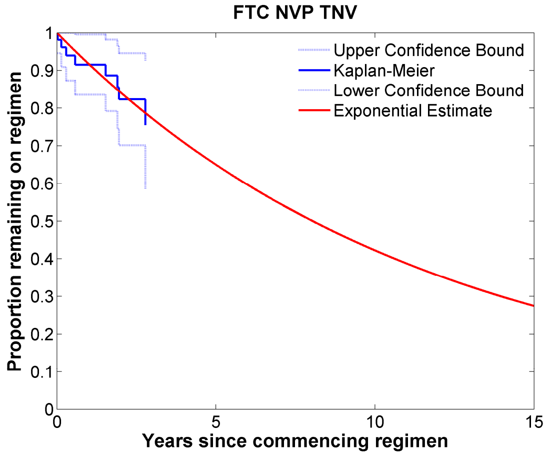


Figure 16: Kaplan-Meier curves and exponential fits for each first-line regimen (recorded in the AHOD cohort).

Rate of stopping second-line regimens

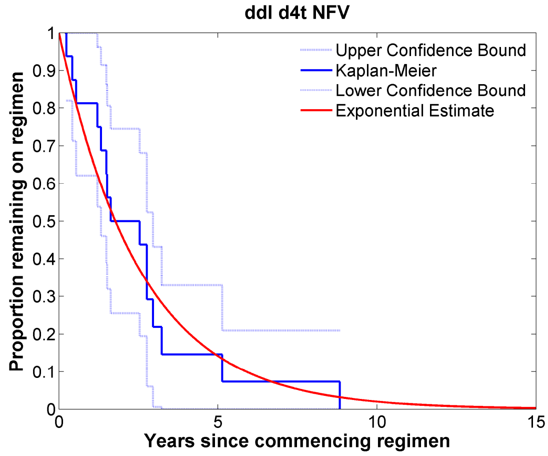
a)

FTC/NVP/TNV
(4.9% of second-line)
Median time on regimen
8.04 years (3.34-16.07 IQR)



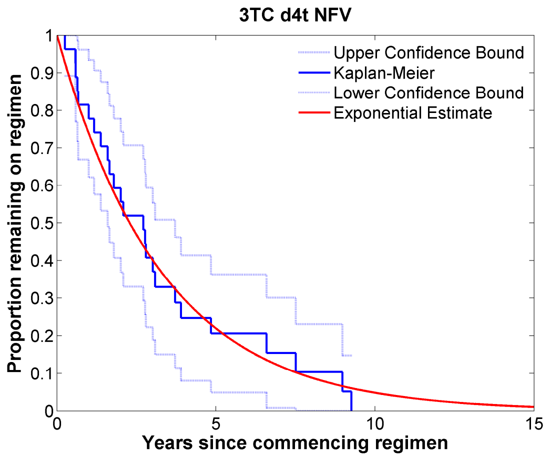
b)

ddI/d4t/NFV
(1.5% of second-line)
Median time on regimen
1.77 years (0.74-3.55 IQR)



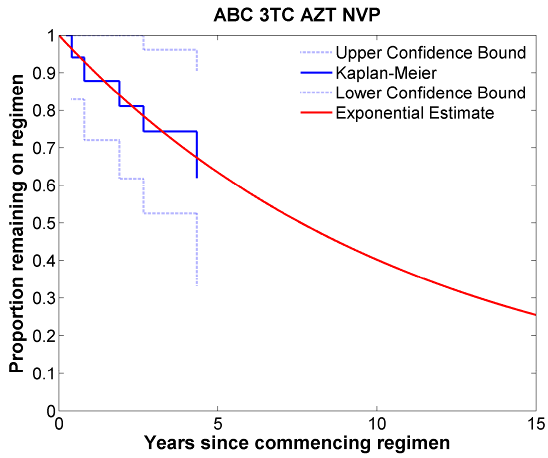
c)

3TC/d4t/NFV
(2.4% of second-line)
Median time on regimen
2.28 years (0.95-4.57 IQR)



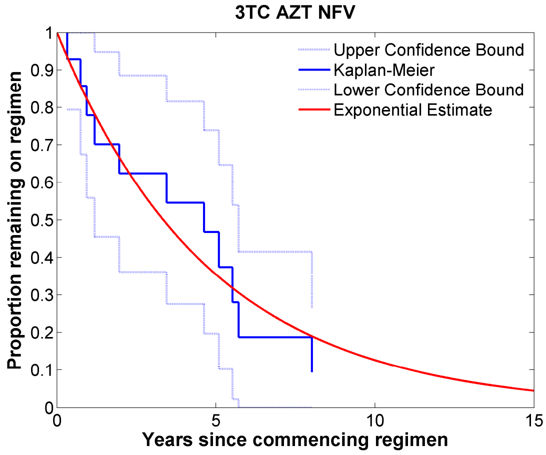
d)

ABC/3TC/AZT/NVP
(1.6% of second-line)
Median time on regimen
7.6 years (3.16-15.21 IQR)



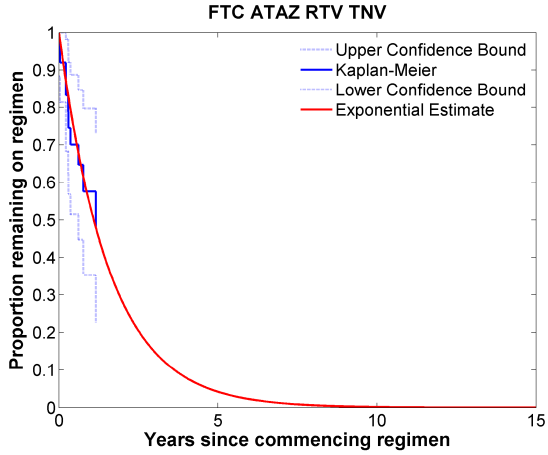
e)

3TC/AZT/NFV
(1.3% of second-line)
Median time on regimen
3.34 years (1.39-6.68 IQR)



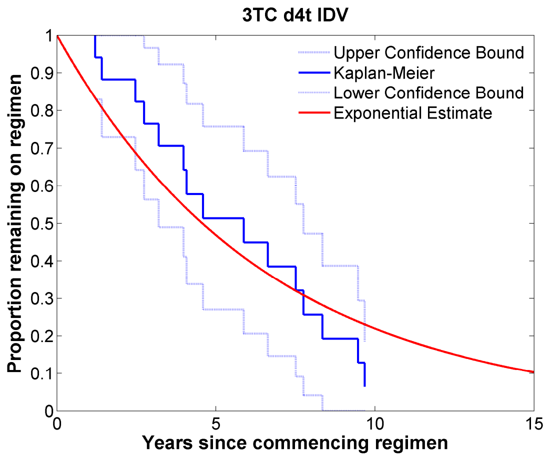
f)

FTC/ATAZ/RTV/TNV
(2.2% of second-line)
Median time on regimen
1.09 years (0.45-2.18 IQR)



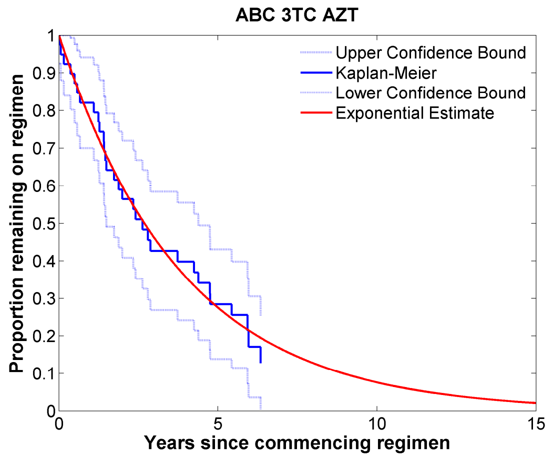
g)

