Epidemiol. Infect. (2012), **140**, 2190–2198. © Cambridge University Press 2012
doi:10.1017/S0950268812000489

Estimating the variability in the risk of infection for hepatitis C in the Glasgow injecting drug user population

A. J. SUTTON[1]*, S. A. McDONALD[2,3], N. PALMATEER[2], A. TAYLOR[4] AND S. J. HUTCHINSON[2,3]

[1] *Health Economics Unit, Public Health Building, University of Birmingham, Edgbaston, Birmingham, UK*
[2] *Health Protection Scotland, Glasgow, UK*
[3] *Department of Mathematics and Statistics, University of Strathclyde, Glasgow, UK*
[4] *Institute for Applied Social and Health Research, University of the West of Scotland, Paisley, UK*

Received 2 November 2011; Final revision 17 January 2012; Accepted 29 February 2012; first published online 30 March 2012

SUMMARY

Glasgow (Scotland's largest city) has a high prevalence of injecting drug use and has one of the highest prevalences of hepatitis C virus (HCV) infection in injecting drug users (IDUs) in Western Europe. HCV prevalence data from surveys of Glasgow's IDUs from 1990 to 2007 were utilized and a model was applied that described the prevalence of HCV as a function of the rate (force) of infection. Force-of-infection estimates for HCV that may vary over time and injecting career length over a range of variables were investigated. New initiates to injecting were found to be at increased risk of HCV infection, with being recruited from a street location and reporting injecting in prison leading to a significant increase in the risk of infection in new initiates. These results indicate areas of importance for the planning of public health measures that target the IDU population.

Key words: Hepatitis C, incidence, infectious disease, injecting drug users (IDUs), mathematical modelling.

INTRODUCTION

Injecting drug users (IDUs) are at increased risk of infection from hepatitis C virus (HCV) [1], due to their sharing of used needles/syringes and other injecting paraphernalia [2]. Glasgow (Scotland's largest city) has a high prevalence of injecting drug use (with 1–2% of the population aged 15–55 years actively injecting throughout the 1990s and 2000s [3, 4]) and has seen one of the highest prevalences of HCV infection in IDUs in Western Europe (with up to 90% of its IDU population infected during the mid-1980s/early 1990s [5, 6]). Reductions in HCV prevalence in young, newly initiated IDUs were observed in Glasgow during the early to mid-1990s, which suggests that harm reduction interventions such as the provision of sterile needles/syringes and opiate substitution therapy have played a role in reducing the spread of the virus. However, the prevalence of HCV remains high in IDUs in Glasgow (60–70% in the 2000s) [7], as in many other resource-rich cities around the world [8].

Previous modelling studies have quantified the risk of bloodborne virus (BBV) infection in the IDU population through the estimation of the force of infection (FOI) [9, 10]; this is defined as the

* Author for correspondence: Dr A. J. Sutton, Health Economics Unit, Public Health Building, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK.
(Email: A.J.Sutton@bham.ac.uk)

instantaneous *per capita* rate at which susceptible individuals acquire infection and reflects the degree of contact between susceptible and infectious individuals [11]. The FOI is closely related to the incidence of new infections through the following relationship:

$$\text{No. of new infections (incidence)} = \text{FOI} \times \text{no. of susceptible individuals.}$$

It can therefore be seen that although the FOI in isolation cannot directly be used to calculate the number of new infections it is nevertheless a useful proxy. Moreover, while the incidence of BBVs in IDUs is usually difficult to measure directly [12], statistical methods have been developed to estimate the FOI from data describing the prevalence of the infection which is often more readily available [10]. The FOI can also be used to estimate an individual's probability of being infected given their period of exposure to infection through the following equation:

$$P = 1 - e^{-\lambda t},$$

where P is the probability of being infected over the period from time 0 to time t, λ is the FOI, and t is the period of exposure to infection. However, if the FOI changes over time, then the cumulative FOI over the period from time 0 to time t must be considered, thereby giving the following equation:

$$P = 1 - e^{-\Lambda},$$

where Λ is the cumulative FOI over the period from time 0 to time t.

Application of FOI estimation methods to BBV prevalence data from IDUs across Europe have demonstrated that new initiates to injecting are at increased risk of BBV infection compared to more experienced IDUs, and these have highlighted the need to increase interventions designed to target new initiates to injecting [9, 10]. Although previous studies have focused on estimating FOI according to the time since onset of injecting (injecting career length) [9, 10], investigation of the influence of other key characteristics of the IDU population on the FOI will help to inform where intervention measures should be directed in the future. Therefore, the aim of this study was to estimate the FOI for HCV in Glasgow's IDU population, using HCV prevalence data from a series of cross-sectional surveys undertaken during 1990–2007, and examine, in particular, the extent to which the FOI varies according to demographic and behavioural factors. Additionally, the HCV FOI estimates for Glasgow IDUs will also be compared to those previously derived for IDUs in England and Wales [10] and other European countries [9].

