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Trends and correlates of abscess history among people who inject drugs in Massachusetts: A mixed methods exploration of experiences amidst a rapidly evolving drug supply

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HIGHLIGHTS

- We assessed risk factors for recent abscesses among people who inject drugs (PWID).
- Correlates included: injection frequency, stimulant/fentanyl use, neck injection.
- PWID cited injection behavior, stigma, and self-treatment as risk factors.
- Lifetime prevalence of abscesses was 65.5%, of which 67.5% occurred in past year.
- Indicated interventions include: drug checking, bias training, supervised injection.

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ABSTRACT

Background: Injection drug use poses significant risk for skin and soft tissue infections, such as abscesses. In places with endemic fentanyl and an increasingly contaminated drug supply, injecting and injection-related harms may be increasing, yet are understudied. We aimed to explore abscess prevalence, experiences, and themes among people who inject drugs (PWID) in the context of an evolving drug supply.

Methods: Between 2019 and 2022, we surveyed and interviewed Massachusetts- based PWID about current drug use behaviors and abscess experiences. Chi-square tests explored correlates of abscess history and trends for past-year abscess percentages over time. Transcribed interview data were analyzed to identify themes related to abscess risk and opportunities for intervention.

Results: Of the 297 PWID surveyed, 65.3% reported having an abscess at the injection site in their lifetime; 67.5% of these instances occurred within the last year. Reported past-year abscesses increased from 36.7% to 75.6% between 2019 and 2022. Correlates of past-year abscesses included frequent injection; methamphetamine, crack, or fentanyl use; and injection into the neck or calf. Methadone treatment was associated with significantly fewer recent abscesses. Interview data (n=151) confirmed the identified abscess risks, including syringe sharing and lack of hygienic supplies. Qualitative interviews provided additional data regarding healthcare provider stigma contributing to healthcare avoidance and the self-treatment of abscesses with adverse results.

Conclusions: Abscesses are an increasing concern among PWID residing in areas of high fentanyl prevalence and a contaminated drug supply. Community drug checking, overdose prevention sites, injection hygiene interventions, and improved access to care are indicated.

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1. Introduction

Drug injection is a major public health concern amid the United States opioid crisis. Compared to other routes of administration such as smoking or sniffing, drug injection poses an increased risk of overdose and infection (Cranston et al., 2019; Mathers et al., 2013; Peters et al., 2016; Wurcel et al., 2016; Zibbell et al., 2018). The majority of hospital visits among people who inject drugs (PWID) are the result of skin and soft tissue infections, especially abscesses (Ebright and Pieper 2002). Left untreated, abscesses can lead to significant morbidity and mortality (Cornford and Close 2016; Del Giudice 2004; Ebright and Pieper 2002; See et al., 2020).

Across studies, the prevalence of abscesses and other infections in PWID is between 21%−37% (Binswanger et al., 2000; Fink et al., 2013; Lloyd-Smith et al., 2005). The use of illicit drugs such as heroin and cocaine is associated with high healthcare utilization, with one systematic review finding that people who use non-prescription drugs were hospitalized 4.8–7.1 times more often than the general population (Lewer et al., 2020). Other studies have determined that having an injection-related abscess or other infection is associated with longer hospital stays and higher cost (Takahashi et al., 2010; Tookes et al., 2015).

Rapid recognition and treatment of abscesses and other infections are effective in preventing serious sequelae of infection (Tognetti et al., 2012). Wound care and antibiotics can be effective for treating abscesses in their early stages (Khalil et al., 2008). Conversely, delayed treatment can result in more invasive and costly procedures, with greater risk for amputation, heart damage, and death (Lloyd-Smith et al., 2010). Many studies postulate that PWID may delay abscess treatment due to limited access to medical centers, self-treatment via attempts to drain abscesses, use of street-acquired antibiotics (Fink et al., 2013; Phillips and Stein 2010), and anticipated healthcare provider stigma (Ahern et al. 2007; Cornford and Close 2016; Paquette et al., 2018).

Emerging findings of drug supply contamination and polysubstance use are a concerning yet understudied phenomenon influencing overdose and abscess prevalence in the US ("NCDAS: Substance Abuse and Addiction Statistics 2022"; Singh et al., 2020). For example, in Massachusetts, fentanyl prevalence among overdose decedents rose from 2015 to 2019 (Shrestha et al. 2021). Further investigation of the drug supply also detected fentanyl contamination in the cocaine and methamphetamine supply ("Current Opioid Statistics | Mass.Gov".; Hughto et al., 2022; "Streetcheck.Org"). Additionally, xylazine, an unscheduled veterinary sedative ("Xylazine - DEA" 2021), has been reported in increasing prevalence and higher concentrations in the drug supply (Alexander et al., 2022; Friedman et al., 2022). Xylazine causes significant sedation and extensive skin deterioration and abscesses, posing greater risk for overdose and abscess-related complications (Ball et al., 2022; Reyes et al., 2012; Ruiz-Colón et al., 2014).

Much of the research exploring risk and protective factors for abscesses was conducted prior to the widespread presence of fentanyl and other contaminants (e.g., xylazine) in the drug supply. Given the high risk for fatal overdose and delayed wound healing associated with the injection of fentanyl and xylazine (Montero et al., 2022), there is a need to identify the characteristics of people at-risk for abscesses and the factors that may mitigate the health-related sequelae of drug injection in regions where these substances are endemic (Friedman et al., 2022; Hedegaard 2018; Montero et al., 2022; Singh et al., 2020). To fill these research gaps, we aimed to assess trends in the prevalence of injection-associated abscesses and explore risk and protective factors for abscesses among PWID in regions of Massachusetts where fentanyl and xylazine are present in the drug supply.

