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Fate and Behaviour of Gunshot Residue: Recreational Shooter Vehicle Distribution

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ABSTRACT: The susceptibility for recreational shooters to transfer gunshot residue (GSR) to both the interior and exterior of a vehicle is investigated. A comprehensive sampling protocol was used to assess the most likely areas of GSR transfer from recreational shooter contact, such as the steering wheel and the area the firearms were stored (the trunk). Up to 315 characteristic GSR particles were found in several locations throughout the interior of a vehicle. As many as 876 characteristic particles were found throughout a single vehicle. The data indicates that vehicles frequently occupied by firearms users are a potential source for inadvertent transfer of GSR to persons unrelated to firearm activity. In criminal cases where vehicles have been used, such transfer processes for GSR need to be considered within the context of any case interpretation. The implications for subsequent contamination and transfer processes from such vehicles requires further investigation.

KEYWORDS: forensic science, ballistics, gunshot residue, fate and behaviour, distribution, transfer, scanning electron microscopy, energy dispersive X-ray spectroscopy

Gunshot residue (GSR) is the collective term used to define the residues expelled from a firearm during discharge (1). GSR particles can be deposited onto the shooter and surfaces within the shooter's vicinity. These residues are routinely used to provide forensic evidence of firearm contact in criminal cases.

Vehicles may be used in a shooting incident in a variety of ways. These include, being used to transport a shooter to and/or from the scene of a shooting and the discharge of a firearm from within or near to a vehicle (1). The level of GSR transfer in such instances is thought to be closely linked to the nature and duration of contact between the contaminated individual or surface and the vehicle (1) (see (2) for a more detailed account of how these contaminant processes affect GSR distribution). Before sampling a vehicle, it is important to determine a strategy based on the case circumstances, taking into consideration the most likely places of GSR transfer in the vehicle. Where a vehicle has been used post-firearms activity, areas of direct contact between the shooter, the firearm and the vehicles surfaces are of utmost interest (1). This is due to the potential for direct transfer of GSR to occur between the recently contaminated shooter and/or firearm and these surfaces. The exterior of a vehicle is thought to have a lower retention rate than the interior, due to both the exposure to the external environment and its typical impermeable surface texture not facilitating particle persistence (1-3).

The presence of GSR on an individual is not exclusive to the direct discharge of a firearm (4-6). GSR can undergo secondary and potentially even tertiary transfer (7). Airborne GSR particles may also be deposited onto nearby individuals and surfaces (8-10), which could result in the contamination of surfaces not in direct contact with a GSR contaminated individual or object. Secondary transfer of GSR has been shown to occur via skin to skin contact (5, 11), interaction with clothing at the scene of the shooting (9), and contact with police vehicles and equipment (12). It has already been established that a non-shooting individual could be contaminated with GSR through a number of contact routes (6).

The potential for police facilities, personnel and vehicles to act as a prospective source of GSR contamination during arrest and transit due to their exposure to high levels of GSR, has been widely explored (13-17). Recreational shooters can similarly be routinely exposed to high levels of GSR and thus, these individuals may present a high risk of contamination to those who come into direct contact with them and/or their belongings that were in close vicinity to the discharge of a firearm (6). However, little is known about the potential contamination of their vehicles, belongings and personnel. An improved understanding of the possible levels of GSR contamination of vehicles belonging to persons lawfully using firearms, will further aid a practitioners assessment of an individual's involvement in firearm activity (18). Refining our knowledge of possible sources of contamination is imperative to ensure consistency in casework practices and sampling strategies (19).

In this study, 170 samples were taken from a pool of seven recreational shooters' vehicles, when shooting had taken place within the previous week. To our knowledge, this is the first time such an extensive sampling and analysis protocol has been undertaken on recreational shooters vehicles. Using SEM-EDX analysis, the areas of highest and lowest GSR contamination occurring within recreational shooters vehicles are highlighted.