METHODS

Data source

Voluntary, anonymous, cross-sectional surveys of Glasgow's IDUs have been performed to determine the prevalence of BBVs and risk behaviours associated with acquiring infection within this population; 11 surveys were undertaken in total: in each of the years during 1990–1994 and in 1996, 1999, 2000/2001, 2004, 2005 and 2007 [5, 8, 13–15]. Recruitment was at multiple sites (needle exchange, drug treatment centres, street locations) for years up to 2004, and was at needle exchange services during 2005 and 2007; recruitment at sites providing injecting equipment was open to individuals who were attending for the purpose of either injecting equipment and/or other services (e.g. methadone prescription). Because the focus of the surveys has changed over time, the criteria for inclusion has varied: a respondent was eligible for inclusion if he/she reported injecting within the previous month (2004 survey), within the previous 2 months (1990–1994, 1996 surveys), had started injecting during the period 1990–1999 (1999 survey) or 1996–2002 (2001–2002 survey), or had reported ever injecting (2005 and 2007 surveys). For the latter two surveys (2005 and 2007), recruitment of non-recent injectors (i.e. those who had not injected in the previous 6 months) was limited to a maximum of 20% of the sample. The number of IDUs recruited in each survey was in the range of 248–595, with a total sample of $n = 5239$ recruited.

In each survey, participants were interviewed and asked to provide (i) responses on key demographic and behavioural information using standardized questionnaires, and (ii) a saliva specimen which was linked to their questionnaire responses through an assigned study number and thereafter anonymously tested for HCV antibodies. Sensitivity of the saliva tests used for detection of HCV antibody was 85% up to and including 1999, and 92% from 2000/2001 onwards, with a specificity of 100% throughout [16]. The study's high participation rates and the inclusion of large numbers of IDUs who were recruited on street sites would not have been possible if venous blood rather than saliva specimens had been requested [17]. Participants who either provided an insufficient saliva sample or who had an indeterminate HCV antibody

test result were excluded from this analysis; with analysis in this study also restricted to those IDUs aged 16–56 years at the time of the survey and with an age of first injection of 11–49 years, resulting in a total study population of 4137 IDUs across all survey years.

Demographic and behavioural variables

It is assumed that the period of risk during which an individual could have acquired HCV infection is equal to the injecting career length, which is defined as the time between the age at first injection and age at survey (mean 8·3 years, range 0–36 years). A variety of bands describing the grouping of the injecting career length were investigated during the model fitting process (see Supplementary material, available online). Other demographic variables considered included gender, recruitment setting (defined as either street or harm reduction; the latter involved services providing either or both needle exchange and drug treatment), and survey year with various year bands also being investigated during the course of the model fitting (see Supplementary material).

Behavioural variables investigated included: (*a*) age when first injected drugs (categorized as those aged $\leqslant 25$ years and >25 years), (*b*) ever used needle/syringes and/or other injecting paraphernalia (i.e. spoons, filters, water) previously used by someone else (otherwise referred to here as having *shared* injecting equipment and was categorized into those who had ever shared needles/syringes, those who had ever shared other injecting paraphernalia (but had never shared needles/syringes), and those had never shared any injecting equipment (needles/syringes and other injecting paraphernalia), (*c*) ever injected in prison (categorized as ever injected in prison, ever imprisoned but never injected in prison, and never imprisoned). A detailed summary of the dataset used in this analysis is provided in Table 1.

Sample characteristics

In total, 73·5% of the sample were males with 94·3% reporting having injected in the last 6 months prior to being surveyed. The majority (82%) of the sample reported having started injecting before the age of 25 years. A total of 68·5% of IDUs had an injecting career length of $\geqslant 5$ years, while 16% of IDUs had started injecting in the previous 2 years. Most of the IDUs in the sample had been previously imprisoned (74%).

It can be seen (Table 1) that the prevalence of HCV increases with increased injecting career length, showing that more experienced IDUs are more likely to have been infected compared to new initiates to injecting. Across all surveys the prevalence of HCV appears to have increased during 2000–2007 compared to 1990–1999. HCV prevalence is also seen to be higher in IDUs that have ever been imprisoned, and in those that have ever reported sharing needles and other injecting paraphernalia.