2. Methods

2.1. Setting and design

Between 2017–2022, we conducted a mixed-methods study of people who use drugs in Massachusetts. The goals of the parent study were to learn from participants to improve programs and policies to prevent overdose. Informed by statewide overdose trends ("SUDORS Dashboard: Fatal Overdose Data" 2022), the present analysis focuses on data collected from 2019 to 2022 in nine high-overdose-risk communities: Boston, Chicopee, Cape Cod, Lawrence, Lowell, New Bedford, North Shore (Beverly, Lynn, Peabody, Salem), Quincy, and Springfield. As described elsewhere (Hughto et al., 2022; 2023), we partnered with community organizations (e.g., SSPs, homeless shelters, community clinics) and employed purposive sampling to recruit participants with demographic characteristics roughly proportional to that of overdose decedents in each community according to the statewide data. This approach prioritized the recruitment and enrollment of participants who were diverse in terms of age, race, ethnicity, primary drug of choice, and neighborhood of residence.

Individuals were eligible for the study if they were age 18 or older; residing in a study community; and reported past 30-day illicit drug use. Individuals who only used cannabis were ineligible as cannabis is legal in Massachusetts.

Once consented, all participants completed a one-time, interviewer-administered survey, lasting approximately 45 min. To adequately contextualize the survey data in each geographic location, approximately 15–20 in-depth interviews were conducted with survey participants per site (~one-third of all participants). Using an embedded mixed-methods design (Schoonenboom and Johnson 2017), survey participants were invited to complete an interview if they demonstrated a willingness to discuss their substance use and abscess history during the survey. Interviews covered the topics assessed by the survey in greater depth. Most data were collected in English; a subset was in Spanish. Participants received a $20 gift card for the survey and another for the interview. The study was approved by the Boston University Medical Center and Brandeis University Institutional Review Boards.

2.2. Survey measures

The parent surveys asked about socio-demographic attributes, drug use, and drug-related health consequences such as abscesses. Collectively, this work is guided by the Behavioral Model of Vulnerable Populations (Gelberg et al. 2000) which, alongside a review of current literature, was referenced to help select variables included in this analysis.

2.3. Independent variables

2.3.1. Socio-demographics

Age categorically assessed as 18–35 and >35. Race was assessed as: Black/African American/Cape Verdean, White Only, Multi-Racial, Native American, Another Race, and Asian Only. Hispanic ethnicity (yes/no) was also assessed. Gender categories included: male, female, transgender, or another gender. Housing status was categorized as housed vs. unhoused. We defined unhoused status as living in an abandoned building, tent, street, park, train station, or car; all other responses were considered housed.

2.3.2. Substances use

Participants were asked (yes/no) if they had used any of the following in the past 30 days: crack, cocaine, alcohol, buprenorphine (prescription), buprenorphine (non-prescription), methadone (prescribed, through opioid treatment program), amphetamines, benzodiazepines, fentanyl, heroin, methamphetamine, cannabis, tobacco, pain medication (prescribed or non-prescribed), and another substance (please specify).

2.3.3. Drug use practices

Past 30-day drug injection (yes/no) was assessed. Participants reporting a drug injection history were asked about injection frequency (daily or more, weekly, monthly); number of injections per syringe; and

primary syringe source (SSP, pharmacy, on street, friend, dealer, bodega, family, other). Participants were also shown an outline of a human body and asked to indicate where they inject; locations included: stomach, front calf/shin, back calf, palm-side wrist, chest, fingers, groin, upper leg, back-of-hand, forearm, foot/toes, neck, glute.

2.4. Outcome

2.4.1 Abscess History. Participants with past-30-day injection drug use were asked if they had ever had an "abscess, ulcer, or cellulitis form at the site of injection" (yes/no); and, if yes, when one last formed (<1 month, 1 month-1 year, >1 year, never). In interviews, participants never referenced cellulitis and described both open (ulcers) and closed (abscesses) as one and the same; thus, we use the term abscess throughout.

2.5. Analysis

2.5.1. Quantitative

Quantitative analyses were performed using Jamovi v2.3 (Sydney, Australia). Since only PWID received questions about abscesses, the sample was restricted to those with past-30-day injection drug use (n = 297). Chi-square tests were used to test for global differences between the independent variables and abscess history. Chi-square linear-by-linear tests explored associations between independent variables and abscess recency. Small cell sizes (<5) were analyzed via Fisher-Freeman-Halton Exact Tests. The Kruskal-Wallis one-way analysis of variance test examined the association between number of injections-per-syringe and abscess recency, which we also explored through nonparametric correlation tests. The percent of abscesses within the last calendar year (2019–2022) was calculated. To account for minimal data collection taken during the 2020 COVID-19 pandemic, the total abscesses reported within one year were separated into two equal time periods of data collection (Feb 2019-Sept 2020, Oct 2020-April 2022) and analyzed via Chi-square tests. All statistical tests considered Type I error rate with $p<0.05$.