3TC/d4t/IDV
(1.5% of second-line)
Median time on regimen
4.57 years (1.9-9.14 IQR)



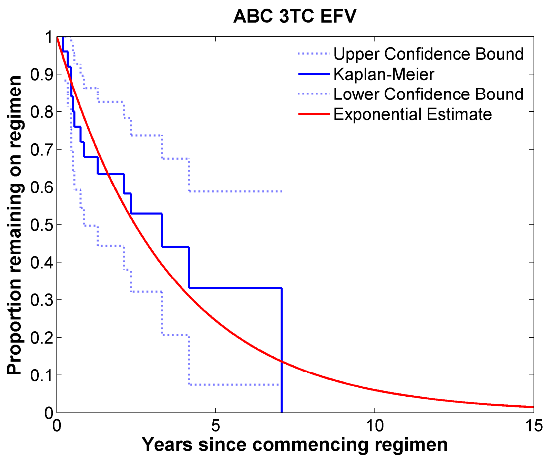
h)

ABC/3TC/AZT
(3.5% of second-line)
Median time on regimen
2.69 years (1.12-5.37 IQR)



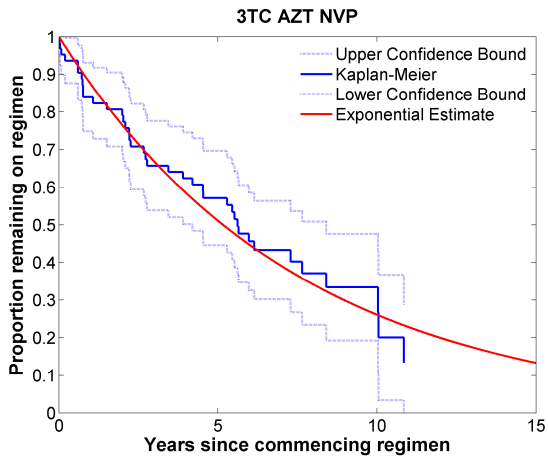
i)

ABC/3TC/EFV
(2.2% of second-line)
Median time on regimen
2.46 years (1.02-4.92 IQR)



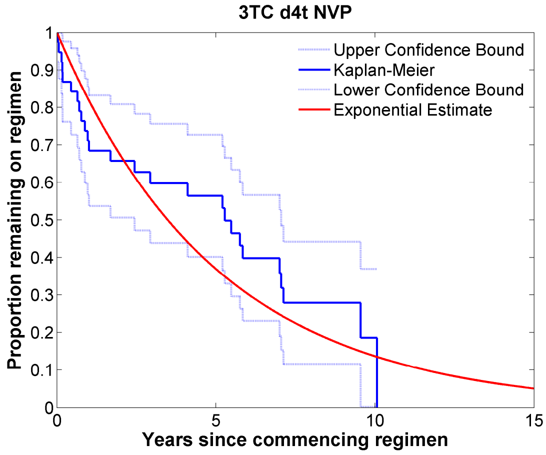
j)

3TC/AZT/NVP
(5.7% of second-line)
Median time on regimen
5.16 years (2.14-10.31 IQR)



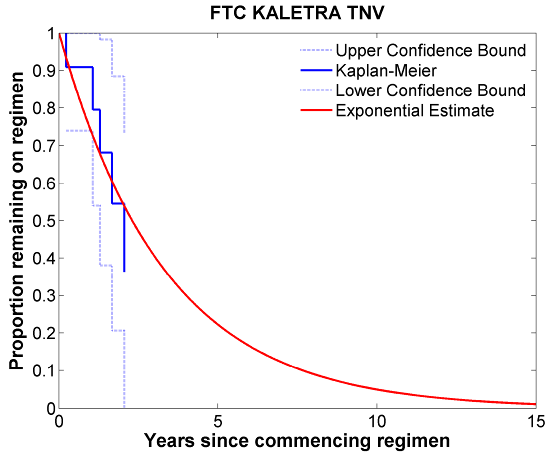
k)

3TC/d4t/NVP
(3.4% of second-line)
Median time on regimen
3.48 years (1.44-6.96 IQR)



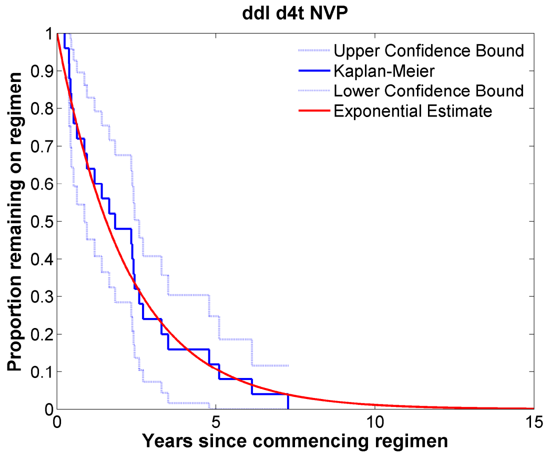
l)

FTC/KALETRA/TNV
(1% of second-line)
Median time on regimen
2.3 years (0.96-4.61 IQR)



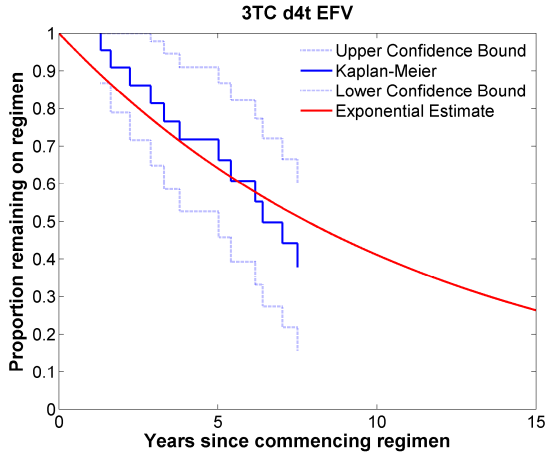
m)

ddI/d4t/NVP
(2.2% of second-line)
Median time on regimen
1.55 years (0.64-3.1 IQR)



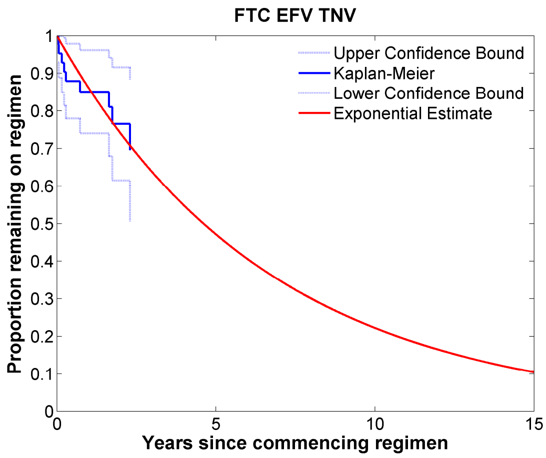
n)

3TC/d4t/EFV
(2% of second-line)
Median time on regimen
7.79 years (3.23-15.58 IQR)



