Received: 30 October 2016 | Accepted: 30 January 2017

DOI: 10.1111/jvh.12701

ORIGINAL ARTICLE

WILEY JOURNAL OF VIRAL HEPATITIS JVH

Ongoing incident hepatitis C virus infection among people with a history of injecting drug use in an Australian prison setting, 2005-2014: The HITS-p study

E. B. Cunningham[1] | B. Hajarizadeh[1] | N. A. Bretana[1,2] | J. Amin[1] | B. Betz-Stablein[2] | G. J. Dore[1] | F. Luciani[1,2] | S. Teutsch[2] | K. Dolan[3] | A. R. Lloyd[1,2] | J. Grebely[1] | On behalf of the HITS-p investigators

[1]The Kirby Institute, UNSW Sydney, Sydney, NSW, Australia

[2]Inflammation and Infection Research Centre, School of Medical Sciences, UNSW Sydney, Sydney, NSW, Australia

[3]National Drug and Alcohol Research Centre, UNSW Sydney, Sydney, NSW, Australia

Correspondence
Evan Cunningham, Viral Hepatitis Clinical Research Program, The Kirby Institute, UNSW Sydney, Sydney, NSW, Australia.
Email: ecunningham@kirby.unsw.edu.au

Funding information
This work was supported by grants from the National Health and Medical Research Council (NHMRC; Nos. 222887 and 1016351) including NSW Health, the Justice Health & Forensic Mental Health Network, Corrective Services NSW and Hepatitis NSW as partners. Evan Cunningham is supported by a PhD Scholarship from the Canadian Network on Hepatitis C. Gregory J. Dore is supported through National Health and Medical Research Council of Australia Practitioner Fellowship. Andrew R. Lloyd is supported by a NHMRC Practitioner Fellowship (No. 1043067). Jason Grebely is supported by a National Health and Medical Research Council Career Development Fellowship. Behzad Hajarizadeh is supported by a National Health and Medical Research Council Early Career Fellowship

Summary

Hepatitis C virus (HCV) transmission is high in prisons. This study investigated trends in HCV incidence and associated factors among a cohort of prisoners with a history of injecting drug use in New South Wales, Australia. Data were available from the Hepatitis C Incidence and Transmission Study—prisons (HITS-p) from 2005 to 2014. Temporal trends in HCV incidence were evaluated. Factors associated with time to HCV seroconversion among people with ongoing injecting was assessed using Cox proportional hazards. Among 320 antibody-negative participants with a history of injecting drug use (mean age 26; 72% male), 62% (n=197) reported injecting drug use during follow-up. Overall, 93 infections were observed. HCV incidence was 11.4/100 person-years in the overall population and 6.3/100 person-years among the continually imprisoned population. A stable trend in HCV incidence was observed. Among the overall population with ongoing injecting during follow-up, ≥weekly injecting drug use frequency was independently associated with time to HCV seroconversion. Among continuously imprisoned injectors with ongoing injecting during follow-up, needle/syringe sharing was independently associated with time to HCV seroconversion. This study demonstrates that prison is a high-risk environment for acquisition of HCV infection. Needle and syringe sharing was associated with HCV infection among continually imprisoned participants, irrespective of frequency of injecting or the type of drug injected. These findings highlight the need for the evaluation of improved HCV prevention strategies in prison, including needle/syringe programmes and HCV treatment.

KEYWORDS
Australia, hepatitis C Virus, incidence, prison, PWID

Abbreviations: CI, confidence interval; DAA, direct-acting antiviral; HCV, hepatitis C virus; IDU, injecting drug use; NSP, needle-syringe programmes; OST, opioid substitution therapies; PWID, people who inject drugs.

Andrew R. Lloyd and Jason Grebely contributed equally to this work.

The HITS-p investigators are listed in Acknowledgements.

1 | INTRODUCTION

Hepatitis C virus (HCV) is a significant global health burden with 64-103 million people chronically infected worldwide.[1-4] In many countries, the majority of new HCV infections occur among people who

inject drugs (PWID).[5,6] There are close ties between injecting drug use and incarceration as a result of imprisonment for drug-related crimes.[7] Hence, HCV infection is common among the prison population with an estimated 2.2 million detainees being anti-HCV positive worldwide.[8,9] The most effective strategies to prevent HCV transmission in the community setting, including needle-syringe programmes (NSP) and opioid substitution therapies (OST), are commonly unavailable in the prisons.[10] In the emerging era of simple, highly effective direct-acting antiviral (DAA) therapy, there has also been considerable interest in the use of HCV treatment as prevention strategies to reduce the incidence of new infections, including in the prison setting.[11-14] However, better understanding of the incidence of HCV infection in correctional centres as well as empirical evidence of efficacy are needed to recommend each of these programmes for use in the prison setting.

Recent reviews and meta-analyses of HCV prevalence and incidence in the prison setting have provided an estimated incidence of HCV in the global prison population of 1.4 cases per 100 person-years, with a higher incidence of 15.1 cases per 100 person-years among those with a history of injection drug use.[8,9] However, the epidemiological studies conducted to date have been limited by retrospective designs, short follow-up periods, small sample sizes and limited to single institutions.[9,15-20] Given that injecting drug use continues in the prison setting,[21-24] a better understanding of the incidence and detailed risk behaviours associated with HCV infection in prisons is crucial for development of improved prevention strategies.

This study investigated HCV incidence and injecting risk behaviours in the Hepatitis C Incidence and Transmission study—prisons (HITS-p) cohort between 2005 and 2014. The aim was to determine the temporal trends in HCV incidence and associated factors among a cohort of participants followed prospectively between 2005 and 2014 in prisons in New South Wales (NSW), Australia, including detailed analysis of a subcohort of continuously incarcerated participants to reliably attribute events occurring within the prison setting.