2.5.2. Qualitative

Extensive details on the qualitative analysis procedures can be found elsewhere (Hughto et al., 2022). Briefly, the interviews were recorded, transcribed, entered into NVivo (QSR, International, Version 12), and analyzed using an inductive and deductive approach. First, an initial codebook was created using the interview guide domains (e.g., injection drug use, abscess history). The transcripts were then reviewed and open-coded for emerging themes. Through a series of team meetings and ongoing transcript review, emerging themes were integrated into the codebook. Using Nvivo, two experienced research assistants coded the transcripts using a rapid, first-cycle coding approach (Saldaña 2016). A total of 25% of the transcripts were double-coded for consistency in coding application. The coders met weekly with the third author to review the application of the codes and revise the codebook/coding application as necessary. As an initial data integration step, the second author identified transcripts with an abscess code and applied another layer of codes based on the quantitative variables used in this analysis and emerging related themes (e.g., injection frequency, injection location). Using *complementarity and expansion* contextual analysis (Schoonenboom and Johnson 2017), the coded interviews were used to illustrate, elaborate, and extend the quantitative findings. Mirroring our analytical steps, the quantitative results are presented first and later integrated into the qualitative findings below.

3. Results

3.1. Quantitative results

3.1.1. Participant characteristics

Overall, 65.3% (n = 194) of the sample reported having an abscess at an injection site (Table 1). Heroin, fentanyl, cocaine, and crack use were more common than methamphetamine use. No participants reported xylazine use (i.e., "other drug") in the survey. SSPs were the primary syringe source for 63.8% of participants.

3.1.2. Abscess history over time

The proportion of participants with a past-year abscess increased over the data collection period (Table 2). When survey collection was equalized into two time periods, there was a significant difference in past-year abscess experience, indicating a 57.2% increase in the proportion of PWID reporting past-year abscess in period two compared to period one.

3.1.3. Risk and protective factors related to abscess formation

As shown in Table 3, abscess history and more recent abscesses were associated with frequent injecting, methamphetamine and crack use, and injection into the neck or back of the calf. Overall, lifetime abscess history was associated with past-30-day fentanyl use, and current prescribed methadone use was associated with a lower proportion of recent abscesses.

3.2. Qualitative results

3.2.1. Abscess risk factors

Frequent injection was pervasive in this sample, with many interview participants linking this practice to the emergence of fentanyl in the drug supply. One male participant shared:

> "See, with the fentanyl, that's different to me, that's different from heroin. Because, heroin, you don't have to need a shot every two hours. With the fentanyl, it just changed the game. Now you need to do heroin, fentanyl, or whatever you want to call it, they're, like chasing it. Like, every two hours or so, they're getting high."

Several participants also alluded to concerns about fentanyl inducing a strong, sedating experience. For instance, in 2021, a male participant noted:

> "It [fentanyl] terrifies me, I think the word is petrify… This [fentanyl] is all brand new to me, even to this day, you know? I don't know what it is, besides it's a tranquilizer."

Although prior research from this and other studies (Ciccarone 2021; Hughto et al., 2023; Jones et al., 2020) have linked fentanyl to an uptick in stimulant use, and methamphetamine and crack use was quantitatively linked to abscess experiences in the present analysis, participants did not explicitly draw a connection between stimulant use and abscesses in interviews. However, due to fentanyl's short half-life, PWID may need to inject more frequently to avoid withdrawal symptoms, therefore introducing more opportunities for skin infections (Jones et al., 2020; Sanchez et al., 2021). To that end, the quantitative analyses found an association between frequent injecting and abscesses, and many participants reported limited access to new, sterile syringes and SSPs. Further, in interviews, many participants described dull syringes as painful and a risk factor for missing veins and more frequent injections. One male participant shared:

Usually if I've used [a syringe] a couple times or a lot of times…if one ended up getting clogged or just didn't feel as sharp. You can feel it when you put it in. They start to get dull. Especially, when I was using heavily, the skin was not as smooth.

Similarly, a female participant spoke about the dangers of using dull syringes as well as reported sharing syringes – a well-documented risk factor for infection (Jawa et al., 2021; Kerr et al., 2010; Sanchez et al., 2021). She shared:

> "I use dull syringes sometimes…Where it pokes, and that's dangerous. You could puncture your vein, you know? Make it collapse. Anything…it's crazy. I used dirty water…off the buildings,

Table 1
Characteristics of the sample among people who inject drugs in Massachusetts, 2019–2022 ($N = 297$).