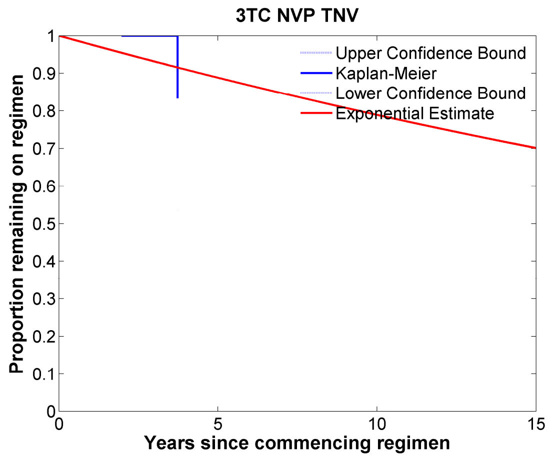
o)

FTC/EFV/TNV
(3.8% of second-line)
Median time on regimen
4.61 years (1.91-9.21 IQR)



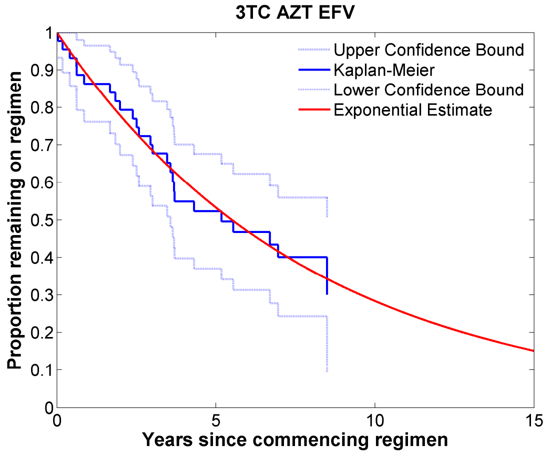
p)

3TC/NVP/TNV
(0.9% of second-line)
Median time on regimen
29.28 years (12.15-58.57 IQR)



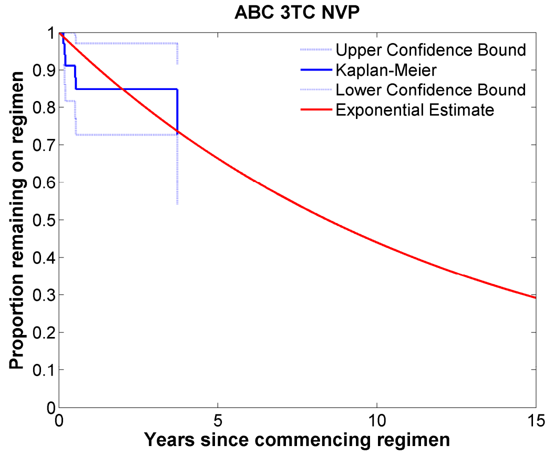
q)

3TC/AZT/EFV
(4% of second-line)
Median time on regimen
5.5 years (2.28-11 IQR)



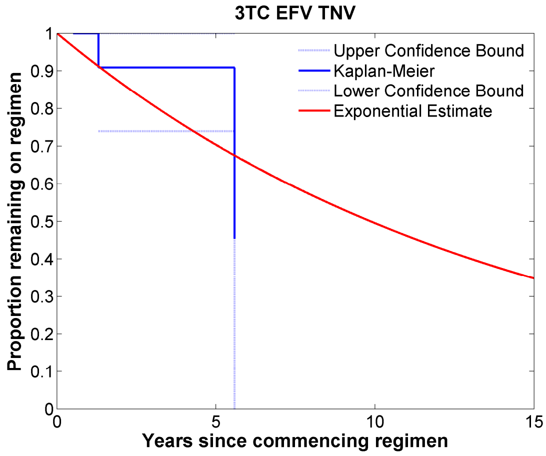
r)

ABC/3TC/NVP
(3.1% of second-line)
Median time on regimen
8.44 years (3.5-16.88 IQR)



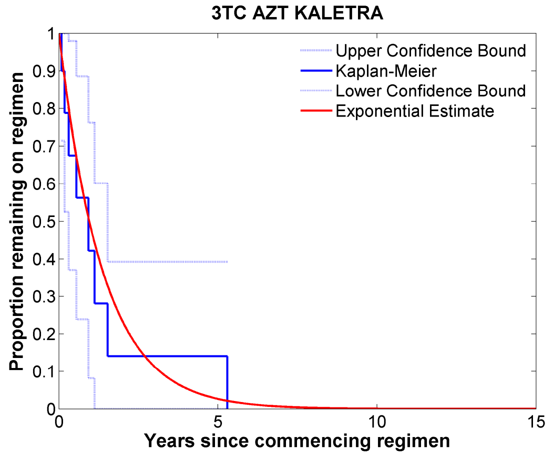
s)

3TC/EFV/TNV
(1.1% of second-line)
Median time on regimen
9.85 years (4.09-19.71 IQR)



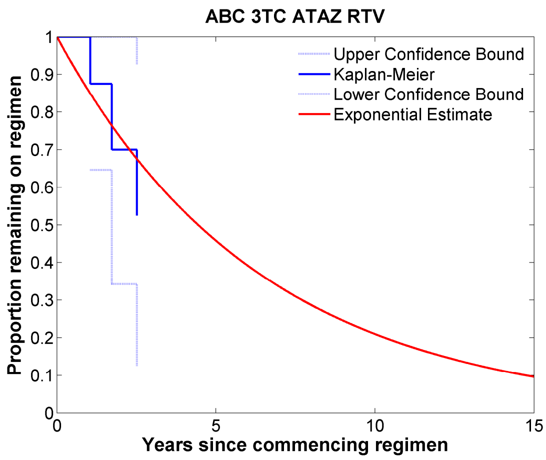
t)

3TC/AZT/KALETRA
(0.9% of second-line)
Median time on regimen
0.95 years (0.4-1.91 IQR)



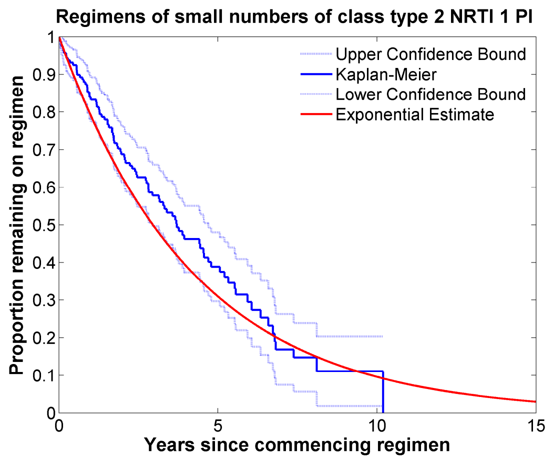
u)

ABC/3TC/ATAZ/RTV
(1% of second-line)
Median time on regimen
4.44 years (1.84-8.87 IQR)



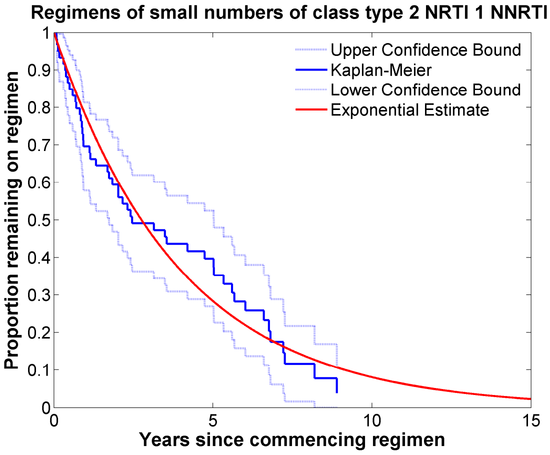
v)

Other regimens: 2 NRTI + 1PI
(14.6% of second-line)
Median time on regimen
2.95 years (1.23-5.9 IQR)