Materials and Methods

Sampling

Standard 12.5mm diameter SEM Specimen Stubs with a Leit Carbon tab (Agar Scientific, Essex, UK) were used for sampling throughout. The stub collection method involved dabbing the adhesive coated aluminium stub over the area of interest, until the tackiness had gone (approx. 30-50 dabs) (20). The collected stubs were covered with a conductive layer of carbon, using Quorum Technologies Q150T ED Rotary-Pumped Carbon Coater, in order to avoid the charging of organic debris such as hair, fragments of skin epithelium and particles of partially-burned propellant.

In total 170 samples were processed from 7 recreational shooters' vehicles from 5 different gun clubs across the region. All the vehicles in this study were of a standard hatchback configuration. These vehicles were used to transport firearms on the day sampling was conducted, but the driver (recreational shooter) and sample collector had not discharged a firearm on that day. Additionally, the driver had discharged a firearm and subsequently used the vehicle earlier the same week. Firearms (rifles and shotguns), as well as live and spent ammunition, were transported in soft cases in the trunk of each of the vehicles. To ensure consistency, a minimum of 24 standard samples were taken from the locations shown in Table 1 and Figure 1. The 24 locations chosen represent the minimum number of samples required to provide an assessment of the GSR distribution of the entire vehicle. These areas were targeted as the most probable areas GSR could transfer to, based on physical contact from a person recently contaminated with GSR. Where the area of interest was particularly dirty and contained large amounts of organic matter, care was taken to avoid overloading the carbon tab. Entering the vehicle was only necessary when sampling the driver's area to fully access the controls. This entry was kept to a minimum, with full PPE (personal protective equipment) worn at all times.

Analysis

Samples were analysed in a FEI Quanta200 ESEM with variable vacuum and a four quadrant BSD with a working distance of 10 mm, an accelerating voltage of 25 kV, and a magnification of 250x. Automatic search using INCA GSR software (Oxford Instruments) was chosen for faster analysis and the removal of operator subjectivity. The brightness threshold was initially set using a ANCPAS Particle Analysis Standard 13mm (diam.) aluminium pin stub containing Rh, Co, Au and C. A reference sample (positive control) containing a known number and range of particles types was analysed at the start of each run to ensure the instrument was correctly calibrated. Automatically identified particles were reacquired by manual relocation and any 'multiple hits' on large particles were removed (as per ASTM E1588-17 (21)). Quality controls consisted of SEM stubs taken from the hands of the sampler prior to sampling, none of which contained any GSR particles.

Results and Discussion

Particles were classified in line with ASTM E1588-17 guidelines (21). Particles identified as characteristic of GSR had one of the following elemental compositions: PbBaSb, PbBaSbAl or PbBaSbSn. The sampling procedure was also applied to a 'clean vehicle' with no known association with any firearms or firearms material - no GSR particles were detected.

Despite no firearm discharge taking place on the day of sampling, characteristic GSR particles were found in all of the vehicles sampled. The presence of these GSR particles may indicate GSR persistence in the vehicles from previous transfer processes, or direct transfer from the firearm that was discharged earlier the same week. The total number of characteristic GSR particles seen in each vehicle varied from 51 - 876 (Table 2). The persistence of GSR depends largely upon a number of variables, such as the time since discharge and the number of shots fired (2). Rosenberg and Dockery (22) suggest that the detection window for GSR on hands may be days rather than hours. Similarly, our study suggests that for vehicles GSR persistence may be days after discharge. Within a vehicle the detection window will be variable as frequently used areas are likely to shed GSR at a faster rate.

For the purpose of this study a set of 6 ranges were employed to distinguish between different levels of GSR contamination. These arbitrary ranges are based on levels reported in casework by forensic scientists in England. In the context of this study, it is important to recognise that the GSR particle numbers reported herein are illustrating the range of GSR throughout the vehicles. Thus, the scale used should be considered purely for visual representation of GSR contamination in the seven recreational vehicles, as shown in Figure 2.

GSR particles were distributed throughout the vehicles across a range of different surface types. The area of highest GSR contamination differed between the vehicles; nevertheless, the trunk and rear seats were shown to be heavily contaminated (TABLE *3*). The contamination seen in the trunk of these recreational shooters' vehicles are likely explained by its contact with recently discharged firearms and ammunition. Transport of firearms and ammunition occurred exclusively in the trunk of each vehicle.