SOCIO-DEMOGRAPHICS	N	%
Age ($n = 297$)		
18–35	142	47.8
>35	155	52.2
Gender ($n = 297$)		
Female	142	47.8
Male	150	50.5
Transgender or Another Gender	5	1.7
Race ($n = 297$)		
White Only	171	57.6
Black, African American, or Cape Verdean	49	16.5
Another Race	42	14.1
Multi-racial	29	9.8
Native American	6	2.0
Hispanic Ethnicity ($n = 297$)	89	30.0
Unhoused ($n = 290$)	95	32.8
DRUG TAKING PRACTICES		
Injection Frequency ($n = 295$)		
Daily or More	236	80
Weekly	42	14.2
Monthly	17	5.8
Primary Syringe Source ($n = 293$)		
Syringe or Needle Exchange	187	63.8
Pharmacy	71	24.2
Other	35	11.9
Use of Syringe Exchange Program ($n = 297$)	232	78.1
Mean (SD) injections per Syringe ($n = 293$)		4.0 (5.5)
ABSCESS EXPERIENCE	**N**	**%**
Ever had Skin Infection ($n = 297$)	194	65.3
Most Recent Skin Infection ($n = 295$)		
< 1 Month	60	20.3
1 Month through 1 Year	71	24.1
> 1 Year	61	20.7
Never	103	34.9
SUBSTANCES USED	**N**	**%**
Heroin Use – Past 30 Days ($n = 297$)	258	86.9
Cocaine Use – Past 30 Days ($n = 297$)	212	71.4
Fentanyl Use – Past 30 Days ($n = 297$)	209	70.4
Tobacco Use – Past 30 Days ($n = 297$)	208	70.0
Crack Use – Past 30 Days ($n = 297$)	202	68.0
Cannabis Use – Past 30 Days ($n = 297$)	138	46.5
Alcohol Use – Past 30 Days ($n = 297$)	91	30.6
Prescription Methadone Use – Current ($n = 267$)	80	30.0
Benzodiazepines Use – Past 30 Days ($n = 297$)	78	26.3
Pain Medication – Past 30 Days ($n = 297$)	47	15.8
Prescription Buprenorphine Use – Past 30 Days ($n = 297$)	47	15.8
Methamphetamine Use – Past 30 Days ($n = 297$)	46	15.5
Amphetamines Use – Past 30 Days ($n = 297$)	23	7.7
Nonprescription Buprenorphine Use – Past 30 Days ($n = 297$)	23	7.7
Other Drug – Past 30 Days ($n = 235$)	17	7.2
INJECTION LOCATION (select all that apply)	**N**	**%**
Forearm ($n = 251$)	208	82.9
Wrist, Palm Side ($n = 251$)	69	27.5
Neck ($n = 251$)	57	22.7
Hand, Back ($n = 251$)	44	17.5
Feet or Toes ($n = 251$)	30	12.0
Fingers ($n = 251$)	24	9.6
Calf, Front (Shin) ($n = 251$)	21	8.4
Calf, Back ($n = 251$)	14	5.6
Leg, Upper ($n = 251$)	12	4.8
Chest ($n = 251$)	7	2.8

Note: Table reports all study variables where $n>5$.

you know? I've done a lot. Shared needles. I thought [I], cleaned them. Sometimes I didn't."

Participants also shared where and why they prefer to inject in specific parts of their bodies, including their legs and necks. One female participant noted:

> "I don't have any veins left on my arms, my hands, or my legs…I don't know if I have really bad blood. I guess I don't have low blood pressure or whatever it is. So, using, like my needles instantly clog. Like even hospitals have a hard time getting my veins. So, I went right to my neck."

Table 2
Number and percentages of PWID reporting abscess within 1 year of survey date, by year and equalized survey periods, Massachusetts, 2019–2022 ($n = 297$).

Calendar Year	Number reporting no abscess within 1 year	Number reporting abscess within 1 year	Total sample size per survey period	% abscess in survey period
2019	121	70	191	36.6%
2020	3	5	8	62.5%
2021	29	24	53	45.3%
2022	11	34	45	75.6%
Equalized Survey Periods				
Feb 2019 – Sept 2020	122	73	195	37.4%
Oct 2020 – April 2022	42	60	102	58.8%

Several participants described the health hazards of injecting with one female participant noting that her shift to neck injections made her reflect on the bodily harms of injection drug use. She noted:

> "I shoot the cocaine in my neck. And it's kind of getting to the point where I'm getting scared. Because, I'm really thinking about what I'm doing to my body."

3.2.2. Barriers to abscess treatment & related health harms

To enhance and extend the quantitative findings, the relationship between abscesses and healthcare and treatment utilization was qualitatively explored. Several participants spoke about their approach to treating abscesses. One approach was avoidance and delayed care, oftentimes because of the stigma associated with injecting. One male participant shared:

> "It's just the whole politics behind it. Basically, the fear of, you know, just getting looked down on, and I've experienced it once and it was horrible. So that was, like, I carried that image with me going to the Emergency Room. Like, everybody's, right there…in the bubble and just looking at you, giving you the familiar look of someone that doesn't fit in, but like…It's not shame or embarrassment, it's more like disappointment, you know what I mean? I'm disappointed in myself that I got to this point of having the mainstream look down on me."

Similarly, another participant discussed how past experiences of stigma caused them to delay abscess care with adverse consequences, stating:

> "The doctor was so mean to me. I put off going because I was an addict and I didn't want to go to the hospital, but when I finally went, it was really bad, and they had to cut it open and whatever and the doctor was just really rude to me about it and telling me like, 'This is what's going to happen if you keep using."

Participants also reported attempting to self-treat their abscesses, often ineffectively. One male participant reported:

> "Right away [the abscess] bubbled and my arm got bigger and bigger and I was like holy shit 'cause before it happened and it goes away after a day or two. It'll be a little sore, but they go away. So, I'm like oh, man, that's crazy. It'll probably go away and I put it off for a couple of days. I was just shooting in this arm and then my arm blew up like this, so I said oh, and it hurt. It was so much pressure. I figured I'll drain it myself with my needles you know? And I put it in and I

Table 3
Results of abscess recency by characteristic among participants who indicated injection drug use in the 30 days prior to the survey, Massachusetts, 2019-2022.