2 | METHODS

2.1 | Study design and population

HITS-p was a prospective cohort of prisoners enrolled between 2005 and 2014 in NSW, Australia. Adult male and female inmates were recruited in 23 correctional centres and followed across 30 of 35 centres as described previously.[16]

Participants were enrolled into the HITS-p cohort if they: were currently incarcerated in a NSW prison; had reported a lifetime history of injecting drug use (IDU; enrolled 2005-2009) or a lifetime history of any risk factors for bloodborne virus transmission (IDU, tattooing, piercing, blood fights; enrolled 2012-2014); and had negative anti-HCV status documented prior to recruitment.

Of the participants enrolled in HITS-p, the current analysis included participants who were: HCV RNA-negative and antibody-negative at enrolment, were 18 years or older, provided written informed consent and completed at least one prospective follow-up visit after enrolment while in prison (having either been continuously incarcerated or upon re-imprisonment after a period of release to freedom). Due to a change in study inclusion criteria in 2009 to include those without a specific history of IDU, participants were included in this analysis only if they had reported a lifetime history of IDU. Participants were excluded from this analysis if they were: anti-HCV or HCV RNA positive at enrolment, released to freedom before follow-up or withdrew before follow-up.

2.2 | ETHICAL APPROVAL

The study was approved by the Human Research Ethics Committees of Corrective Services New South Wales (no. 05/0884) and of Justice Health (no. GEN 31/05).

2.3 | Study assessments

At enrolment (baseline), participants were interviewed using a previously validated schedule[16] to record demographic characteristics, injecting behaviour, history of physical assaults or injuries, tattooing and body piercing—before and during the current imprisonment. Participants completed structured follow-up interviews at 6- to 12-month intervals thereafter while in prison, to ascertain risk factors for HCV transmission, as well as receipt of OST and use of bleach [or the quaternary amine disinfectant, Fincol (Jasol, North Ryde, NSW, Australia)] to cleanse injecting equipment. Follow-up interviews and blood collection were performed by a research nurse, whose employment was independent of the custodial authority. The interview questions avoided disclosure of specific details of individual injecting or risk behaviour events (as such events may constitute criminal behaviour necessitating reporting to authorities).

Participation was voluntary, and all participants provided written informed consent. Participants received payment (AUD $10) following each visit through the approved prison inmate banking system to compensate for their time and effort in completing research interviews and providing blood samples.

2.4 | Hepatitis C virus serological and virological testing

A venous blood sample was collected at each interview to screen for HCV antibodies and RNA, as described previously.[16] HCV test results were reported back to participants by the research nurse in association with post-test counselling. Referral to hepatitis clinical services was offered to incident cases, where antiviral treatment for HCV was offered if appropriate.

2.5 | Outcome

The primary study outcome was HCV seroconversion (defined by an HCV-antibody-negative test at enrolment followed by an HCV-antibody-positive test). The estimated date of HCV seroconversion was calculated as the mid-point between the first positive HCV antibody test and the previous negative HCV antibody test.

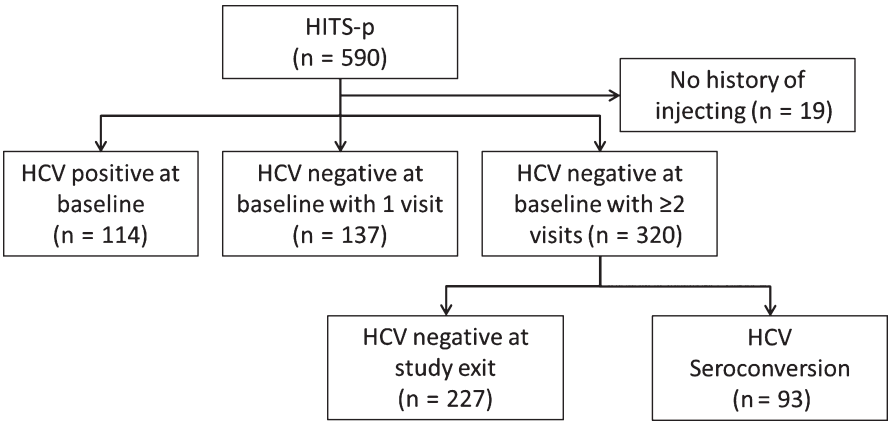

FIGURE 1 Participant disposition [Correction added on 02 June 2017, after first online publication: Figure 1 has been revised and is now corrected in this version.]

2.6 | Statistical analyses

The first aim was to evaluate trends in HCV incidence over the study period. Three time periods were chosen (2006-2008, 2009-2010 and 2011-2013) to reflect study recruitment periods and to ensure sufficient follow-up time within each time period. HCV incidence density and confidence intervals were calculated using the person-years method among: (i) the overall study population; and (ii) among those who were continuously imprisoned during the follow-up period (so that follow-up and incident HCV infections could be reliably attributed to time spent in prison). Further analyses evaluated HCV incidence density among people with ongoing injecting during follow-up. Trends in HCV incidence density were assessed by calendar period (2006-2008, 2009-2010 and 2011-2013). Individual follow-up times were truncated at 5 years to minimize the effect of depletion of the susceptible population.

The second aim was to evaluate factors associated with time to HCV seroconversion among those with ongoing injecting drug use during follow-up (since the previous visit). The primary independent predictors included frequency of injecting (none, <weekly, ≥weekly) and needle/syringe sharing (yes, no). Cox proportional hazards analysis was used to identify covariates associated with time to HCV seroconversion. Separate analyses were performed among the overall study population (participants continually in prison and those who were released and re-incarcerated) and the continuously imprisoned population, allowing for time-dependent variation in injecting behaviours during follow-up.