Model

The complete model is described in the Supplementary material; however, in brief, a model is proposed that describes the prevalence of HCV as a function of the FOI that may vary over calendar time and injecting career length. The FOI is calculated as the product of two values, which are a time (year) component and an injecting career length component (calculated using maximum likelihood, see below), and then the cumulative FOI is calculated relative to a baseline year, which in this case is the first year of the survey data. So for example the model value for the prevalence in IDUs in 1992 that have injected for 3 years would be equal to the cumulative FOI in 1990 for injectors that have been injecting for 1 year, + the FOI for IDUs that have been injecting for 2 years in 1991 [λ(1991, 2 yr)] + the FOI for IDUs that have been injecting for 3 years in 1992 [λ(1992, 3 yr)]. This therefore allows for the possibility that an IDU's risk of infection can change independently over time and injecting career length.

The model is fitted to prevalence data that varies with injecting career length and calendar time by maximum-likelihood methods, with the most parsimonious model (best-fitted model with fewest parameters) being selected. The first survey year in all cases (in this analysis this is usually 1990 except for data fields not collected in early years, see Table 1) is used to calculate a cumulative FOI and as such will not be included in the FOI results. Ninety-five percent confidence intervals were calculated using profile likelihood. When estimating the model prevalence, the sensitivity of the HCV antibody tests is incorporated in the model. Analysis is repeated to examine the influence of each variable on the FOI estimates.

RESULTS

The estimated FOI for each of the behavioural variables was investigated over both calendar year period

https://doi.org/10.1017/S0950268812000489 Published online by Cambridge University Press

Table 1. *Characteristics of IDUs recruited in Glasgow during 1990–2007 and used in this analysis, according to survey year*

	Survey year												
	All (1990–2007)				1990–1999				2000–2007				
Variable	*N* (%)		HCV pos. (%)		*N* (%)		HCV pos. (%)		*N* (%)		HCV pos. (%)		χ^2
All injectors	4137		2539	(61·4)	2361		1371	(58·1)	1776		1168	(65·8)	25·33*
Injecting status													
Reported injecting in last 6 months	3899	(94·3)	2391	(61·3)	2314	(98)	1354	(58·5)	1585	(89·2)	1037	(65·4)	18·95*
Reported not injecting in last 6 months	237	(5·7)	148	(62·4)	46	(2)	17	(37·0)	191	(10·8)	131	(68·6)	15·82
Gender†													
Male	3042	(73·5)	1921	(63·1)	1658	(70)	995	(60·0)	1384	(78·0)	926	(66·9)	15·41*
Female	1094	(26·5)	617	(56·4)	703	(30)	376	(53·5)	391	(22·0)	241	(61·6)	6·79*
Age (yr)†													
16–24	1269	(30·7)	659	(51·9)	949	(40)	487	(51·3)	320	(18·0)	172	(53·8)	0·57
25–29	1373	(33·2)	844	(61·5)	913	(39)	554	(60·7)	460	(25·9)	290	(63·0)	0·72
⩾30	1495	(36·1)	1036	(69·3)	499	(21)	330	(66·1)	996	(56·1)	706	(70·9)	3·53
Age at first injection (yr)†													
<25 years	3391	(82·0)	2124	(62·6)	2122	(90)	1250	(58·9)	1269	(71·5)	874	(68·9)	33·70*
⩾25	746	(18·0)	415	(55·6)	239	(10)	121	(50·6)	507	(28·5)	294	(58·0)	3·57
Injecting career length (yr)†													
<1	159	(3·8)	36	(22·6)	69	(3)	12	(17·4)	90	(5·1)	24	(26·7)	1·92
1–2	503	(12·2)	200	(39·8)	289	(12)	99	(34·3)	214	(12·0)	101	(47·2)	8·60*
3–4	642	(15·5)	388	(60·4)	346	(15)	189	(54·6)	296	(16·7)	199	(67·2)	10·60*
5–9	1422	(34·4)	900	(63·3)	929	(39)	568	(61·1)	493	(27·8)	332	(67·3)	5·33*
⩾10	1411	(34·1)	1015	(71·9)	728	(31)	503	(69·1)	683	(38·5)	512	(75·0)	6·01*
Ever imprisoned†													
Yes	3063	(74·0)	2051	(67·0)	1839	(78)	1150	(62·5)	1224	(68·9)	901	(73·6)	40·76*
No	1074	(26·0)	488	(45·4)	522	(22)	221	(42·3)	552	(31·1)	267	(48·4)	3·94*
Injected in prison in those previously imprisoned†													
Yes	448	(20·8)	327	(73·0)	243	(26)	167	(68·7)	205	(16·9)	160	(78·0)	4·90*
No	1701	(79·2)	1128	(66·3)	693	(74)	396	(57·1)	1008	(83·1)	732	(72·6)	44·03*
Recruitment site†													
Street	1133	(27·4)	755	(66·6)	570	(24)	358	(62·8)	563	(31·7)	397	(70·5)	7·57*
Harm reduction service (incl. needle exchange)	3004	(72·6)	1784	(59·4)	1791	(76)	1013	(56·6)	1213	(68·3)	771	(63·6)	14·70*
Ever received methadone†													
Yes	2014	(48·8)	1323	(65·7)	616	(26)	370	(60·1)	1398	(78·9)	953	(68·2)	12·46*
No	2115	(51·2)	1212	(57·3)	1742	(74)	1000	(57·4)	373	(21·1)	212	(56·8)	0·04
Ever shared injecting equipment†													
Needles/syringes	1263	(57·9)	834	(66·0)	247	(58)	113	(45·7)	1016	(57·9)	721	(71·0)	56·33*
Other equipment only	530	(24·3)	314	(59·2)	108	(25)	45	(41·7)	422	(24·0)	269	(63·7)	17·36*
Never shared	387	(17·8)	199	(51·4)	70	(16)	33	(47·1)	317	(18·1)	166	(52·4)	0·63