SOCIO-DEMOGRAPHICS	<1 mo n=60 (%)	1 mo – 1 yr n=71 (%)	>1 yr n=61 (%)	Never n=103 (%)	Chi Square *p*-value
Age (n = 295)					2.22 (df = 3)
18-35	31 (51.7%)	34 (47.9%)	24 (39.3%)	51 (49.5%)	0.529
>35	29 (48.3%)	37 (52.1%)	37 (60.7%)	52 (50.5%)	.11 (df = 1)
					0.742
Gender (n = 295) †					6.07
Female	28 (46.7%)	38 (53.5%)	31 (50.8%)	43 (41.7%)	0.365†
Male	30 (50.0%)	33 (46.5%)	28 (45.9%)	59 (57.3%)	.544 (df = 1)
Transgender or Another Gender	2 (3.3%)	0 (0.0%)	2 (3.3%)	1 (1.0%)	0.475
Race (n = 294)					11.0 (df = 12)
White Only	36 (60.0%)	41 (58.6%)	41 (67.2%)	51 (49.5%)	0.529
Black, African American, or Cape Verdean	7 (11.7%)	13 (18.6%)	6 (9.8%)	23 (22.3%)	.143 (df = 1)
Another Race	10 (16.7%)	8 (11.4%)	7 (11.5)	16 (15.5%)	0.705
Multi-racial	5 (8.3%)	8 (11.4%)	5 (8.2%)	11 (10.7%)	
Native American	2 (3.3%)	0 (0.0%)	2 (3.3%)	2 (1.9%)	
Hispanic Ethnicity (n= 295)					3.02 (df = 3)
No	37 (61.7%)	49 (69.0%)	46 (75.4%)	74 (71.8%)	0.389
Yes	23 (38.3%)	22 (31.0%)	15 (24.6%)	29 (28.2%)	1.891 (df = 1)
					0.169
Housing Status (n = 288)					3.09 (df = 3)
Unhoused	22 (37.9%)	26 (36.6%)	20 (33.3%)	26 (26.3%)	0.377
Housed	36 (62.1%)	45 (63.4%)	40 (66.7%)	73 (73.7%)	2.820 (df = 1)
					0.093

DRUG TAKING PRACTICES	<1 mo	1 mo – 1 yr	>1 yr	Never	Chi Square *p*-value
Injection Frequency (n = 293)					**12.8 (df = 6)**
Daily or More	53 (88.3%)	60 (85.7%)	44 (72.1%)	77 (75.5%)	**0.046**
Weekly	5 (8.3%)	7 (10.0%)	15 (24.6%)	15 (14.7%)	**6.036 (df = 1)**
Monthly	2 (3.3%)	3 (4.3%)	2 (3.3%)	10 (9.8%)	**0.014**
Syringe Source (n = 291)					24.5 (df = 21)
Syringe or Needle Exchange	40 (66.7%)	47 (66.2%)	38 (65.5%)	61 (59.8%)	0.269
Pharmacy	10 (16.7%)	14 (19.7%)	17 (29.3%)	29 (28.4%)	.017 (df = 1)
Other	10 (16.7%)	10 (14.1%)	3 (5.2%)	12 (11.8%)	0.895
Use of Syringe Exchange Program (n=295)					6.29 (df = 3)
No	8 (13.3%)	19 (26.8%)	10 (16.4%)	28 (27.2%)	0.098
Yes	52 (86.7%)	52 (73.2%)	51 (83.6%)	75 (72.8%)	2.297 (df = 1)
					0.130
Injections per Syringe (n=292)	**Median (IQR)**	**Median (IQR)**	**Median (IQR)**	**Median (IQR)**	**One-Way ANOVA Kruskal-Wallis, Non-Parametric Correlation**
	2 (3)	2 (2)	2 (3)	2 (2)	6.733 (df = 3)
					0.866
					r(290) = -.016
					0.785

SUBSTANCES USED	<1 mo n (% of sample)	1 mo – 1 yr n (% of sample)	>1 yr n (% of sample)	Never n (% of sample)	Chi Square *p*-value
Heroin Use – Past 30 Days (n=295)					0.910 (df = 3)
No	7 (11.7%)	8 (11.3%)	10 (16.4%)	14 (13.6%)	0.823
Yes	53 (88.3%)	63 (88.7%)	51 (83.6%)	89 (86.4%)	.296 (df = 1)
					0.587
Cocaine Use – Past 30 Days (n=295)					3.93 (df = 3)
No	23 (38.3%)	18 (25.4%)	15 (24.6%)	27 (26.2%)	0.27
Yes	37 (61.7%)	53 (74.6%)	46 (75.4%)	76 (73.8%)	1.905 (df = 1)
					0.168
Fentanyl Use – Past 30 Days (n=295)					**10.2 (df = 3)**
No	24 (40.0%)	20 (28.2%)	9 (14.8%)	34 (33.0%)	**0.017**
Yes	36 (60.0%)	51 (71.8%)	52 (85.2%)	69 (67.0%)	.800 (df = 1)
					0.371
Tobacco Use – Past 30 Days (n=295)					2.46 (df = 3)
No	13 (21.7%)	22 (31.0%)	18 (29.5%)	34 (33.0%)	0.483
Yes	47 (78.3%)	49 (69.0%)	43 (70.5%)	69 (67.0%)	1.766 (df = 1)
					0.184
Crack Use – Past 30 Days (n=295)					4.79 (df = 3)
No	14 (23.3%)	20 (28.2%)	20 (32.8%)	40 (38.8%)	0.188
Yes	46 (76.7%)	51 (71.8%)	41 (67.2%)	63 (61.2%)	**4.755 (df = 1)**
					0.029
Marijuana Use – Past 30 Days (n=295)					1.02 (df = 3)
No	32 (53.3%)	36 (50.7%)	36 (59.0%)	54 (52.4%)	0.797
Yes	28 (46.7%)	35 (49.3%)	25 (41.0%)	49 (47.6%)	.013 (df = 1)
					0.908