Hypothesized covariates associated with time to HCV infection included: age (per 10 years older); sex (male vs female); education (defined as >10 years schooling; yes vs no); current OST, recent methamphetamine injecting, recent cocaine injecting, recent heroin injecting, recent buprenorphine/methadone injecting, recent injecting of other opioids and bleach cleansing of injecting equipment (always vs less than always). Methamphetamine injecting included both methamphetamine and amphetamine injection. For all injecting drug use variables, recent was defined as since last visit. All exposures were measured at baseline and repeatedly during follow-up and were treated as time-dependent variables in all models, except sex and education. Due to the collinearity of current OST and injecting methadone/buprenorphine, only current OST was included in the final adjusted models.

All statistically significant differences were assessed at $P<.05$; P values are two-sided. All analyses were performed using the statistical package Stata v13.1 (College Station, TX, USA).

3 | RESULTS

3.1 | Participant characteristics

In total, 590 participants were enrolled in HITS-p (Figure 1). Of the 590 participants, 19% (n=114) were anti-HCV or HCV RNA positive at baseline. Of those participants who were anti-HCV negative at baseline (n=476), 137 participants had only one interview at enrolment. The remaining 320 participants were eligible for analyses evaluating trends in HCV incidence. Compared to those with no follow-up interviews, those with >1 follow-up visit and included in the analysis were more likely to be male, to have ever injected heroin and to have injected drugs since entering prison (Table S1).

The baseline characteristics for participants included in this analysis are presented in Table 1. The majority of participants (72%) were male with a median age of 26 years. One hundred and four participants (33%) reported IDU since entering prison, among whom 81 participants (78%) reported sharing of needles and syringes (Table 1).

Of the 320 participants included in the overall population, 211 participants were included in the continuously imprisoned analysis. Compared to those who were not continuously imprisoned, those who were continuously imprisoned were less likely to have ever injected methamphetamines (Table S2).

3.2 | Trends in HCV incidence density

Among the 320 at-risk participants in the overall population, 93 HCV seroconversions were observed between 2005 and 2014. HCV incidence was 11.4/100 person-years [95% confidence interval (95% CI): 9.3-14.0] over a total follow-up time of 815 person-years. The median (quartile, Q1-Q3) number of study visits per participant was 3 (2-5) and median follow-up was 2.3 years (1.0-4.1 years). Among participants who reported injecting during follow-up (n=197), HCV incidence was 17.1/100 person-years (95% CI: 13.6-21.5) over a total follow-up time of 433 person-years.

TABLE 1 Characteristics of anti-HCV and HCV RNA-negative individuals enrolled in the HITS-p cohort between 2005 and 2014 with at least two study visits (n=320)

Characteristic, n (%)	Overall, n (%) (n=320)
Age, y; median (Q1-Q3)[a]	26 (22-32)
Female sex	91 (28)
Aboriginal identity	79 (25)
>10 y of schooling	76 (24)
Years since initiating IDU[a], median (Q1-Q3)	7 (4-12)
Injecting drug use ever[a]	320 (100)
Heroin	206 (64)
Cocaine	143 (45)
Methamphetamine	268 (84)
Any sharing of injection equipment ever[a]	208 (65)
Recent injecting drug use[b]	104 (33)
Heroin	58 (18)
Cocaine	13 (4)
Methamphetamine	44 (14)
Recent IDU frequency[b]	
Never	215 (67)
<Weekly	65 (20)
≥Weekly	35 (11)
Any recent sharing of needle and syringe[b]	81 (25)
Current opioid substitution treatment[a]	49 (15)
Max. sentence length; months; median (Q1-Q3)	18 (10-60)

IDU, Injecting drug use.
[a]At baseline.
[b]Since entering prison.

Among participants who were continuously imprisoned (n=211), 32 HCV seroconversions were observed between 2005 and 2014. HCV incidence was 6.3/100 person-years (95% CI: 4.5-8.9) in the continuously imprisoned population over a total follow-up time of 507 person-years. The median number of study visits per participant was 3 (2-5) and median follow-up was 2.0 years (0.9-4.0 years). Among participants who reported injecting during follow-up (n=99), HCV incidence was 10.0/100 person-years (95% CI: 6.6-15.1) over a total follow-up time of 221 person-years.

Between 2006 and 2013, HCV incidence in the overall population remained constant (Figure 2A). HCV incidence was 12.1/100 person-years (95% CI: 8.9-16.4) in 2006-2008, 9.7/100 person-years (95% CI: 6.8-13.9) in 2009-2010 and 13.1/100 person-years (95% CI: 8.6-20.0) in 2011-2013.

Between 2006 and 2013, HCV incidence among those continuously in prison also remained constant, but was lower than in the overall population (Figure 2B). HCV incidence was 6.7/100 person-years (95% CI: 3.9-11.3) in 2006-2008, 4.6/100 person-years (95% CI: 2.4-8.8) in 2009-2010 and 8.9/100 person-years (95% CI: 4.6-17.2) in 2011-2013.

3.3 | Factors associated with HCV seroconversion in those with ongoing injecting drug use

Factors associated with time to HCV seroconversion were assessed among those with ongoing injecting drug use during follow-up. In unadjusted Cox proportional analysis, current OST, heroin injecting, injecting ≥weekly and needle/syringe sharing were associated with time to HCV infection (Table 2 and Table S3). Using bleach to clean the injecting device was not associated with reduced time to HCV infection (Table 2). In Kaplan-Meier analyses, those injecting ≥weekly had a shorter time to HCV seroconversion compared to those injecting <weekly (Figure 3).