Table 1 (*cont.*)

Variable	Survey year								
	All (1990–2007)				1990–1999		2000–2007		
	N (%)		HCV pos. (%)		*N* (%)	HCV pos. (%)	*N* (%)		HCV pos. (%)	χ^2
Previously shared with HCV positive†										
Yes	327	(18·9)	243	(74·3)			327	(18·9)	243	(74·3)
No	1407	(81·1)	903	(64·2)			1407	(81·1)	903	(64·2)

N (%) describes the breakdown of the population for each question (different options adding up to 100%); HCV positive (%) = % of the population that is infected with HCV.

Recruitment site: IDUs were only recruited from street locations up to and including 2004; **Previously shared with HCV positive**: question asked in surveys from 2001 onwards; **Injected in prison in those previously imprisoned**: question asked in surveys from 1993 onwards; **Ever shared injecting equipment**: question specifically asked in this manner distinguishing between the sharing of needles and the sharing of other injecting equipment from 1999 onwards.

* $P<0{\cdot}05$ for row over time.

† $P<0{\cdot}05$ for variable across all years (χ^2 value not shown).

(1991–2007) and injecting career length (Fig. 1). To help with comparisons between the variables, the cumulative FOI for an injecting career length of 8 years (the mean average injecting career length for all IDUs in the dataset was 8·3 years) was also computed and is shown in Figures 1 and Fig. 2.

FOI by demographic variables

The risk of HCV infection in Glasgow's IDU population was not found to be significantly higher in those surveyed in the period 2000–2007 compared to those surveyed during 1991–1999. Although as can be seen in Figure 1*a*, the overlapping 95% confidence intervals (CI) show that this increase is not statistically significant.

IDUs in their first year of their injecting career were at greatest risk of HCV infection (1991–1999: FOI 0·46/person per year, 95% CI 0·36–0·61; 2000–2007: FOI 0·59/person per year, 95% CI 0·46–0·74), followed by those IDUs who had been injecting between 1 and 2 years (1991–1999: FOI 0·28, 95% CI 0·12–0·57; 2000–2007: FOI 0·35, 95% CI 0·15–0·71), with the risk of infection for IDUs who have been injecting for $\geqslant 3$ years being comparatively low (1991–1999: FOI 0·04, 95% CI 0·02–0·09; 2000–2007: FOI 0·05, 95% CI 0·02–0·10).

When stratifying by gender, the risk of infection was highest in both sexes for new initiates compared to more experienced IDUs (Fig. 1*b*). The risk for females in their first year of injecting was not found to be significantly higher than for males (females: FOI 0·69, 95% CI 0·54–0·85; males: FOI 0·59, 95% CI 0·44–0·76). The risk associated with an average injecting career length of 8 years was similar for males and females. No difference in FOI between the periods 1991–1999 and 2000–2007 was apparent after stratification by sex (not shown); this may be due to the model having insufficient power to detect differences by survey year in smaller stratified datasets. There was also no significant difference in the estimated FOI when comparing the results obtained from individuals who injected in the 6 months prior to survey and those who had injected more than 6 months ago (results not shown).