(*continued on next page*)

Table 3 (*continued*)

SUBSTANCES USED	<1 mo n (% of sample)	1 mo – 1 yr n (% of sample)	>1 yr n (% of sample)	Never n (% of sample)	Chi Square *p*-value
Alcohol Use – Past 30 Days (n=295)					1.33 (df = 3)
No	42 (70.0%)	47 (66.2%)	40 (65.6%)	75 (72.8%)	0.723
Yes	18 (30.0%)	24 (33.8%)	21 (34.4%)	28 (27.2%)	.284 (df = 1)
					0.594
Prescription Methadone Use – Current (n=265)					**8.20 (df = 3)**
No	45 (81.8%)	46 (71.9%)	32 (57.1%)	63 (70.0%)	**0.042**
Yes	10 (18.2%)	18 (28.1%)	24 (42.9%)	27 (30.0%)	2.702 (df = 1)
					0.100
Benzodiazepines Use – Past 30 Days (n=295)					2.87 (df = 3)
No	46 (76.7%)	53 (74.6%)	40 (65.6%)	79 (76.7%)	0.412
Yes	14 (23.3%)	18 (25.4%)	21 (34.4%)	24 (23.3%)	.013 (df = 1)
					0.911
Pain Medication – Past 30 Days (n=295)					1.37 (df = 3)
No	50 (83.3%)	58 (81.7%)	50 (82.0%)	90 (87.4%)	0.713
Yes	10 (16.7%)	13 (18.3%)	11 (18.0%)	13 (12.6%)	686 (df = 1)
					0.407
Prescription Buprenorphine Use – Past 30 Days (n=295)					2.37 (df = 3)
No	50 (83.3%)	58 (81.7%)	49 (80.3%)	91 (88.3%)	0.499
Yes	10 (16.7%)	13 (18.3%)	12 (19.7%)	12 (11.7%)	.935 (df = 1)
					0.334
Methamphetamine Use – Past 30 Days (n=295)					**15.8 (df = 3)**
No	50 (83.3%)	50 (70.4%)	56 (91.8%)	93 (90.3%)	**0.001**
Yes	10 (16.7%)	21 (29.6%)	5 (8.2%)	10 (9.7%)	**5.830 (df = 1)**
					0.016
Amphetamines Use – Past 30 Days (n=295)					1.67 (df = 3)
No	54 (90.0%)	64 (90.1%)	58 (95.1%)	96 (93.2%)	0.643
Yes	6 (10.0%)	7 (9.9%)	3 (4.9%)	7 (6.8%)	.944 (df = 1)
					0.331
Nonprescription Buprenorphine Use – Past 30 Days (n=295)					0.627 (df = 3)
No	55 (91.7%)	67 (94.4%)	56 (91.8%)	94 (91.3%)	0.89
Yes	5 (8.3%)	4 (5.6%)	5 (8.2%)	9 (8.7%)	.124 (df = 1)
					0.725
Other Drug – Past 30 Days (n=234) †					1.41
No	43 (95.6%)	52 (89.7%)	49 (94.2%)	73 (92.4%)	0.711†
Yes	2 (4.4%)	6 (10.3%)	3 (5.8%)	6 (7.6%)	0.051 (df = 1)
					0.821

INJECTION LOCATION (select all that apply)	<1 mo	1 mo – 1 yr	>1 yr	Never	Chi Square *p*-value
Forearm (n=250)					2.83 (df = 3)
No	5 (11.4%)	12 (22.6%)	8 (13.8%)	18 (18.9%)	0.418
Yes	39 (88.6%)	41 (77.4%)	50 (86.2%)	77 (81.1%)	.339 (df = 1)
					0.560
Wrist, Palm Side (n=250)					5.15 (df = 3)
No	28 (63.6%)	41 (77.4%)	38 (65.5%)	74 (77.9%)	0.161
Yes	16 (36.4%)	12 (22.6%)	20 (34.5%)	21 (22.1%)	1.677 (df = 1)
					0.195
Neck (n=250)					**8.91 (df = 3)**
No	29 (65.9%)	37 (69.8%)	47 (81.0%)	81 (85.3%)	**0.03**
Yes	15 (34.1%)	16 (30.2%)	11 (19.0%)	14 (14.7%)	**8.548 (df = 1)**
					0.003
Hand, Back (n=250)					1.46 (df = 3)
No	37 (84.1%)	45 (84.9%)	45 (77.6%)	80 (84.2%)	0.692
Yes	7 (15.9%)	8 (15.1%)	13 (22.4%)	15 (15.8%)	.018 (df = 1)
					0.892
Feet or Toes (n=250)					3.29 (df = 3)
No	40 (90.9%)	43 (81.1%)	51 (87.9%)	86 (90.5%)	0.348
Yes	4 (9.1%)	10 (18.9%)	7 (12.1%)	9 (9.5%)	.362 (df = 1)
					0.547
Fingers (n=250)					2.55 (df = 3)
No	40 (90.9%)	47 (88.7%)	50 (86.2%)	89 (93.7%)	0.466
Yes	4 (9.1%)	6 (11.3%)	8 (13.8%)	6 (6.3%)	.467 (df = 1)
					0.494
Calf, Front (Shin) (n=250) †					4.22
No	40 (90.9%)	47 (88.7%)	51 (87.9%)	91 (95.8%)	0.233†
Yes	4 (9.1%)	6 (11.3%)	7 (12.1%)	4 (4.2%)	1.545 (df = 1)
					0.214
Calf, Back (n=250) †					5.077
No	40 (90.9%)	48 (90.6%)	55 (94.8%)	93 (97.9%)	0.152†
Yes	4 (9.1%)	5 (9.4%)	3 (5.2%)	2 (2.1%)	**4.237 (df = 1)**
					0.040
Leg, Upper (n=250) †					2.675
No	41 (93.2%)	49 (92.5%)	57 (98.3%)	91 (95.8%)	0.439†
Yes	3 (6.8%)	4 (7.5%)	1 (1.7%)	4 (4.2%)	

