ORIGINAL ARTICLE

Laboratory study of the effectiveness of filters used by heroin injectors

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Abstract

Aims: (a) To compare in the laboratory the effectiveness of various filters at removing particles from heroin injections; (b) To measure the amount of heroin retained by the filters; and (c) To describe the relevance of these preliminary findings to future research.

Design: A laboratory-based investigation. Injections were prepared with street heroin obtained from the police, copying the methods of injectors. Pieces of cigarette filter, hand-rolling cigarette filter, cotton wool from buds and commercially produced syringe filters were tested. The Coulter Multisizer (IIe) was used to count and size particles; Capillary Zone Electrophoresis was used to measure the amount of heroin retained in the filters.

Findings: All methods of filtration reduced the amount of particles, with the commercially produced syringe filter producing the largest reduction. The syringe filter retained the most heroin after use; however, less drug material was evident on the spoon, suggesting further work is needed with a range of quantities. The cigarette, hand-rolling and cotton bud filters all retained some drug with no significant difference detected between the different filters.

Conclusions: This preliminary study suggests all the filters tested may convey health benefits. Further work is needed with varying quantities of drug, acid and water and to establish safety in use. Then future studies can establish the health consequences for injecting drug users from the use of such filters.

Keywords: Filter, injecting, heroin.

Unlike pharmaceutical injections, those prepared by injecting drug users (IDUs) are not subject to quality control. They may contain solid particles from street drug powders or tablets that are crushed and injected, which may present health risks. IDUs attempt to remove insoluble particles when preparing injections by filtering the prepared material through a makeshift filter. However, there is a lack of scientific evidence to inform advice on paraphernalia use. Research to inform practice is particularly important in light of the recent legislative changes in the UK, which permit the supply of certain items of injecting paraphernalia to IDUs (Siddiqui, 2003). This preliminary study began to address this need by exploring the effectiveness of filters used by IDUs.
Background

Some of the health problems reported in IDUs have been associated with the injection of insoluble particles. These include: the formation of foreign body granulomas (Ganesan et al., 2003; Posner & Guill, 1985; Shesser, Randall, & Olshaker, 1991; Stein, 1990), which present as localized or systemic hard “lumps; vascular irritation and inflammation (Stein, 1990; Wills, 1997). The first signs of damage are commonly referred to in the UK as “track marks” and may lead to collapsed veins; venous embolism (Shesser et al., 1991; Sternbach, Moran, & Eliastam, 1980), which may be due to obstruction of the vein or capillary with solid material or formation of a thrombus as a consequence of vascular irritation; and, finally, damage to right-side heart valves or cardiac endothelium, which has been linked to particle injecting and is associated with endocarditis (Haverkos & Lange, 1990).

IDUs are known sometimes to filter injections before they administer them. This is done in an attempt to remove insoluble particles that may block the needle, preventing injection. Some needle exchange services are known to supply filters, although there appears to be a lack of scientific evidence to inform the choice of filter type supplied. In theory, if the particle load of injections can be reduced through the use of an appropriate filter, the health risks from the injection of insoluble particles should be reduced. However, if the filter were to retain drug, it is unlikely that it would be acceptable to IDUs, as the psychoactive effects of the injection would be reduced.

Before filters can be tested in a clinical study to evaluate their effects on human health, it is important ethically to establish their theoretical performance, so that only filters likely to reduce harm and be acceptable to IDUs are tested on humans. When examining the effects of filters, it is important, therefore, to measure both their ability to remove particles and the amount of drug they retain. No previous research in this area could be found in the literature. This preliminary laboratory study had three aims: (1) to compare in the laboratory the effectiveness of various filters at removing particles from heroin injections; (2) to measure the amount of heroin retained by the filters; and (3) to describe the relevance of these findings to future research.

Methods

The injection preparation method

Semi-structured interviews were conducted with a quota sample of 20 IDUs attending Drugs Action, a needle exchange agency in the city of Aberdeen, north-east Scotland. Participants were asked to describe their injection preparation practices and the quantities and types of equipment used. Probing statements were used to prompt the interviewee only when necessary to ascertain information. Interviews were tape-recorded and transcribed and the data analysed to identify common practice and variables in the injection preparation process. The preparation process most commonly described was replicated in the laboratory to produce injections, as shown in Figure 1. Note the citric acid is used to convert the heroin, which is in base form to a soluble salt. This process has been explained elsewhere (Scott, Kennedy, Winfield, & Bond, 2000).

Four types of filter were tested. These are as follows, and are shown ready for use in Figure 2.