In adjusted Cox proportional hazard analyses, ≥weekly injecting drug use frequency was independently associated with time to HCV seroconversion, after adjusting for all other

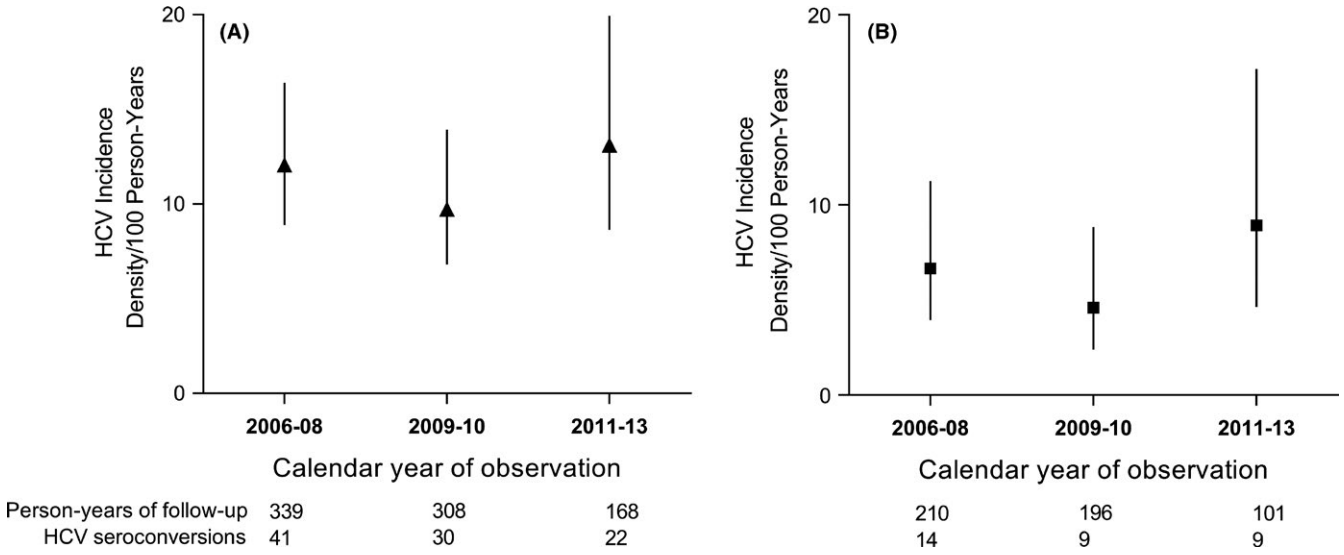

FIGURE 2 Incidence density of HCV infection among participants in the HITS-p cohort by year of study enrolment in: A, the overall population and B, those participants continually in prison during follow-up

TABLE 2 Unadjusted and adjusted Cox proportional hazard analyses of factors associated with time to HCV seroconversion among all participants who reported injecting since the previous visit in the HITS-p cohort between 2005 and 2014 who were included in this study (n=197)

Variable	HR	95% CI	*P*	AHR	95% CI	*P*
Age (10 y increments)	0.66	0.43-1.03	.066	0.68	0.43-1.09	.110
Female sex	1.33	0.82-2.16	.246	1.43	0.86-2.40	.171
≤10 y of schooling	1.10	0.54-2.22	.794	1.07	0.52-2.22	.848
Current OST[b]	1.85	1.13-3.01	.014	1.27	0.74-2.20	.386
Methamphetamine injecting[a]	0.86	0.52-1.42	.548	0.90	0.51-1.57	.701
Cocaine injecting[a]	1.25	0.73-2.13	.410	0.92	0.52-1.62	.768
Heroin injecting[a]	2.29	1.43-3.67	.001	1.70	0.98-2.94	.059
Buprenorphine/methadone injecting[a]	1.22	0.69-2.17	.494	Not included		
Other opiate injecting[a]	1.13	0.61-2.07	.702	0.71	0.37-1.37	.309
Frequency of injecting[a] (≥weekly vs <weekly)	3.08	1.67-5.72	<.001	2.79	1.46-5.36	.002
Syringe sharing[a]	1.35	0.85-2.13	.200	1.23	0.74-2.20	.419
Bleach to clean injecting device[a,c] (always vs <always)[a,c]	0.83	0.43-1.61	.586	Not included		

[a]Since last visit.
[b]At time of interview.
[c]Among those who reported sharing injecting equipment.

covariates, including current OST and needle/syringe sharing (Table 2).

3.4 | Factors associated with HCV seroconversion in those with ongoing injecting drug use and continuously in prison

Factors associated with time to HCV seroconversion were assessed among those with ongoing injecting drug use during follow-up for the population continuously in prison (Table 3 and Table S4). In unadjusted Cox proportional analysis, recent buprenorphine/methadone injecting, injecting ≥weekly and needle/syringe sharing were associated with time to HCV infection (Table 3). Using bleach to clean the injecting device was not associated with reduced time to HCV infection (Table 3). In Kaplan-Meier analyses, those with ≥weekly injecting drug use frequency (Figure 3) had a similar time to HCV seroconversion compared to those injecting <weekly, while those who reported syringe sharing had a significantly shorter time to HCV seroconversion.

In adjusted Cox proportional hazard analyses, needle/syringe sharing was independently associated with time to HCV seroconversion, after adjusting for all other covariates, including current OST and ≥weekly injecting drug use frequency (Table 3).

4 | DISCUSSION

This study investigated the incidence of HCV infection among a cohort of PWID in the NSW prison setting between 2005 and 2014. Ongoing incident HCV infection was observed over the study period in both the overall population, including those who had time spent outside of prison, and the continually imprisoned population. However, the incidence of infection in the continually imprisoned population was somewhat lower than that of the overall population.

The incidence of HCV infection reported among the overall population was 11.4/100 person-years, while the incidence was lower among those who were continually imprisoned at 6.3/100 person-year. Both results are lower, but within the confidence intervals of the previous report of the incidence of HCV infection in the HITS-p cohort.[16,25] The incidence is also within the confidence intervals of the estimate 7.9/100 person-years (4.9-12.7) reported in a community-based cohort of PWID at risk of HCV (HITS-c), which ran between 2008 and 2011 in Sydney, NSW.[26] The incidence among the continually imprisoned population reported here is similar to other studies of HCV incidence in prison PWID populations.[9,17,18,20,27,28] The higher incidence observed among the overall population may be explained by a higher incidence in the period immediately following release from prison. This period has been demonstrated to be one of particularly high risk among PWID.[9,29,30] Alternatively, this could be explained by different risk behaviours between those with and without continuous imprisonment (e.g those without continuous imprisonment were more likely to have ever injected methamphetamine). The trend in the incidence of HCV infection over the study period was stable. Given the paucity of observational cohorts evaluating HCV incidence among PWID in the prison setting, in particular studies comparing those continuously imprisoned to those released and reimprisoned, these data are novel. The substantial incidence further highlights the need for improved prevention strategies to reduce the incidence of HCV infection in the Australian prison setting.