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Table 3 (*continued*)

INJECTION LOCATION (select all that apply)	<1 mo	1 mo – 1 yr	>1 yr	Never	Chi Square *p*-value
					.993 (df = 1)
					0.319
Chest (n=250) †					0.709
No	43 (97.7%)	51 (96.2%)	57 (98.3%)	92 (96.8%)	0.954†
Yes	1 (2.3%)	2 (3.8%)	1 (1.7%)	3 (3.2%)	.010 (df = 1)
					0.922

Note: The first test statistic in each cell is Pearson's Chi Square Test and the second test is Chi Square Linear-by-Linear Association unless otherwise noted. An † indicates Fisher-Freeman-Halton Exact Test was run due to small sample size. Bolded *p*-value = significant at $p < 0.05$. Table reports all study variables where $n>5$. Because some syringe sources were uncommon, we collapsed responses for syringe source to SSP, pharmacy, or other when conducting bivariate analysis.

drained it myself a little bit and then the blood would start trickling out with like a little bit of pus and shit and it would smell and I was like oh, all right that's clean, you know? Next time I drain out maybe I'll be better. Before long all the spots I stabbed to drain it turned into a big purple nipple."

Similar to others, the same male participant explained how his self-treatment resulted in a serious infection that eventually needed to be treated by medical specialists.

"It was huge and it popped on my arm. When it popped there was a big hole in my muscle. You could see my muscles and my nerves. All like tendons and shit. And I wrapped it with toilet paper 'cause addict behavior, like I wrap it with toilet paper and the smell that was coming out I had to get rid of-I was wearing a winter coat in the middle of June. […] I was like I'll go to the hospital after I get high and I'll have some shit with me to bring to [the hospital], which I did. When the nurse unwrapped it, 'cause I had it wrapped like a mummy. I kept just wrapping it every time and I saw it. It was all like chunky skin, like all inflamed."

Together, these mixed-methods findings highlight risk and protective factors associated with injection-related abscesses, barriers to abscess treatment, and related threats to health.

4. Discussion

In surveying PWID in Massachusetts from 2017 to 2022, we found that abscess is a common experience, with many participants indicating recent abscesses. Over the period of serial cross-sectional data collection, an increasing percentage of PWID reported a recent abscess with specific behavioral and substance-related risk factors, including frequent injection, use of fentanyl, crack, and methamphetamine, and using the neck and back calf/shin as injection sites. The use of prescribed methadone, a medication for treating opioid use disorder, appeared to be protective against abscess occurrence, though in the absence of qualitative data to contextualize this relationship, more research is needed. Still, our qualitative data served to contextualize most of the quantitative results, by linking specific injection practices and fentanyl in the drug supply to increased injection frequency and the formation of abscesses. Our findings extend results reported by a hospital-based study of urine drug screens from suspected PWID, which found fentanyl to be positively associated with abscesses and infected wounds (Lloyd et al., 2021). The interview data also extended the survey findings by describing stigma as a barrier to abscess treatment and the health harms associated with self-treating or delaying medical care for abscesses. These findings have implications for future research and needed harm reduction and treatment interventions.

Local injury and inflammation from suboptimal injection practices decrease blood flow, cause thrombosis, and delay wound healing (Del Giudice 2004; Sanchez et al., 2021). In combination with unsanitary supplies and environments, each episode of injection poses significant risks to abscess formation. Our quantitative finding of injection frequency and increased prevalence of recent abscesses support these mechanisms. Our qualitative results also indicate that participants reported missing veins and re-using supplies, which have been shown to increase tissue injury and contribute to the inflammation that can cause wounds (Robertson et al., 2021; Smith et al., 2015). Additionally, we found a quantitative association between neck injections and increased abscesses. Existing literature suggests that the neck poses a high risk of abscess due to its larger size, allowing for pathogens to spread quickly, with proximity to many important structures, including the carotid arteries and jugular veins (Rafful et al., 2015). Interventions for safer drug use practices should be expanded, including overdose prevention sites (Potier et al., 2014), where injection episodes could occur under more hygienic, less rushed, and supervised conditions.