It can be seen that new initiates to injecting recruited from a street location are at significantly increased risk of infection compared to all other IDUs considered in this analysis (Fig. 1*c*). Interestingly, a slight although not statistically significant increase in the FOI over time was detected in the model from

https://doi.org/10.1017/S0950268812000489 Published online by Cambridge University Press

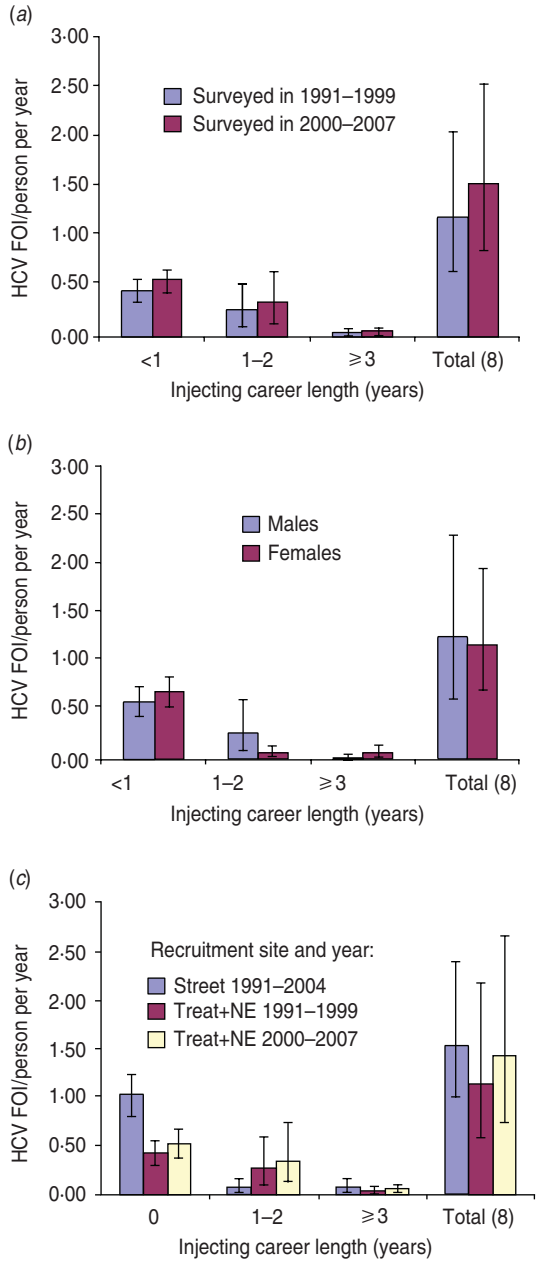

Fig. 1 [*colour online*]. The estimated force of infection (FOI) stratified by injecting career length and: (*a*) survey year, (*b*) gender and (*c*) recruitment site.