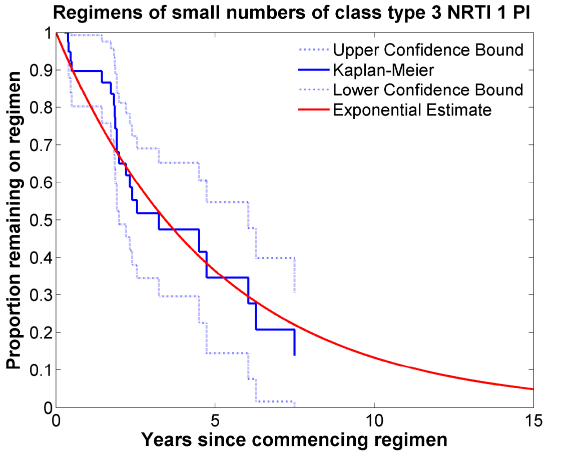
w)

Other regimens: 2 NRTI + 1 NNRT
(5.4% of second-line)
Median time on regimen
2.75 years (1.14-5.5 IQR)



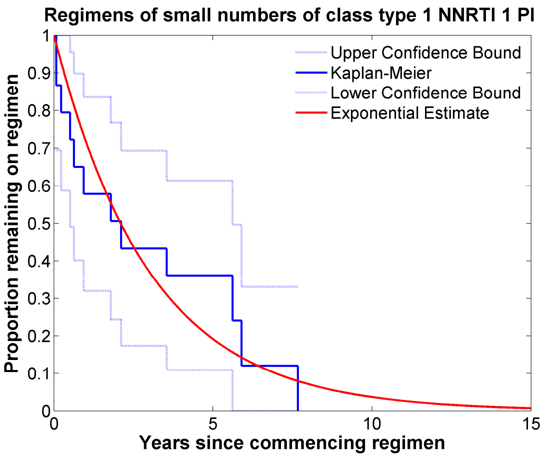
x)

Other regimens: 3 NRTI + 1 PI
(3.6% of second-line)
Median time on regimen
3.43 years (1.43-6.87 IQR)



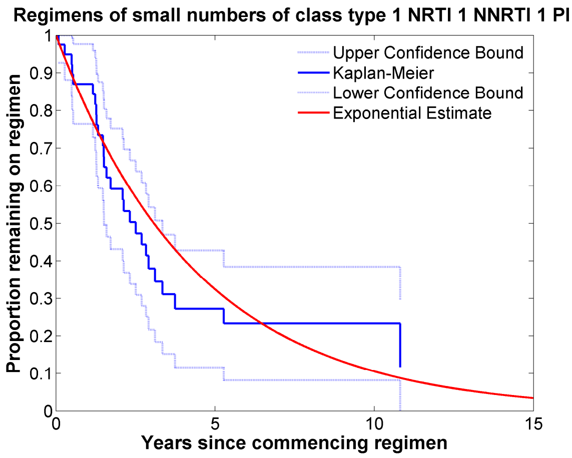
y)

Other regimens: 1 NNRTI + 1 PI
(1.3% of second-line)
Median time on regimen
2.1 years (0.87-4.19 IQR)



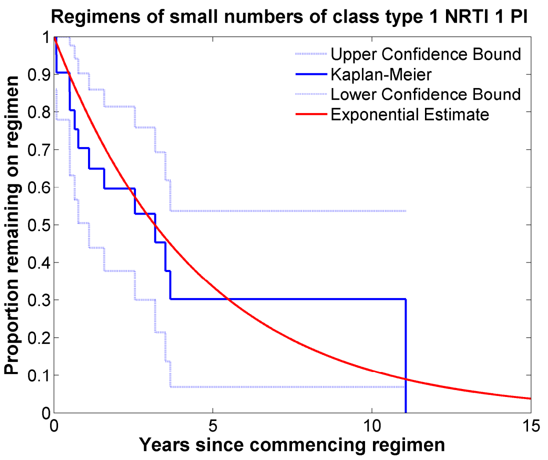
z)

Other regimens: 1 NRTI + 1 NNRTI + 1 PI
(3.6% of second-line)
Median time on regimen
3.08 years (1.28-6.15 IQR)



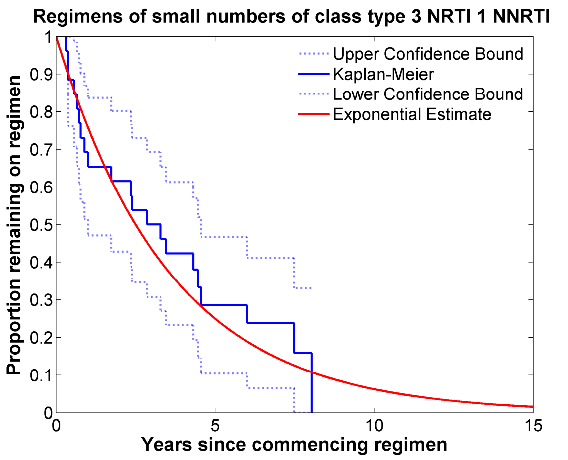
aa)

Other regimens: 1 NRTI + 1 PI
(1.9% of second-line)
Median time on regimen
3.17 years (1.32-6.34 IQR)



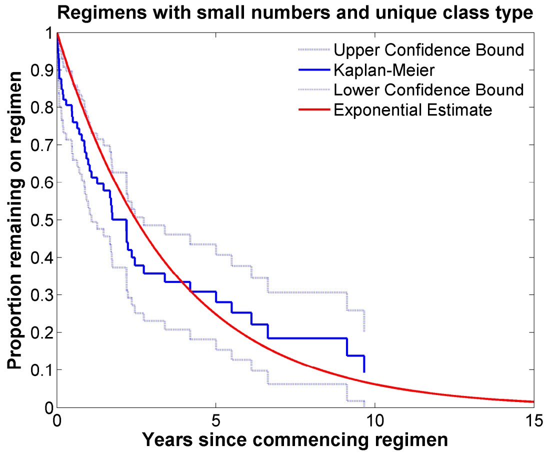
ab)

Other regimens: 3 NRTI + 1 NNRTI
(2.3% of second-line)
Median time on regimen
2.5 years (1.04-4.99 IQR)



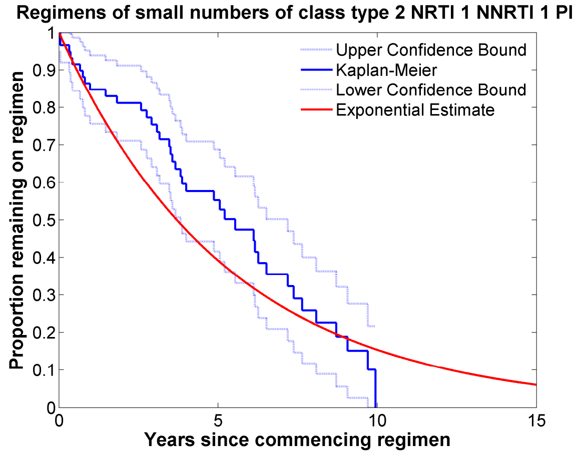
ac)

Other regimens
(6.6% of second-line)
Median time on regimen
2.49 years (1.03-4.97 IQR)



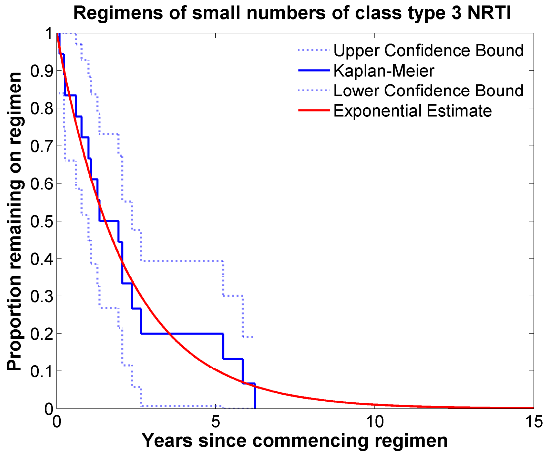
ad)