Our quantitative findings also found more recent abscesses among participants who used methamphetamine and crack cocaine. There is an increasing prevalence of methamphetamine in the Northeast (Wakeman et al., 2021), which may promote abscess formation when injected (Salamanca et al., 2015). Broader access to safer smoking materials for people who inject stimulants, opioids, and other drugs as a means to encourage transitions to smoking may also serve to reduce abscess experiences (Fitzpatrick et al., 2022; Kral et al., 2021). Further, existing literature emphasizes syringe reuse as a common practice related to abscess formation (Ropelewski et al., 2011; Smith et al., 2015). We found that syringe reuse occurs with individual drug injection and through sharing with other PWID, with participants recognizing the adverse consequences of re-using syringes. Moreover, many of the communities where data were collected lacked an SSP, and participants named non-SSP locations as their main source of syringes. No-cost, anonymous access to new sterile syringes and the infection prevention education shared through the operation of SSPs reduce syringe reuse, promote injection hygiene, stop the spread of blood-borne diseases, and mitigate the risk of abscesses (Bluthenthal et al., 2000). Thus, expanding SSPs to more of the study communities could meaningfully reduce rates of abscesses and allow for additional points of contact for PWID to get connected to care.

Additionally, we found that stigmatizing interactions with healthcare providers led some participants to delay treatment for abscesses and engage in efforts to self-treat their abscesses – a form of makeshift medicine (Kelly et al. 2023) that may be ineffective and lead to health complications (Monteiro et al., 2020). Our findings align with prior research that documents provider bias, fear of deception or dangerous behavior, and lack of adequate training as potential reasons PWID avoid seeking medical attention for abscess (Brener et al., 2010; van Boekel et al., 2013). As described by participants in our study, PWID may drain or treat abscesses without adequate training or sterile equipment, which further traumatizes the skin, delays wound healing, and provides an opportunity for infection (Monteiro et al., 2020). Because of these barriers to care, wounds may become harder to treat as they spread from local infection into surrounding structures and the blood. Advanced infection is associated with more serious complications, such as sepsis, infectious endocarditis, gangrene, and loss of life or limbs (Sanchez et al., 2021). Our findings underscore the need for low-barrier wound care, particularly in light of the unprecedented levels of drug contaminants such as xylazine entering the illicit drug supply (Singh et al.,

2020). However, it is worth noting that even low-barrier harm reduction staff may be ill-equipped for wound care provision of the type and severity we have documented; thus, primary and emergency room clinicians should receive training in implicit and explicit bias and trauma-informed care in order to reduce stigma and facilitate engagement in care by PWID with abscesses.

Finally, the emergence of new adulterants, like xylazine, in the fentanyl supply and its relationship to abscess risk was difficult to discern using these self-reported data. Only interview data from the most recent data collection period made mention of the tranquilizing effects of fentanyl, suggesting a possible nascent emergence and awareness of the adulteration of fentanyl with xylazine. Since xylazine blends with other white powder drugs, it is often after exposure that its presence can be deduced from acute symptoms of oversedation and fast-growing ulcerative abscess (Ruiz-Colón et al., 2014). However, in the absence of biological samples or objective testing of the drug samples used by participants, measurement and confirmation of participants' true exposure to fentanyl is limited. Whether xylazine, a new fentanyl analog, or another substance, our observations are consistent with previous findings that PWID may be unaware and unprepared to navigate exposure to novel substances in their drugs (Alexander et al., 2022; Friedman et al., 2022; "Massachusetts Drug Supply Stream (MADDS) 2022; Singh et al., 2020). The increase in abscess prevalence in our results suggests the vital role of community drug checking to monitor the drug supply and educate PWID and inform harm reduction measures. Future studies should include drug checking, and directly assess knowledge and the health effects of xylazine and other adulterants in order to characterize the rapidly changing drug supply and its impact on the health of PWID.

Several limitations exist in this study. Given the nature of survey data, causality cannot be inferred from these results. Additionally, the impacts of COVID-19 disrupted data collection efforts, leading to fewer surveys and interviews between June 2020-June 2021, which may have influenced our data on abscess prevalence recency. Further, some variables had few responses, which may have restricted the power of the analyses. Finally, we acknowledge that data collection is subject to sampling bias based on the locations of the fieldwork chosen and who agreed to participate; thus, our findings may not be representative of all PWID.

5. Conclusions

Injection-related abscesses are an increasing concern among PWID and account for substantial morbidity and mortality (Cornford and Close 2016; Lloyd-Smith et al., 2010; See et al., 2020). As illustrated by this study, adulterants in the drug supply, injection practices, and barriers to care shape abscess risk. Interventions are needed along the continuum of drug use, including providing sterile injection materials, educating PWID on safer injection practices, checking the drug supply for contaminants, and reducing structural and stigma-related barriers to traditional and low-threshold medical care to reduce the acquisition of abscess and improve treatment outcomes for PWID.

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CRediT authorship contribution statement

Leah M. Benrubi: Writing – original draft, Writing – review & editing, Conceptualization, Investigation, Methodology, Formal analysis, Visualization. **Joseph Silcox:** Data curation, Project administration, Writing – original draft, Writing – review & editing, Data curation, Formal analysis. **Jaclyn Hughto:** Data curation, Writing – review & editing, Conceptualization, Data curation. **Thomas J. Stopka:** Conceptualization, Writing – review & editing. **Wilson R. Palacios:** Data curation, Conceptualization, Writing – review & editing. **Shikhar Shrestha:** Conceptualization, Writing – review & editing. **Patricia Case:** Data curation, Conceptualization, Writing – review & editing. **Traci C. Green:** Funding acquisition, Formal analysis, Conceptualization, Data curation, Project administration, Data curation, Supervision, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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