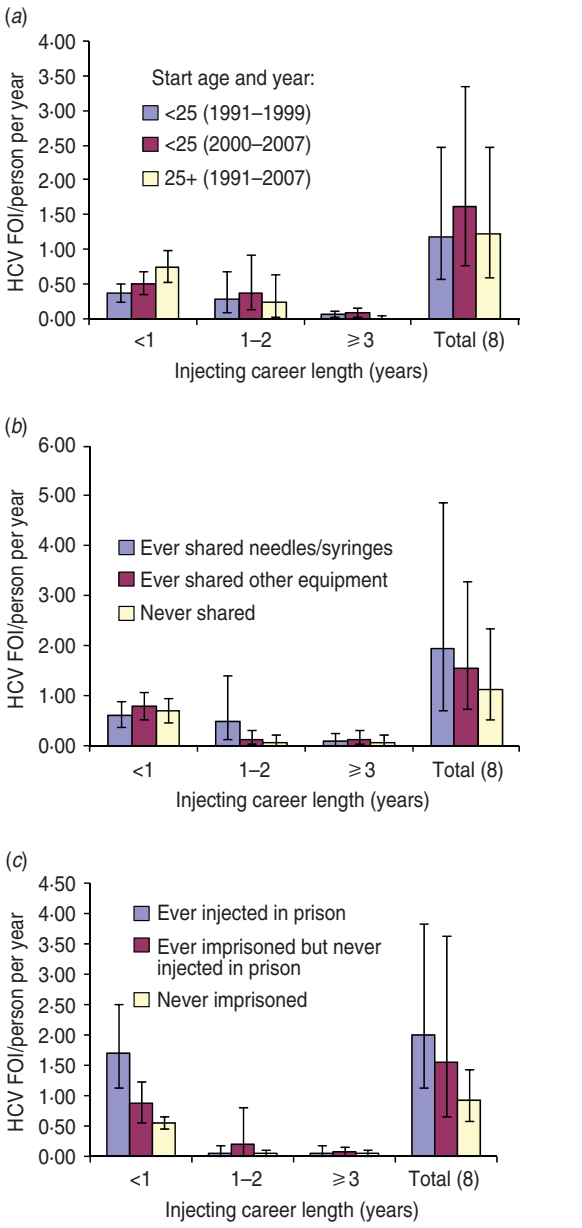

Fig. 2 [*colour online*]. The estimated force of infection (FOI) stratified by injecting career length and: (*a*) age at first injection, (*b*) ever shared injecting equipment, and (*c*) whether ever imprisoned and injected. (Note the differing scale on the y axis for each panel.)

2000–2007 compared to 1991–1999 for those IDUs recruited from treatment settings (no time trends were seen for IDUs from street locations during 1991–2004, the period over which these IDUs were surveyed).

FOI by behavioural variables

The impact of age at first injection on the FOI is shown in Figure 2*a*. For those injectors that started injecting when they were aged <25 years, it can be seen that the cumulative risk of infection was greater over the period 2000–2007, compared to 1991–1999, although no trends over time were detected for those in injectors that started injecting at ⩾25 years. Of interest, it should be noted that those individuals that start injecting at older ages (⩾25 years) are at an increased although not statistically significant risk of infection during their first year of injecting (FOI 0·74,

https://doi.org/10.1017/S0950268812000489 Published online by Cambridge University Press

95% CI 0·53–0·99) compared to injectors starting at younger ages (<25 years) (1991–1999: FOI 0·37, 95% CI 0·25–0·51; 2000–2007: FOI 0·50, 95% CI 0·34–0·69).

IDUs who reported ever having shared needles/syringes and those who had shared other injecting paraphernalia (but not needles/syringes) were at an increased although not statistically significant risk of acquiring HCV infection over an 8-year period compared to those that reported having never shared injecting equipment (either needles/syringes or other injecting paraphernalia) [cumulative FOI at 8 years injecting career length: 1·94 (95% CI 0·71–4·88), 1·54 (95% CI 0·72–3·30), and 1·11 (95% CI 0·51–2·35), respectively; Fig. 2*b*]. An increased risk of HCV infection in the first year of injecting was seen for all IDUs irrespective of whether they reported sharing or not (ever shared needles: FOI 0·60, 95% CI 0·38–0·88; ever shared other equipment: FOI 0·78, 95% CI 0·53–1·08; never shared: FOI 0·69, 95% CI 0·47–0·95) In the 1–2 years of injecting, a higher but not statistically significant FOI continues only for those IDUs that reported having ever shared needles/syringes (ever shared needles: FOI 0·48, 95% CI 0·14–1·41; ever shared other equipment: FOI 0·11, 95% CI 0·03–0·32; never shared: FOI 0·11, 95% CI 0·03–0·32).

There was an association between imprisonment and an increased risk of acquiring HCV infection (Fig. 2*c*). For IDUs reporting having ever injected in prison, the risk of infection was highest, particularly for new initiates to injecting (FOI 1·69, 95% CI 1·13–2·50) followed by those reporting being imprisoned but never having injected in prison (FOI 0·87, 95% CI 0·56–1·23), with those reporting never having been imprisoned having the lowest FOI in new initiates (FOI 0·55, 95% CI 0·45–0·66). There was a significant difference in new initiates between those that have ever injected in prison, and those that have never been imprisoned. Only a very minor difference in the risk of infection was seen depending on prison status for injectors injecting for >1 year.

DISCUSSION

Using prevalence data collected in Glasgow over the period 1990–2007 to estimate the FOI within the IDU population, this study investigated the associations between a range of demographic and behavioural variables and the risk of acquiring HCV infection. The model used here uses FOI as a proxy for the risk of infection, and describes how the risk of infection varies over time and injecting career length. In line with previous studies [9, 10], the results demonstrate that new initiates to injecting – individuals who have been injecting for <1 year – are at greatly increased risk of infection compared to more experienced IDUs. The results also indicate an increased risk of HCV infection associated with previous imprisonment.