Other regimens: 2 NNRTI + 1 NRTI + 1 PI
(5.5% of second-line)
Median time on regimen
3.7 years (1.53-7.4 IQR)



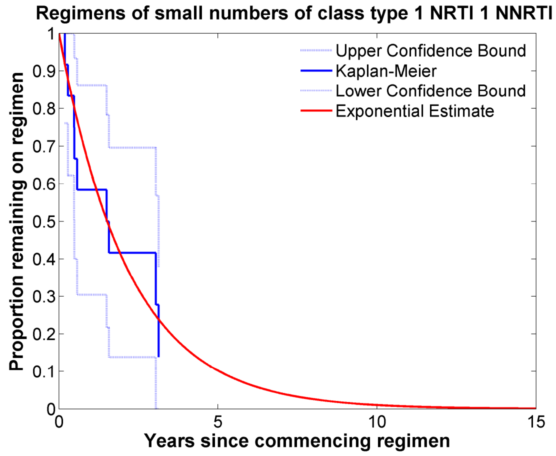
ae)

Other regimens: 3 NRTI
(1.6% of second-line)
Median time on regimen
1.53 years (0.63-3.05 IQR)



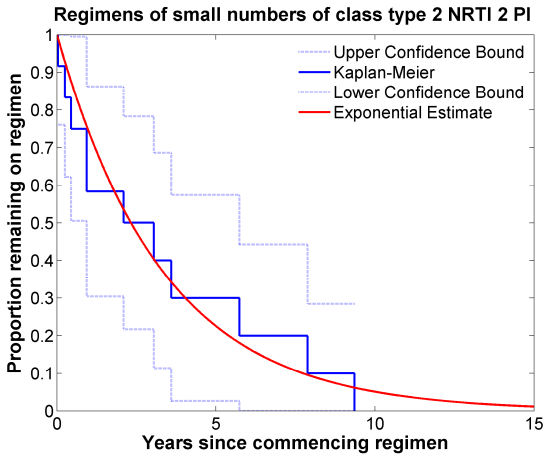
af)

Other regimens: 1 NRTI + 1 NNRTI
(1.1% of second-line)
Median time on regimen 1.52 years (0.63-3.03 IQR)



ag)

Other regimens: 2 NRTI + 2 PI
(1.1% of second-line)
Median time on regimen
2.33 years (0.97-4.65 IQR)



ah)

Other regimens: 2 NRTI
(1.1% of second-line)
Median time on regimen
0.74 years (0.31-1.48 IQR)

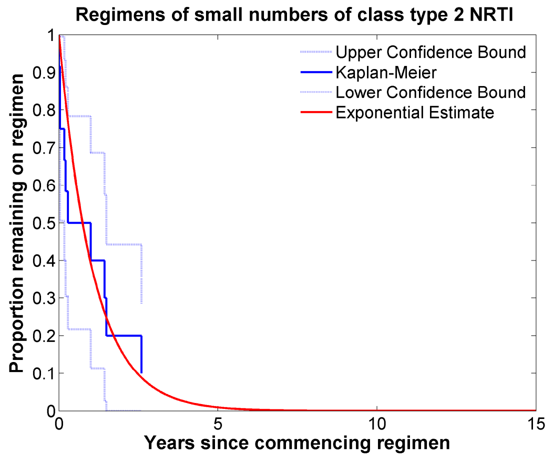
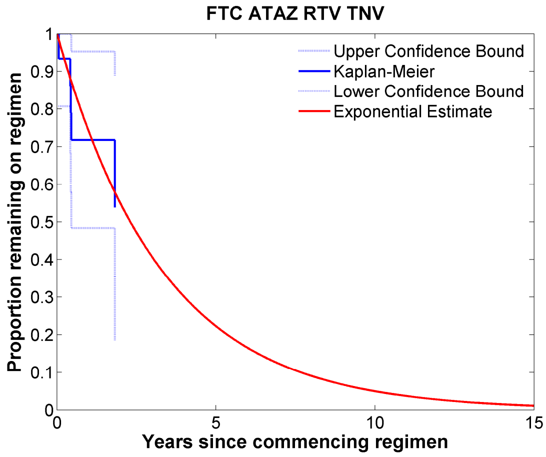


Figure 17: Kaplan-Meier curves and exponential fits for each second-line regimen (recorded in the AHOD cohort).

Rate of stopping third-line regimens

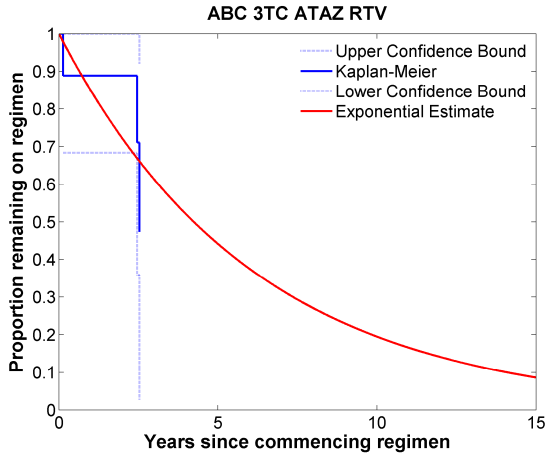
a)

FTC/ATAZ/RTV/TNV
(2.8% of third-line)
Median time on regimen
2.31 years (0.96-4.61 IQR)



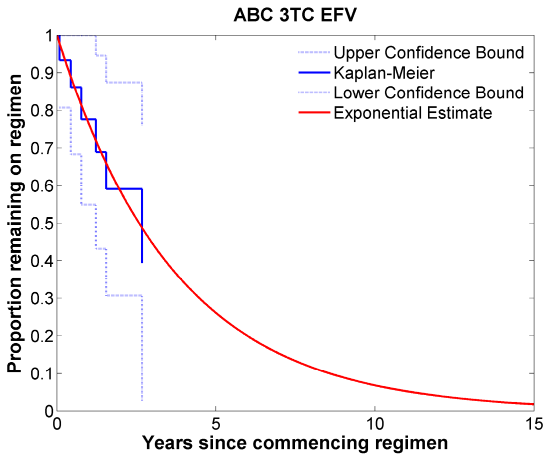
b)

ABC/3TC/ATAZ/RTV
(1.7% of third-line)
Median time on regimen
4.24 years (1.76-8.47 IQR)



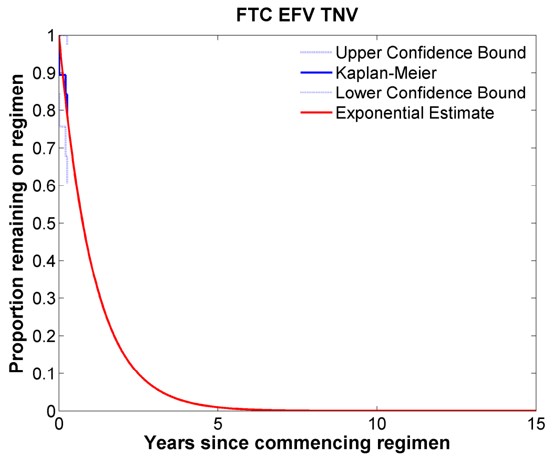
c)