1. Quarter-pieces of cigarette filter (Lambert and Butler®, King Size). Cigarette filters were most commonly used by the interviewees.
2. Cotton wool removed from the stem of a cotton bud (Unichem Cotton Buds). These were also reported to be used by interviewees.

3. Whole hand-rolling cigarette filters (Rizla+ Extras\textsuperscript{\textregistered}, 7-mm acetate Streamline filter tips), selected because they were supplied by some needle exchange agencies.

4. Syringe filters (Sterile Acrodisc\textsuperscript{\textregistered}, 5 microns, Gelman Sciences, product no. 4199) of the type known to be supplied by some needle exchange agencies in Australia and New Zealand. This was chosen to allow comparison with a commercially produced filter.

The heroin used was obtained from Grampian Police, with permission from the Home Office and Crown Office. The heroin used for the experiments reported here was all from the same batch. Heroin was chosen for this study as it is the drug most commonly injected in Scotland according to national statistics (Scottish Drug Misuse Database). The prepared injections were analysed as follows.

**Particles size analysis method**

The Coulter Multisizer (Mark IIe) (Coulter Electronics) was used to count and size particles. The method was validated and the equipment calibrated before use. The Multisizer determines the number and size of particles within a selected preset size range. The range used for this work was between 2 and 60 \(\mu\text{m}\). This allowed detection of particles

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**Figure 1.** Preparation process used for heroin injections made in the laboratory.
within the size ranges of interest in pharmaceutical manufacturing, known to be of risk to health. The conductive fluid used was normal saline (room temperature), prepared in-house in 2-litre batches using 18 g of sodium chloride (Fison Scientific Equipment, Loughborough), dissolved in de-ionized water, prepared in-house using the Milli-Q ion exchange system (Millipore, Watford). The saline was filtered twice through 0.2-μm filter paper (German, Michigan, USA) to minimize particulate contamination. The Multisizer was set to count and measure linear diameter of the particles. Seventy-five millilitres of saline were added to the sampling beaker and a background count measured three times and the mean calculated. A 50-μl sample of injection was removed from the syringe immediately after preparation and added to the sampling saline, mixed by the automatic stirrer (speed 2) to keep particles in suspension. Analysis was performed immediately. The machine counted and sized the particles drawn through the orifice in a 12-s sampling time. The sample count was measured once and for each filter the experiment was repeated three times. The background count was subtracted from the total count to allow for its contribution. All samples were measured under the same conditions, allowing comparisons to be made between filters. Particles were grouped into size ranges. The size range 2–5 μm was selected because it would show the presence of particles smaller than lung capillaries (approx. 5 microns). The range 5–10 μm would show particles that may

Figure 2. The four types of filter tested in the laboratory shown ready for use in the preparation of heroin injections.
potentially block lung capillaries. The other sizes were set because the terminal arterioles of the vascular system are between 20 and 50 μm (Friedman, Klien, & Specter, 1996), so particles within these size ranges may block these small vessels. Three unfiltered injections were analysed and the average particle load calculated. The filters were compared by calculating the percentage reduction in particles that they produced compared with the unfiltered injections.

Method used to measure heroin retained by filters

The ISCO Model 3850 Capillary Electropherograph with built-in ultraviolet detectors was used to measure the amount of heroin (diamorphine) retained by the filters after use. The method was validated and equipment calibrated before use. The method reported by Taylor, Low, and Reid (1996) was followed, with the detection wavelength set at 220 nm to avoid interference with caffeine, which may be present in street heroin (Huizer, 1983; Kaa, 1991, 1994). Paracetamol would also not absorb. The capillary was unmodified silica, Lincoln ISCO Quality CE, 50 μm in diameter and 1 m in length. The equipment requires the use of an electrolyte. This comprised disodium hydrogen orthophosphate 100 mM, buffered to pH 6 with orthophosphoric acid (both AnalR grade, Fisons; Loughborough, UK), degassed by filtration through a 0.45 μm Acrodisc® (Gelman, MI, USA). The water used was prepared to HPLC grade in-house using a Millipore Milli-Q system. Diamorphine standard was used in validation (D. M. Wood, Aberdeen, UK). An internal standard (IS) was required to allow results to be compared. Levallorphan (D. M. Wood, Aberdeen, UK) was used, as it had similar mobility to the analytes of interest in the buffer used, so there would not be a long delay between IS peak and sample peak detection. A stock solution of levallorphan in methanol (HPLC grade, Ratheburn; Walkerburn, UK) at a concentration of 104 μg/ml was made. Low (1998) had shown that the first three injections from an aliquot of sample gave satisfactory linear response. Further injections lost linearity. Therefore, for each analysis the peaks from the initial electropherogram and two consecutive runs were measured. The peak height ratio of the sample peaks to the internal standard was calculated and the average ratio from the three runs taken. This average ratio was compared with results from standard diamorphine solutions and used to calculate the amount of diamorphine (heroin) retained by the filters.