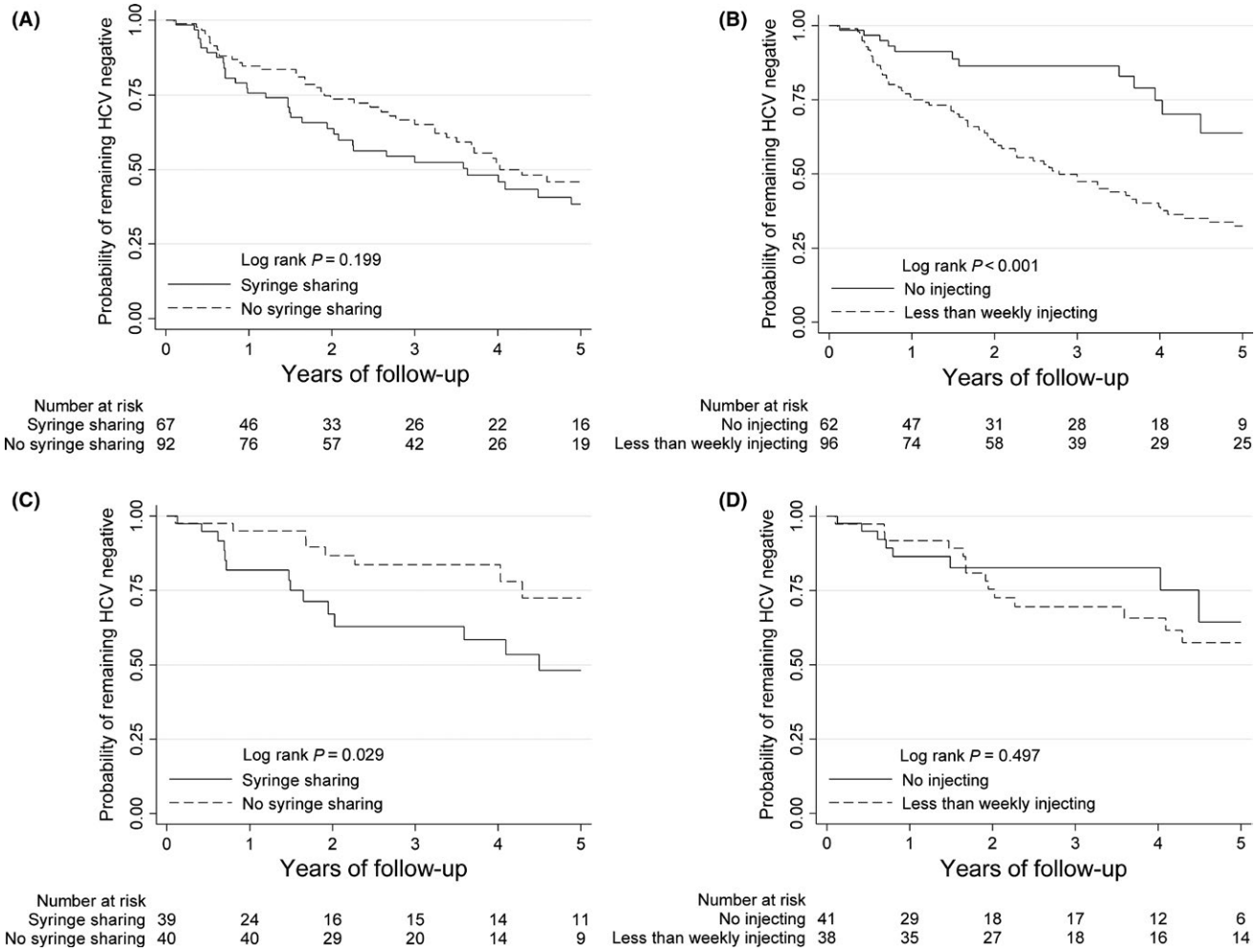

FIGURE 3 Kaplan-Meier graphs of time to HCV seroconversion among injectors in the overall study population (panels A and B) stratified by syringe sharing (A) and injecting frequency (B); and among injectors in the continuously imprisoned population (panels C and D) stratified by syringe sharing (C) and injecting frequency (D)

Among people with ongoing injecting drug use during follow-up in the overall population, ≥weekly injecting drug use frequency was independently associated with time to HCV seroconversion. When restricted to the continually imprisoned population, only needle/syringe sharing was independently associated with time to HCV seroconversion. These data suggest that among injectors who are continuously imprisoned, any needle and syringe sharing (irrespective of a lower frequency of injecting) is associated with a high risk of HCV acquisition. This likely reflects high rates of sharing in the prison setting due to the scarcity of sterile injecting equipment in Australian prisons, resulting in each individual injecting event carrying a higher risk of HCV infection.[31,32] The data suggests that this scarcity of sterile injecting equipment is compounded by the fact that many people in the prison inject methadone/buprenorphine (either prescribed or nonprescribed) necessitating high rates of sharing among this population. This finding that HCV transmission is associated with sharing of needles/syringes in the prison setting is consistent with findings from other studies in prison populations.[23,33] A previous analysis of data from HITS-p estimated the per-event probability of transmission associated with injecting drug use and sharing as 0.57% (CI: 0.32%-1.05%) and a sensitivity analysis varying the presumed prevalence of the virus in injecting equipment revealed the transmission risk to range up to 6%.[34]