ABC/3TC/EFV
(2.5% of third-line)
Median time on regimen
2.58 years (1.07-5.16 IQR)



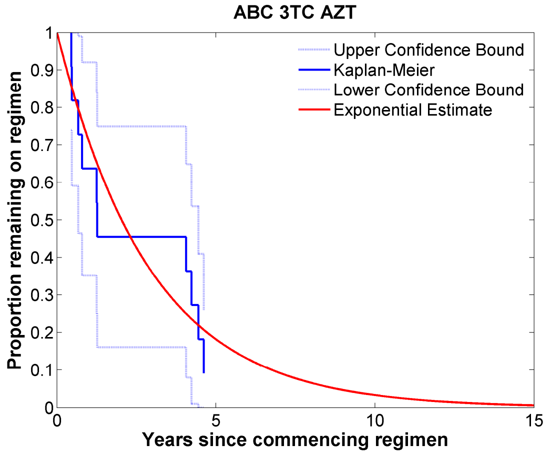
d)

FTC/EFV/TNV
(3.3% of third-line)
Median time on regimen
0.75 years (0.31-1.5 IQR)



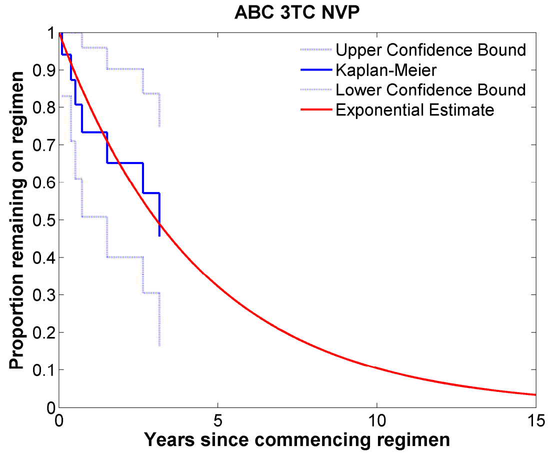
e)

ABC/3TC/AZT
(1.8% of third-line)
Median time on regimen
2.03 years (0.84-4.06 IQR)



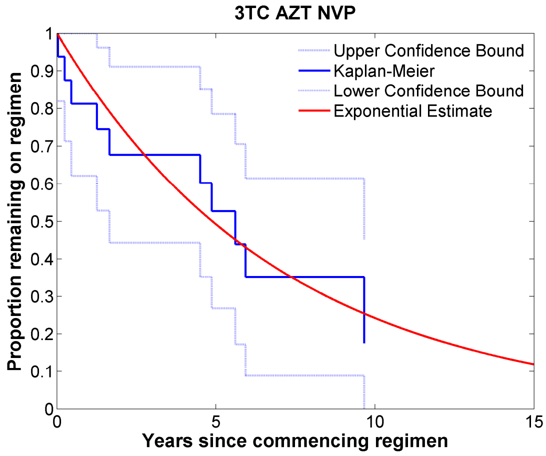
f)

ABC/3TC/NVP
(2.8% of third-line)
Median time on regimen
3.06 years (1.27-6.12 IQR)



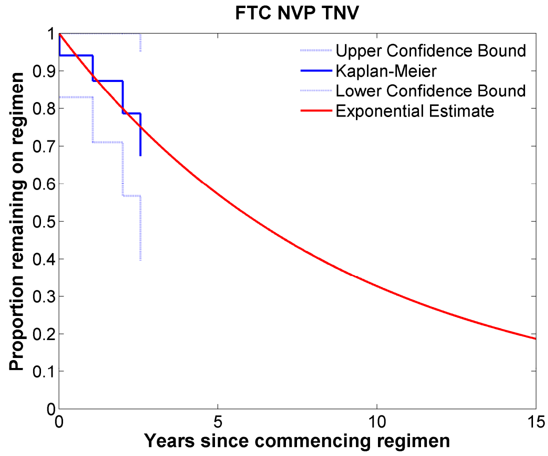
g)

3TC/AZT/NVP
(2.6% of third-line)
Median time on regimen
4.89 years (2.03-9.77 IQR)



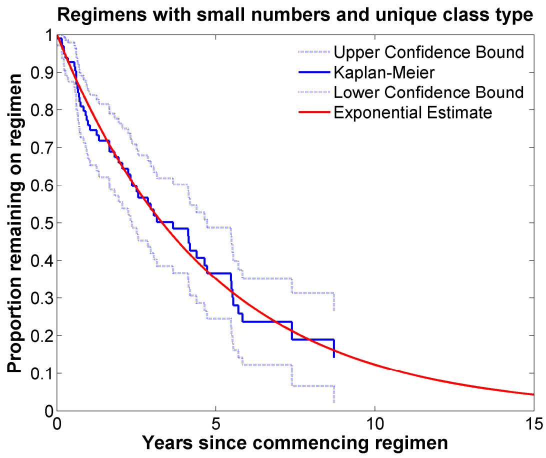
h)

FTC/NVP/TNV
(2.8% of third-line)
Median time on regimen
6.2 years (2.57-12.4 IQR)



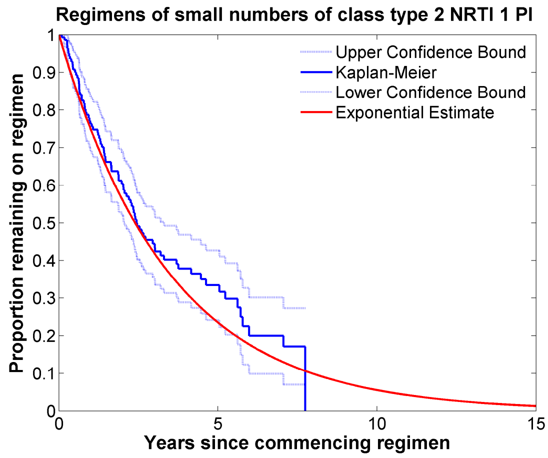
i)

Other regimens
(17.4% of third-line)
Median time on regimen
3.31 years (1.37-6.61 IQR)



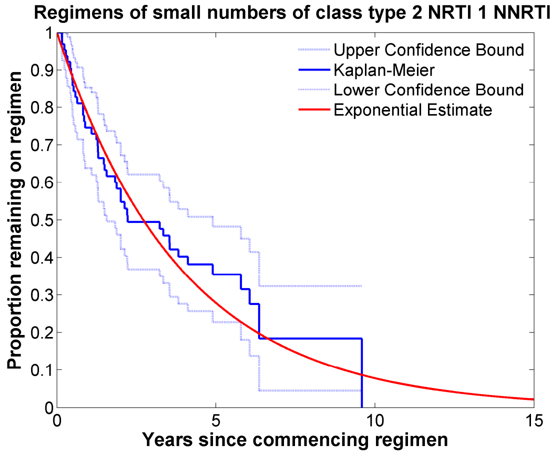
j)

Other regimens: 2 NRTI + 1 PI
(24.2% of third-line)
Median time on regimen
2.39 years (0.99-4.79 IQR)



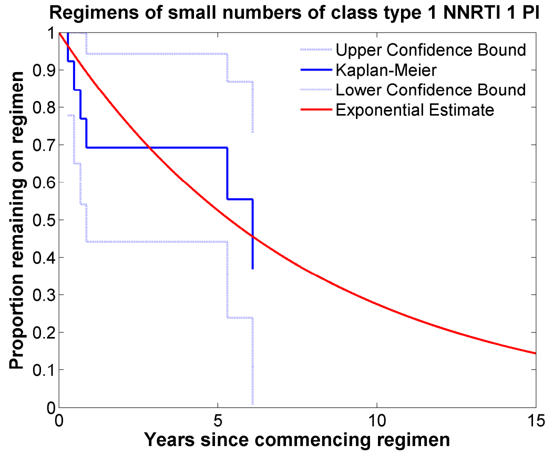
k)