A previous study that used similar data sources to compare new initiates to injecting between Glasgow and London found that having injected crack, having been in prison, or having a longer injecting career were all risk factors for HCV infection [18]. The data used in this study shows an increased prevalence of HCV with injecting career length, while the FOI estimates here concur that imprisonment is an important risk factor for HCV infection, which is consistent with previous research showing that HCV prevalence in prisoners tends to be higher than in the general population in many countries [8, 19]. This increased risk may be attributable to increased at risk behaviour in prisons (such as injecting or tattooing), or it may be due to high at-risk behaviour following imprisonment as a result of an extended period of drug withdrawal during imprisonment.

It is notable that we did not observe a significant difference in FOI estimates when we compared findings from IDUs reporting having injected within the previous 6 months and those that had injected in the last 4 weeks. The injecting career length here has been used as a proxy for the period of risk of HCV infection, and so injectors that report injecting within the previous 6 months compared to those within the previous month may be at risk of infection for less time even if the injecting career length is the same. However, reduced FOI estimates were not seen, which may reflect information bias in that injectors may be unable to recall when they last injected. Previous studies have used 4 weeks to define current injector status [10, 20–22], which is generally a more robust approach for drawing conclusions about the current injecting population.

In terms of magnitude, the estimated FOI for Glasgow's IDUs over the period 1991–2007 was considerably greater than the FOI estimated for current IDUs (injected in the previous 4 weeks prior to being surveyed) in England and Wales from 1999 to 2003 (<1 year of injecting, Glasgow: FOI 0·55/person per year, 95% CI 0·43–0·67; England and Wales: FOI 0·16, 95% CI 0·13–0·19) [10]. In comparison with FOI estimates obtained from other European

countries [9], IDU data from Belgium in 2005 provided a FOI estimate across all injecting career lengths (FOI 0·75, 95% CI 0·35–2·51) that was considerably higher than the value obtained from Glasgow, although there is much uncertainty in this estimate. While a FOI estimate from Spanish IDU data in 2002, again across all injecting career lengths (FOI 0·53, 95% CI 0·35–0·85), was much more comparable to the estimate for new initiates obtained from Glasgow.

Although our method for estimating the risk of HCV infection by modelling the FOI has certain strengths, it also has several limitations which should be considered when interpreting the results. First, it is difficult to ascertain how representative our study population is of Glasgow's IDU population as a whole. Although it was the aim in the early years of the surveys to recruit as representative a sample as possible, including IDUs that were not in treatment, many of the survey respondents were self-selected with some in contact with drug services whether this be in a treatment or street setting. They therefore may not be representative of all IDUs. In general IDUs in contact with services are probably more stable (i.e. less chaotic, less injecting risk) and are usually older or have a longer injecting career length because IDUs often do not come into contact with services in the early stages of their injecting careers. Therefore, it is possible that the FOI might even be an underestimate in those with very short injecting careers. Second, several important variables under examination (e.g. age at first injection, sharing behaviour, whether or not injected in the previous 6 months) rely on accurate survey responses. Information bias due to poor participant recall is a potentially serious limitation, especially for those IDUs who began injecting some years in the past. Needle/syringe sharing may be underreported in surveys eliciting quantitative responses [23]. Third, as seen by the frequent overlapping confidence intervals, the size of the surveys used in this analysis have limited the conclusions that can be drawn from this analysis. Nevertheless it is hoped that the uncertain findings here can be used to direct future research in this area, so that these can be either confirmed or refuted.

In summary, the results here are useful in showing how the FOI for HCV in Glasgow's IDUs varies over calendar time and injecting career length, and have provided additional insights into the impact of key behavioural variables on the risk of acquiring infection. Targeting new initiates to injecting drugs would appear to have the potential to significantly reduce the spread of infection. There is also a clear need to target intervention methods at drug users in a prison setting, although the need to support drug users during potential periods of high-risk following their discharge from prison [24] should not be ruled out.

SUPPLEMENTARY MATERIAL

For supplementary material accompanying this paper, visit http://dx.doi.org/10.1017/S0950268812000489.

ACKNOWLEDGEMENTS

We thank the participants, the researchers and interviewers who collected the data and the drug treatment and needle exchange services where the research took place. Funding for the surveys was provided by the Scottish Government.

DECLARATION OF INTEREST

None.