It is of note that in adjusted analyses, current OST was not associated with reduced time to HCV seroconversion in either the overall population or the continuously imprisoned population. These findings contrast with data from a cohort of PWID in the community in NSW (HITS-c), which demonstrated a lower HCV incidence among people receiving OST.[26] Data from other international studies has demonstrated that provision of OST to PWID in the community can reduce HCV transmission.[26,35-38] That being said, previous prison-based studies have demonstrated that the initiation of OST in prison can result in a reduction in injecting drug use and needle and syringe sharing, provided that OST dosing is both timely and adequate.[10,39,40] These contrasting results may be explained, at least in part, by OST serving as a surrogate marker for high-risk behaviours such as injecting drug use and syringe sharing in prison as previous studies have shown that those who reported being on OST therapy were more likely to exhibit high-risk behaviours.[41,42] A recent modelling study of scale up of OST and NSP in Scottish prisons demonstrated that the greatest reduction in HCV incidence was achieved through a combination of both high

TABLE 3 Unadjusted and adjusted Cox proportional hazard analyses of factors associated with time to HCV seroconversion among all continuously imprisoned participants who reported injecting since the previous visit in the HITS-p cohort between 2005 and 2014 who were included in this study (n=99)

Variable	HR	95% CI	*P*	AHR	95% CI	*P*
Age (10 y increments)	0.89	0.43-1.82	.749	0.85	0.43-1.65	.623
Female sex	0.45	0.13-1.54	.205	0.48	0.13-1.80	.276
≤10 y of schooling	0.86	0.30-2.72	.859	0.67	0.21-2.16	.500
Current OST[b]	1.21	0.44-3.29	.709	1.32	0.43-4.10	.627
Methamphetamine injecting[a]	0.61	0.26-1.43	.253	0.78	0.31-1.99	.609
Cocaine injecting[a]	0.64	0.19-2.17	.477	0.64	0.17-2.42	.512
Heroin injecting[a]	1.61	0.69-3.78	.275	1.25	0.49-3.18	.644
Buprenorphine/methadone injecting[a]	4.25	1.83-9.86	.001	Not included		
Other opiate injecting[a]	0.68	0.20-2.32	.535	0.33	0.08-1.37	.126
Frequency of injecting[a] (≥weekly vs <weekly)	1.35	0.56-3.24	.498	1.82	0.70-4.74	.222
Syringe sharing[a]	2.56	1.07-6.12	.035	2.63	1.03-6.74	.043
Bleach to clean injecting device[ac] (always vs <always)[ac]	0.93	0.29-2.97	.897	Not included		

[a]Since last visit.
[b]At time of interview.
[c]Among those who reported sharing injecting equipment.

coverage of OST and NSP.[43] These results suggest the need for scale up of OST beyond the 15% demonstrated in this study and the implementation of high-coverage NSP in the Australian prison setting.

With regard to bleach cleansing, it is noteworthy that among injectors, no association with reduced HCV incidence was found in those who reported "always" using bleach to clean injecting equipment. A qualitative analysis of within-prison incident infection episodes in HITS-p revealed the substantial challenges in negotiating HCV transmission risk among PWID in prison.[44] In this study, individuals believed that despite the high prevalence of HCV in the prison setting, they were sharing syringes with others who were uninfected, and one subject reported that he may have acquired HCV as a result of using a syringe preloaded with drugs that was given to him in return for lending a syringe to another inmate. Some participants also described cleaning equipment with water alone, rather than with bleach. In combination, these data suggest that the primary focus for prevention within prisons should be integrated strategies to: reduce injecting drug use, including via OST; reduce sharing via needle and syringe programmes; and to reduce the probability of transmission associated with sharing via HCV treatment as prevention approaches, which should lower the prevalence of HCV viremia in the prison setting provided adequate scale up of antiviral therapy is achieved.[45,46]

There are some limitations of this study. Although steps were taken to avoid bias in the surveys using a research nurse whose employment was independent of the custodial authority, there remains a possibility of reporting bias which may have impacted the responses to survey questions. The study design, in which there were two distinct recruitment periods with an intervening period of ongoing follow-up without recruitment, had the potential to result in a depletion of the susceptible population over time. This was addressed by truncating the follow-up time of participants to 5 years poststudy entry. Finally, given the design of the study, which focused only on prisons in NSW, and the inability to compare those who did not participate to those who did, results are not necessarily generalizable to the general prison population in NSW or other prison populations nationally, particularly in areas with differing prevention strategies available inside and outside of prison. Irrespective of these limitations, HITS-p is the only prospective prison-based study to evaluate trends in HCV incidence and provides valuable insights into the prevention needs in this setting.

This study demonstrates that HCV infection among PWID in prison in Australia has remained high and stable during the period of 2005-2014. While the incidence of HCV infection was lower among those who were continually imprisoned, the trend was similar to the overall population, showing neither an increase nor a decrease in the incidence of infection over the study period. This study demonstrates that the prison is a high-risk environment for acquisition of HCV infection, given that needle and syringe sharing was associated with HCV infection among continually imprisoned participants, irrespective of frequency of injecting or the type of drug injected. These data suggest that due to the scarcity of clean injecting equipment in the prison setting, each individual injecting event carries with it a higher chance of HCV infection. As a result, even people with a lower frequency of injecting drug use in the prison environment have a high risk of infection per injection event. Given the provision of methadone/buprenorphine within Australian prisons without adequate access to sterile injecting equipment, this population has a higher risk of HCV infection in the prison setting. Further studies are needed to understand the risk behaviours of PWID in the prison setting and further evaluation of NSP programmes in prisons as a strategy to reduce HCV transmission in this setting.

ACKNOWLEDGEMENTS

The HITS-p investigators include Andrew Lloyd, Kate Dolan, Paul Haber, William Rawlinson, Carla Treloar, Greg Dore, Lisa Maher, and Fabio Luciani.