The method of removing the retained heroin from the used filters was as follows. For the cigarette filter piece, the cotton bud and the hand-rolling cigarette filter, the used filter material was dropped in a 25-ml flask containing approximately 10 ml of methanol and shaken for 30 s. The filter was left in the solution. For the syringe filter, the filter was flushed twice into a 25-ml flask in both directions to wash both surfaces. The volume of methanol used for this was 10 ml (5 ml per flush). In all cases the resulting solution was immediately made up to 25 ml with methanol and analysed. Samples for analysis were prepared by mixing 1 ml of this methanolic solution with 1 ml of levallorphan standard solution and diluting with water to 10 ml. The calculated quantities of heroin released from the filters were compared statistically, using ANOVA and post hoc Tukey’s HSD test (95% c.i, one-way).

Results

Particles size analysis

Figure 3 shows the mean percentage reduction in particle count for each of the filters tested. Table I shows the mean particle size analysis results, for each size range of interest.
Amount of heroin retained in the filters

Table II shows the average quantities of heroin removed from the used filters.

Statistical analysis

ANOVA gave a significant $F$ ratio ($18.12$, $df=3$), indicating it appropriate to compare using post hoc Tukey’s HSD. This Tukey's HSD test (95% c.i, one-way) showed there to be a significant difference ($p<0.05$) between the amounts of diamorphine that was removed from the syringe filter and the amounts removed from all three of the makeshift filters (cigarette and syringe filter: $p=0.000$; hand-rolling filter and syringe filter: $p=0.01$; cotton bud and syringe filter: $p=0.000$). No significant differences were found between the makeshift filters.

Discussion

It is important to comment that the particles detected (Table I) do not represent the total number of particles in the prepared injections as samples of 50 $\mu$l of the injection were

![Figure 3. Percentage reduction in the number of particles in injections after filtration, taking the average total number of particles in unfiltered injections to be 100%.](image)

Table I. Average coincidence corrected particle count and average particle size distribution (shown to the nearest whole particle) in injections prepared with street heroin ($n=3$). (% of total number detected)

<table>
<thead>
<tr>
<th></th>
<th>Unfiltered injection</th>
<th>Cigarette filter</th>
<th>Hand-rolling filter</th>
<th>Cotton bud filter</th>
<th>Syringe filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$ avg.</td>
<td>2326</td>
<td>487</td>
<td>225</td>
<td>255</td>
<td>63</td>
</tr>
<tr>
<td>Particle size distribution:</td>
<td>avg. no. of particles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(% total $n$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2–5 $\mu$m</td>
<td>1895 (81.5)</td>
<td>477 (98.0)</td>
<td>210 (93.3)</td>
<td>208 (81.6)</td>
<td>59 (93.7)</td>
</tr>
<tr>
<td>5–10 $\mu$m</td>
<td>347 (14.9)</td>
<td>6 (1.2)</td>
<td>11 (4.8)</td>
<td>32 (12.5)</td>
<td>3 (4.8)</td>
</tr>
<tr>
<td>10–20 $\mu$m</td>
<td>7 (0.3)</td>
<td>4 (0.8)</td>
<td>4 (1.8)</td>
<td>11 (4.3)</td>
<td>2 (3.2)</td>
</tr>
<tr>
<td>20–50 $\mu$m</td>
<td>14 (0.6)</td>
<td>0</td>
<td>0</td>
<td>5 (2.0)</td>
<td>0</td>
</tr>
</tbody>
</table>
compared. Sampling was necessary because of the requirements of the machinery. The samples were added to saline and stirred, so some particles may have dissolved in this process. However, the analysis process was controlled, with the only variable being the type of filter used, so, therefore, on this basis, it is fair to compare the results to give an indication of the relative performance of the filter compared with an unfiltered injection (Figure 3). Although in diagnostic and formulation work this type of comparison would be inaccurate, it is appropriate for this work given that the particle count and distribution will vary greatly, depending on the batch of drug, the way it is prepared and the equipment used. Exact results are meaningless, so statistical comparison of values is inappropriate, but the overall trends give an indication of the effects of the filters. Additionally, the use of laser detection was not possible as the available equipment required a sample much larger than the volume of a prepared injection.