Other regimens: 2 NRTI + 1 NNRTI
(10.9% of third-line)
Median time on regimen
2.71 years (1.12-5.42 IQR)



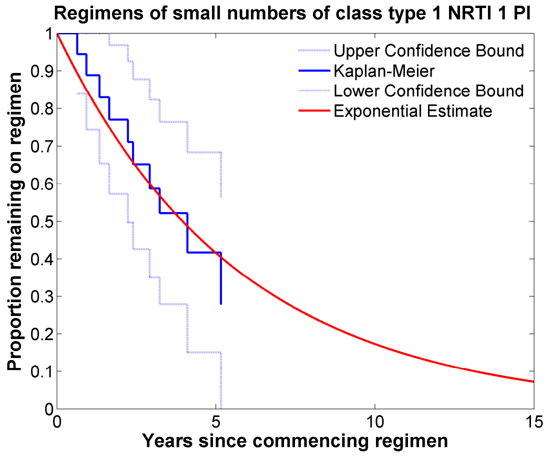
l)

Other regimens: 1 NNRTI + 1 PI
(2.2% of third-line)
Median time on regimen
5.37 years (2.23-10.74 IQR)



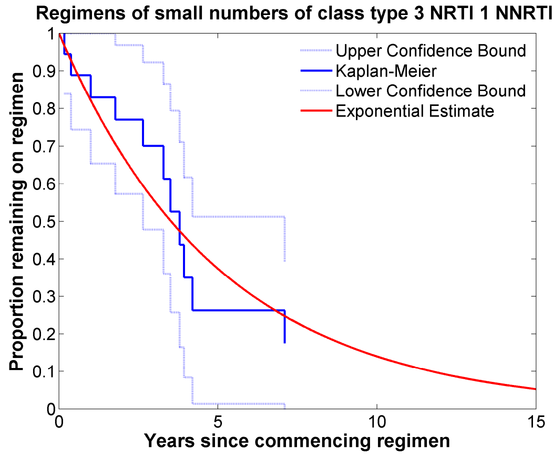
m)

Other regimens: 1 NRTI + 1 PI
(3.1% of third-line)
Median time on regimen
3.95 years (1.64-7.9 IQR)



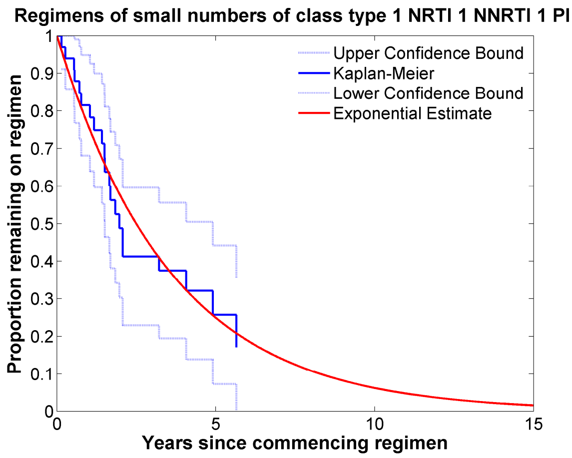
n)

Other regimens: 3 NRTI + 1 NNRTI
(3% of third-line)
Median time on regimen
3.52 years (1.46-7.05 IQR)



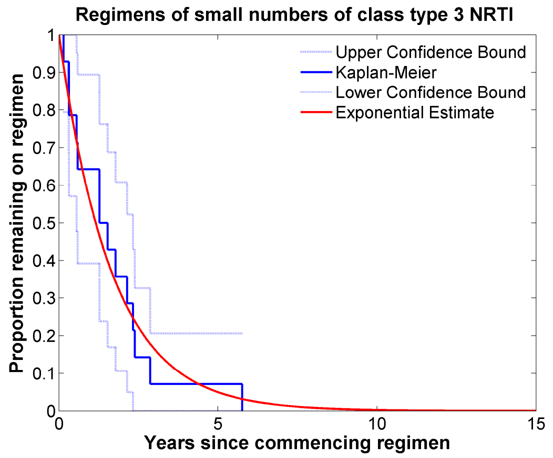
o)

Other regimens: 1 NRTI + 1 NNRTI + 1 PI (5.6% of third-line)
Median time on regimen
2.49 years (1.04-4.99 IQR)



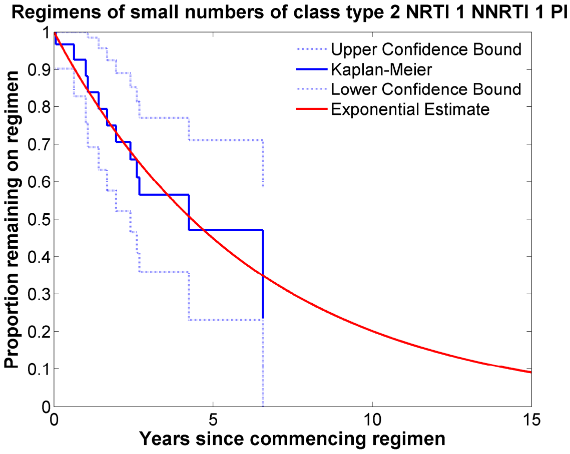
p)

Other regimens: 3 NRTI
(2.3% of third-line)
Median time on regimen
1.15 years (0.48-2.31 IQR)



q)

Other regimens: 2 NRTI + 1 NNRTI + 1 PI
(5% of third-line)
Median time on regimen
4.32 years (1.79-8.65 IQR)



r)

Other regimens: 3 NRTI + 1 PI
(6% of third-line)
Median time on regimen
5.86 years (2.43-11.73 IQR)

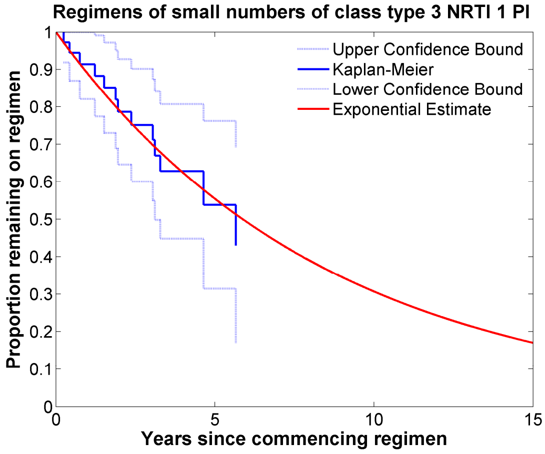
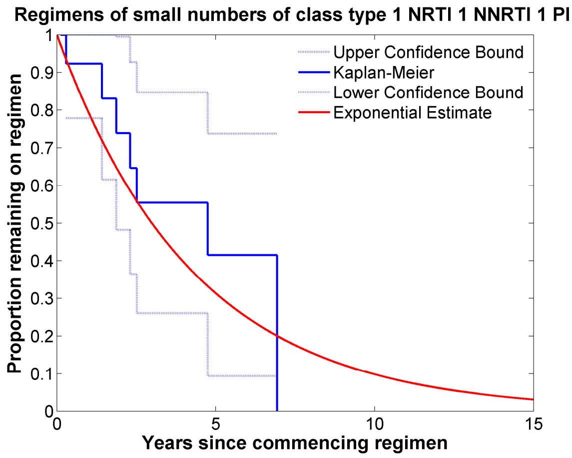


Figure 18: Kaplan-Meier curves and exponential fits for each third-line regimen (recorded in the AHOD cohort).