REFERENCES

1. **Roy K, *et al.*** Monitoring hepatitis C virus infection among injecting drug users in the European Union: a review of the literature. *Epidemiology and Infection* 2002; **129**: 577–585.
2. **De P, *et al.*** Risk of hepatitis C virus transmission through drug preparation equipment: a systematic and methodological review. *Journal of Viral Hepatitis* 2008; **15**: 279–292.
3. **Frischer M, *et al.*** Estimating the population prevalence of injection drug use and infection with human immunodeficiency virus among injection drug users in Glasgow, Scotland. *American Journal of Epidemiology* 1993; **138**: 170–181.
4. **Hay G, *et al.*** Estimating the national and local prevalence of problem drug misuse in Scotland. Executive Report. University of Glasgow, 2004.
5. **Hutchinson SJ, *et al.*** Prevalence of hepatitis C among injectors in Scotland 1989–2000: declining trends among young injectors halt in the late 1990s. *Epidemiology and Infection* 2002; **128**: 473–477.
6. **Roy KM, *et al.*** Hepatitis C virus infection among injecting drug users in Scotland: a review of prevalence and incidence data and the methods used to generate them. *Epidemiology and Infection* 2007; **135**: 433–442.
7. **HPA**. Health Protection Agency, Centre for Infections. Hepatitis C in the UK, 2009. London, 2009.
8. **Hutchinson SJ, *et al.*** Hepatitis C virus infection in Scotland: epidemiological review and public health challenges. *Scottish Medical Journal* 2006; **51**: 8–15.

9. **Sutton AJ, *et al.*** A comparison between the force of infection estimates for blood-borne viruses in injecting drug user populations across the European Union: a modelling study. *Journal of Viral Hepatitis* 2008; **15**: 809–816.
10. **Sutton AJ, *et al.*** Modelling the force of infection for hepatitis B and hepatitis C in injecting drug users in England and Wales. *BMC Infectious Diseases* 2006; **6**: 93.
11. **Farrington CP.** Modelling forces of infection for measles, mumps and rubella. *Statistics in Medicine* 1990; **9**: 953–967.
12. **Hope VD, *et al.*** Measuring the incidence, prevalence and genetic relatedness of hepatitis C infections among a community recruited sample of injecting drug users, using dried blood spots. *Journal of Viral Hepatitis* 2011; **18**: 262–270.
13. **Hutchinson SJ, *et al.*** Extent and contributing factors of drug expenditure of injectors in Glasgow. Multi-site city-wide cross-sectional study. *British Journal of Psychiatry* 2000; **176**: 166–172.
14. **Taylor A, *et al.*** High risk injecting behaviour among injectors from Glasgow: cross sectional community wide surveys 1990–1999. *Journal of Epidemiology and Community Health* 2001; **55**: 766–767.
15. **Hutchinson SJ, *et al.*** Factors associated with injecting risk behaviour among serial community-wide samples of injecting drug users in Glasgow 1990–94: implications for control and prevention of blood-borne viruses. *Addiction* 2000; **95**: 931–940.
16. **Judd A, *et al.*** Evaluation of a modified commercial assay in detecting antibody to hepatitis C virus in oral fluids and dried blood spots. *Journal of Medical Virology* 2003; **71**: 49–55.
17. **Taylor A, *et al.*** Prevalence of hepatitis C virus infection among injecting drug users in Glasgow 1990–1996: are current harm reduction strategies working? *Journal of Infection* 2000; **40**: 176–183.
18. **Judd A, *et al.*** Prevalence of, and risk factors for, hepatitis C virus infection among recent initiates to injecting in London and Glasgow: cross sectional analysis. *Journal of Viral Hepatitis* 2005; **12**: 655–662.
19. **Weild AR, *et al.*** Prevalence of HIV, hepatitis B, and hepatitis C antibodies in prisoners in England and Wales: a national survey. *Communicable Disease and Public Health* 2000; **3**: 121–126.
20. **Sutton AJ, *et al.*** Modelling the characteristics of the male injecting drug user population in England and Wales. *International Journal of Drug Policy* 2005; **16**: 176–182.
21. **Sutton AJ, *et al.*** Modelling the hepatitis B vaccination programme in prisons. *Epidemiology and Infection* 2006; **134**: 231–242.
22. **Sutton AJ, Gay NJ, Edmunds WJ.** Modelling the impact of prison vaccination on hepatitis B transmission within the injecting drug user population of England and Wales. *Vaccine* 2006; **24**: 2377–2386.
23. **Rhodes T, Davis M, Judd A.** Hepatitis C and its risk management among drug injectors in London: renewing harm reduction in the context of uncertainty. *Addiction* 2004; **99**: 621–633.
24. **Adams J, *et al.*** HIV risk after release from prison: a qualitative study of former inmates. *Journal of Acquired Immune Deficiency Syndrome* 2011; **57**: 429–434.