Table I shows the size distribution of the detected particles. All filters tended to remove larger particles and move the distribution of particles towards the smaller size ranges. Theoretically this suggests that the filters may reduce the risks of lung capillary blockage, so potentially reducing vascular damage. However, to reduce the risks of tissue granuloma formation around smaller particles (<5 microns), a filter with a smaller pore size would be needed to remove these particles. Attempts to use 0.2-micron and 0.45-micron syringe filters found that the filters blocked and the time and effort needed to filter the injections was considered likely to be unacceptable to IDUs.

The results in Table I show that the filtered injection samples gave significantly smaller particle counts compared with the unfiltered samples. The particles in all size ranges were reduced, which suggests potentially fewer health risks from blockage in the vascular system, where the smallest capillaries are approximately 5 microns. Further clinical work would, however, be necessary to test this theory. As can be seen from Table I and Figure 3, the syringe filter performed most favourably. This may be expected since it has a small pore size (5 microns) and is made for the purpose of filtering liquids from or to syringes. These filters are, however, costly compared with the makeshift filters. The makeshift filters all also produced a reduction in particulate contamination, suggesting they may also confer health benefits. However, further work is needed to explore the safety of using these makeshift filters, to answer questions such as ‘Do they shed fibres into the injection?’ or ‘Do they add contaminants to the injection?’

Table II shows that all filters retain some heroin after use. This is not surprising as it is known that some IDUs keep used filters for future use (Taylor, Fleming, Rutherford, & Goldberg, 2004). Data presented here quantifies what is already known and also shows that the syringe filter, although more effective at particle removal, could also promote sharing or reuse. This suggests that further work is needed to develop a commercial filter specifically for IDU use that removes particles but does not retain drug.

Statistically more heroin was removed from the syringe filter than the others; however, it was observed that the syringe filter left little residue on the spoon compared with the other
filters, so it probably drew up what remained when the other injections were filtered. Analysis of residue remaining on the spoons when makeshift filters were used confirmed this to contain heroin. It is likely also to contain other insoluble psychoactive alkaloids from the opium poppy. Further work would be necessary to explore the effects of this. Other undissolved materials may include poorly soluble bulking agents such as magnesium stearate (talc). The method of removing the drug from the syringe filter was different from that of the makeshift filters. This is because, had the syringe filter just been shaken in methanol, its plastic casing would have prevented adequate washing of the surfaces of the filter and 10 ml would not have been a large enough volume to submerge the filter. It can be argued that caution is needed in making this direct comparison owing to the difference in the method of removal used for the syringe filter compared with that used for the makeshift filters. However, in defence, both methods are likely to have removed the majority of the solid material from the filter. The data from the three makeshift filters can be compared without this concern and show that the quantity of heroin retained was not statistically different between them.

Sharing of used filters is of particular concern regarding the transmission of hepatitis C (Hagan et al., 2001; Thorpe et al., 2002). As said, the data suggest that there is a need for further research to establish an appropriate filter that does not retain drug and thereby does not promote reuse or sharing. However, the acceptability of such a filter to IDUs would need to be explored since the keeping of used filters for times when no drug is available is seen as a “back-up” by some IDUs (Taylor et al., 2004) and they may not wish to lose this.

A limit of this study is that only one combination of drug, water and acid quantities were tested. There is a need for further work to test a greater combination of quantities, to dissolve more of the drug material and to explore a wider range of injection preparation methods used by IDUs. A method of direct measure of particulate contamination would be advantageous. Additionally, work with other drugs known to be used by injectors (e.g. crack cocaine) would be useful. Future work in our laboratory will take forward these preliminary findings to undertake a more comprehensive study of the effectiveness and safety of injecting paraphernalia, informed by the recent work of Taylor et al. (2004). One concern highlighted by Taylor et al. is the storage and reuse of filters. More work is needed to examine the microbiological hazards of this practice.

Conclusions

This study has performed preliminary laboratory investigation into the effectiveness of filters used by IDUs. The data suggest that all the filters tested may potentially convey health benefits because they all removed significant amounts of particles. However, the safety of the makeshift filters requires further exploration before this theory can be tested on humans. All filters retained heroin when used, suggesting all have the potential to be reused or shared by IDUs. This raises concerns regarding the transmission of blood-borne viruses including hepatitis C and bacterial infections. It is not possible from this preliminary study to draw conclusions on the overall health impact of filters on IDUs, but the direction of future studies in this area has been better defined.

References