Rate of stopping fourth-line regimens

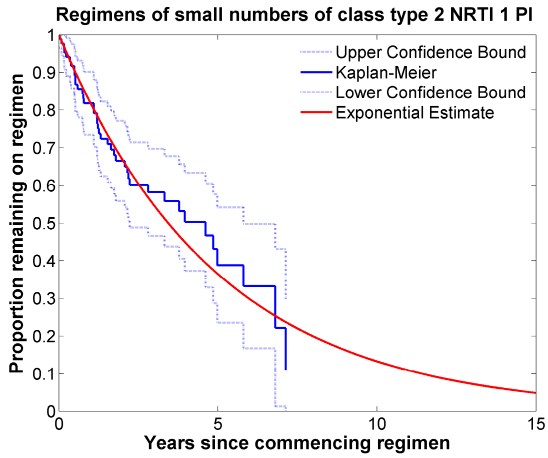
a)

Other regimens: 1 NRTI + 1 NNRTI + 1 PI
(4.8% of fourth-line)
Median time on regimen
2.99 years (1.24-5.97 IQR)



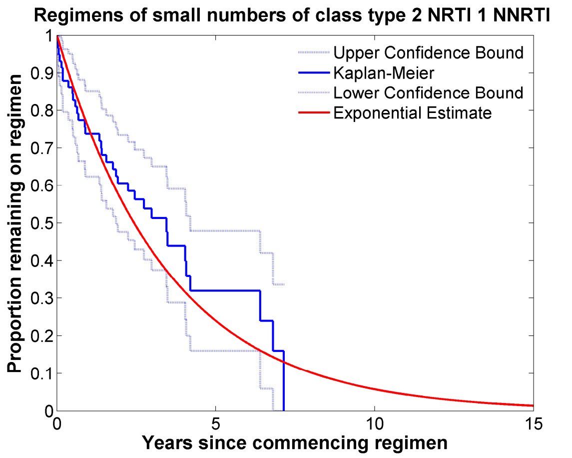
b)

Other regimens: 2 NRTI + 1 PI
(29.8% of fourth-line)
Median time on regimen
3.43 years (1.42-6.87 IQR)



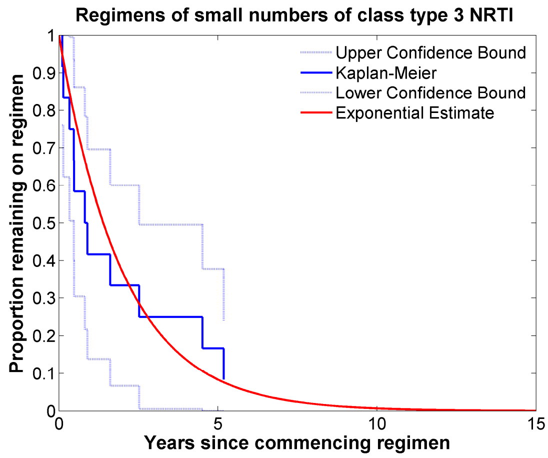
c)

Other regimens: 2 NRTI + 1 NNRTI
(20.1% of fourth-line)
Median time on regimen
2.43 years (1.01-4.85 IQR)



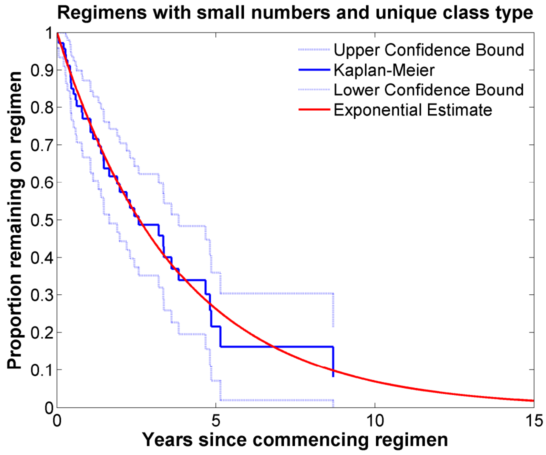
d)

Other regimens: 3 NRTI
(4.2% of fourth-line)
Median time on regimen
1.39 years (0.58-2.78 IQR)



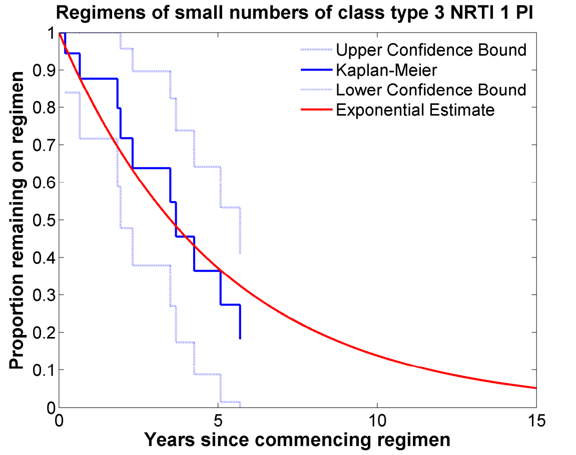
e)

Other regimens
(25.6% of fourth-line)
Median time on regimen
2.59 years (1.07-5.18 IQR)



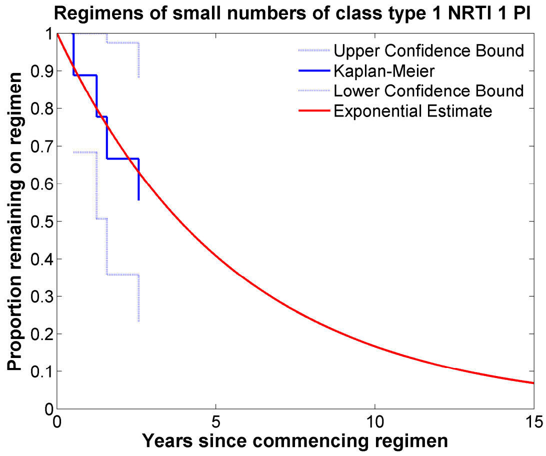
f)

Other regimens: 3 NRTI + 1 PI
(6.6% of fourth-line)
Median time on regimen
3.5 years (1.45-7 IQR)



g)

Other regimens: 1 NRTI + 1 PI
(3.5% of fourth-line)
Median time on regimen
3.87 years (1.61-7.74 IQR)



h)

Other regimens: 2 NRTI + 1 NNRTI + 1 PI
(5.5% of fourth-line)
Median time on regimen
2.5 years (1.04-5 IQR)

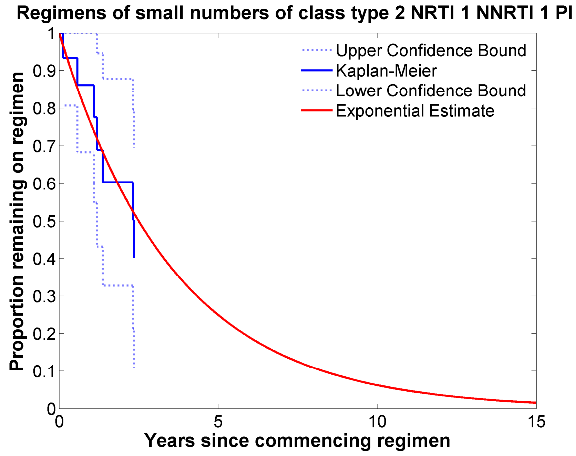


Figure 19: Kaplan-Meier curves and exponential fits for each fourth-line regimen (recorded in the AHOD cohort).

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