CONFLICT OF INTERESTS

Gregory Dore is a consultant/advisor and has received research grants from AbbVie, Abbot Diagnostics, Bristol-Myers Squibb, Cepheid, Gilead, GlaxoSmithKline, Merck, Janssen and Roche. Jason Grebely is a consultant/advisor and has received research grants from AbbVie, Bristol-Myers Squibb, Cepheid, Gilead Sciences and Merck/MSD. Andrew Lloyd is a consultant/advisor and has received research grants from Bristol-Myers Squibb, Gilead and Merck.

REFERENCES

1. Hajarizadeh B, Grebely J, Dore GJ. Epidemiology and natural history of HCV infection. *Nat Rev Gastroenterol Hepatol*. 2013;10:553-562.
2. Hatzakis A, Chulanov V, Gadano AC, Bergin C, Ben-Ari Z, Mossong J, et al. The present and future disease burden of hepatitis C virus (HCV) infections with today's treatment paradigm - volume 2. *J Viral Hepat*. 2015;22(Suppl 1):26-45.
3. Saraswat V, Norris S, de Knegt RJ, Sanchez Avila JF, Sonderup M, Zuckerman E, et al. Historical epidemiology of hepatitis C virus (HCV) in select countries - volume 2. *J Viral Hepat*. 2015;22(Suppl 1):6-25.
4. The Polaris Observatory HCV Collaborators. Global prevalence and genotype distribution of hepatitis C virus infection in 2015: a modelling study. *The Lancet Gastroenterology & Hepatology*. 2017;2(3):161–176.
5. Lavanchy D. The global burden of hepatitis C. *Liver Int*. 2009;29:74-81.
6. Nelson PK, Mathers BM, Cowie B, Hagan H, Des Jarlais D, Horyniak D, et al. Global epidemiology of hepatitis B and hepatitis C in people who inject drugs: results of systematic reviews. *The Lancet*. 2011;378:571-583.
7. Levy MH, Treloar C, McDonald RM, Booker N. Prisons, hepatitis C and harm minimisation. *Med J Aust*. 2007;186:647-649.
8. Larney S, Kopinski H, Beckwith CG, Zaller ND, Jarlais DD, Hagan H, et al. Incidence and prevalence of hepatitis C in prisons and other closed settings: results of a systematic review and meta-analysis. *Hepatology*. 2013;58:1215-1224.
9. Dolan K, Wirtz AL, Moazen B, Ndeffo-mbah M, Galvani A, Kinner SA, et al. Global burden of HIV, viral hepatitis, and tuberculosis in prisoners and detainees. *Lancet*. 2016;388:1089-1102.
10. Kamarulzaman A, Reid SE, Schwitters A, Wiessing L, El-Bassel N, Dolan K, et al. Prevention of transmission of HIV, hepatitis B virus, hepatitis C virus, and tuberculosis in prisoners. *Lancet*. 2016;388:1115-1126.
11. Harris RJ, Martin NK, Rand E, Mandal S, Mutimer D, Vickerman P, et al. New treatments for hepatitis C virus (HCV): scope for preventing liver disease and HCV transmission in England. *J Viral Hepat*. 2016;23:631-643.
12. Hickman M, De Angelis D, Vickerman P, Hutchinson S, Martin N. HCV treatment as prevention in people who inject drugs – testing the evidence. *Curr Opin Infect Dis*. 2015;28:576-582.
13. Martin NK, Vickerman P, Goldberg D, Hickman M. HCV treatment as prevention in prison: key issues. *Hepatology*. 2015;61:402-403.
14. Hajarizadeh B, Grebely J, Martinello M, Matthews GV, Lloyd AR, Dore GJ. Hepatitis C treatment as prevention: evidence, feasibility, and challenges. *Lancet Gastroenterol Hepatol*. 2016;1:317-327.
15. Macalino GE, Hou JC, Kumar MS, Taylor LE, Sumantera IG, Rich JD. Hepatitis C infection and incarcerated populations. *Int J Drug Policy*. 2004;15:103-114.
16. Dolan K, Teutsch S, Scheuer N, Levy M, Rawlinson W, Kaldor J, et al. Incidence and risk for acute hepatitis C infection during imprisonment in Australia. *Eur J Epidemiol*. 2010;25:143-148.
17. Butler T, Kariminia A, Levy M, Kaldor J. Prisoners are at risk for hepatitis C transmission. *Eur J Epidemiol*. 2004;19:1119-1122.
18. Champion JK, Taylor A, Hutchinson S, Cameron S, McMenamin J, Mitchell A, et al. Incidence of hepatitis C virus infection and associated risk factors among Scottish prison inmates: a cohort study. *Am J Epidemiol*. 2004;159:514-519.
19. Vlahov D, Nelson KE, Quinn TC, Kendig N. Prevalence and incidence of hepatitis C virus infection among male prison inmates in Maryland. *Eur J Epidemiol*. 1993;9:566-569.
20. Larney S, Kopinski H, Beckwith CG, Zaller ND, Jarlais DD, Hagan H, et al. Incidence and prevalence of hepatitis C in prisons and other closed settings: results of a systematic review and meta-analysis. *Hepatology*. 2013;58:1215-1224.
21. Hayashi K, Mj Milloy, Fairbairn N, Kaplan K, Lai C, Wood E, et al. Incarceration experiences among a community-recruited sample of injection drug users in Bangkok, Thailand. *BMC Public Health*. 2009;9:492.
22. Pollini RA, Alvelais J, Gallardo M, Vera A, Lozada R, Magis-Rodriquez C, et al. The harm inside: injection during incarceration among male injection drug users in Tijuana, Mexico. *Drug and Alcohol Depend*. 2009;103:52-58.
23. Kinner SA, Jenkinson R, Gouillou M, Milloy MJ. High-risk drug-use practices among a large sample of Australian prisoners. *Drug Alcohol Depend*. 2012;126:156-160.
24. Bretana NA, Boelen L, Bull R, Teutsch S, White PA, Lloyd AR, et al. Transmission of hepatitis C virus among prisoners, Australia, 2005-2012. *Emerg Infect Dis*. 2015;21:765-774.
25. Luciani F, Bretana NA, Teutsch S, Amin J, Topp L, Dore GJ, et al. A prospective study of hepatitis C incidence in Australian prisoners. *Addiction*. 2014;109:1695-1706.
26. White B, Dore GJ, Lloyd AR, Rawlinson WD, Maher L. Opioid substitution therapy protects against hepatitis C virus acquisition in people who inject drugs: the HITS-c study. *Med J Australia*. 2014;201:326-329.
27. Marco A, Gallego C, Cayla JA. Incidence of hepatitis C infection among prisoners by routine laboratory values during a 20-year period. *PLoS ONE*. 2014;9:e90560.
28. Macalino GE, Vlahov D, Sanford-Colby S, Patel S, Sabin K, Salas C, et al. Prevalence and incidence of HIV, hepatitis B virus, and hepatitis C virus infections among males in Rhode Island prisons. *Am J Public Health*. 2004;94:1218-1223.
29. Cepeda JA, Niccolai LM, Lyubimova A, Kershaw T, Levina O, Heimer R. High-risk behaviors after release from incarceration among people who inject drugs in St. Petersburg, Russia. *Drug Alcohol Depend*. 2015;147:196-202.
30. Tyndall MW, Currie S, Spittal P, Li K, Wood E, O'Shaughnessy MV, et al. Intensive injection cocaine use as the primary risk factor in the Vancouver HIV-1 epidemic. *Aids*. 2003;17:887-893.
31. Australian Injecting Drug Users League. *Legislative and Policy Barriers to Needle and Syringe Programs and Injecting Equipment Access for People Who Inject Drugs*. Canberra: Australian Injecting and Illicit Drug Users League (AIVL); 2010.
32. Ryan J, Voon D, Kirwan A, Levy M, Sutton L. Prisons, needles and OHS. *J Health Saf Environ*. 2010;26:63-72.
33. O'Sullivan BG, Levy MH, Dolan KA, Post JJ, Barton SG, Dwyer DE, et al. Hepatitis C transmission and HIV post-exposure prophylaxis after needle- and syringe-sharing in Australian prisons. *Med J Australia*. 2003;178:546-549.

34. Boelen L, Teutsch S, Wilson DP, Dolan K, Dore GJ, Lloyd AR, et al. Per-event probability of hepatitis C infection during sharing of injecting equipment. *PLoS ONE*. 2014;9:e100749.
35. Grebely J, Robaeys G, Bruggmann P, Aghemo A, Backmund M, Bruneau J, et al. Recommendations for the management of hepatitis C virus infection among people who inject drugs. *Int J Drug Policy*. 2015;26:1028-1038.
36. Nolan S, Dias Lima V, Fairbairn N, Kerr T, Montaner J, Grebely J, et al. The impact of methadone maintenance therapy on hepatitis C incidence among illicit drug users. *Addiction*. 2014;109:2053-2059.
37. Aspinall EJ, Weir A, Sacks-Davis R, Spelman T, Grebely J, Higgs P, et al. Does informing people who inject drugs of their hepatitis C status influence their injecting behaviour? Analysis of the Networks II study. *Int J Drug Policy*. 2014;25:179-182.
38. Tsui JI, Evans JL, Lum PJ, Hahn JA, Page K. Association of opioid agonist therapy with lower incidence of hepatitis C virus infection in young adult injection drug users. *JAMA Intern Med*. 2014;174:1974-1981.
39. Dolan K, Hall W, Wodak A. Methadone maintenance reduces injecting in prison. *Brit Med J*. 1996;312:1162.
40. Hallinan R, Byrne A, Amin J, Dore GJ. Hepatitis C virus prevalence and outcomes among injecting drug users on opioid replacement therapy. *J Gastroenterol Hepatol*. 2005;20:1082-1086.
41. Dolan K, Teutsch S, Scheuer N, Levy M, Rawlinson W, Kaldor J, et al. Incidence and risk for acute hepatitis C infection during imprisonment in Australia. *Eur J Epidemiol*. 2010;25:143-148.
42. Teutsch S, Luciani F, Scheuer N, McCredie L, Hosseiny P, Rawlinson W, et al. Incidence of primary hepatitis C infection and risk factors for transmission in an Australian prisoner cohort. *BMC Public Health*. 2010;10:633.
43. Palmateer NE, Taylor A, Goldberg DJ, Munro A, Aitken C, Shepherd SJ, et al. Rapid decline in HCV incidence among people who inject drugs associated with national scale-up in coverage of a combination of harm reduction interventions. *PLoS ONE*. 2014;9:e104515.
44. Treloar C, McCredie L, Lloyd AR. Investigators H-p. Acquiring hepatitis C in prison: the social organisation of injecting risk. *Harm Reduct J*. 2015;12:10.
45. Stoove M, Treloar CJ, Maher L, Tyrrell H, Wallace J. Salvaging a prison needle and syringe program trial in Australia requires leadership and respect for evidence. *Med J Australia*. 2015;203:319-320.
46. Grebely J, Matthews GV, Lloyd AR, Dore GJ. Elimination of hepatitis C virus infection among people who inject drugs through treatment as prevention: feasibility and future requirements. *Clin Infect Dis*. 2013;57:1014-1020.

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

How to cite this article: Cunningham EB, Hajarizadeh B, Bretana NA, et al. Ongoing incident hepatitis C virus infection among people with a history of injecting drug use in an Australian prison setting, 2005-2014: The HITS-p study. *J Viral Hepat*. 2017;24:733–741. https://doi.org/10.1111/jvh.12701