It is well documented that post-discharge activities are the leading causes of particle loss (23-28). GSR contamination seen on the rear seats in a number of the vehicles may be explained by the reduced activity levels experienced in these areas. The rear seats were the least used seats in each of the vehicles. Increased GSR persistence is likely to have taken place on these less disturbed areas (29, 30), and may account for the increased GSR particle counts seen.

The smooth and impervious outside door handles had the least amount of characteristic GSR particles overall. Being the only location exposed to the outside environment, environmental conditions may have influenced the reduced level of GSR contamination seen (31). It has also been suggested that smoother surfaces have a greater rate of GSR loss (3).

It has been reported that the GSR upon a vehicles dashboard may assist in determining whether a firearm has been discharged within a vehicle, due to airborne distribution (32). This assumption however, does not take into account GSR contamination due to transfer. In our study, GSR was found on the dashboard in all but one recreational vehicle (RS03). Despite no firearm discharge occurring within the vehicles at any which time, as many as 48 characteristic GSR particles were identified on the dashboard of RS01. Similarly, high levels of GSR were identified on RS02 and RS06 (40 and 46 characteristic GSR particles respectively). Thus, the presence of GSR particles on the dashboard of a vehicle may occur due to secondary transfer of GSR particles, and it is not solely related to airborne distribution following a firearm discharge within a vehicle.

This study provides an assessment of the levels and distribution of GSR particles seen in the vehicles of individuals actively involved in firearms use. GSR is not confined to areas of direct contact with the recreational shooter and their firearms/ammunition (such as the steering wheel, gear stick and the location of firearm transport). Locations not routinely in contact with the shooter (such as the dashboard) have also been highlighted as potential areas of GSR contamination. The potential exists for substantial levels of GSR to persist in a recreational shooter's vehicle for days after any recreational shooting has taken place.

An association between the varying levels of characteristic GSR particles seen within recreational shooters' vehicles and GSR transfer processes is to be expected. Such processes include the frequency of use of the vehicle, the frequency of firearms related activities of the user of the vehicle, and the types of guns/ammunition used (2, 33).

GSR contamination is dependent upon the circumstances of each case and therefore it is important that the results of any GSR analysis are evaluated within the context of individual circumstances. Recreational shooters vehicles are a potential source for inadvertent GSR transfer to persons unrelated to firearms activity, which is an important consideration with case interpretation. The data presented here may assist in the understanding of the distribution of GSR in vehicles and should be considered as an initial assessment demonstrating the potential areas of GSR contamination of a vehicle. Further work including expanding the range of vehicle types, investigating surface type deposition, transfer and persistence mechanisms, will lead to a greater understanding of the fate and behaviour of these GSR materials and enable a more targeted approach to vehicle sampling.

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TABLE 1—*Locations of the 24 samples taken from each vehicle.*

Sample location	**Number of samples**	**Areas sampled**
Standard vehicle	24	A. Driver's seat back and headrest B. Driver's seat squab C. Front passenger's seat back and headrest D. Front passenger's seat squab E. Left rear passenger seat back and headrest F. Left rear passenger seat squab G. Right rear passenger seat back and headrest H. Right rear passenger seat squab I. Trunk left J. Trunk right K. Dashboard L. Glove box exterior M. Driver's seatbelt (including webbing, latch and buckle) N. Steering wheel O. Handbrake and gear stick P. Driver's seat foot well Q. Driver's inside door handled R. Front passengers inside door handle S. Right rear passenger inside door handle T. Left rear passenger inside door handle U. Driver's outside door handle V. Front passenger's outside door handle W. Right rear passenger outside door handle X. Left rear passenger outside door handle.

TABLE 2—*Summary of number of characteristic particles found in the recreational shooter's vehicles.*

Sample set:	**Total number of characteristic particles**	**Total number of PbBaSb particles**	**Total number of PbBaSbAl particles**	**Total number of PbBaSbSn particles**
RS01	876	816	58	2
RS02	542	316	200	26
RS03	53	12	32	9
RS04	248	214	34	0
RS05	51	13	38	0
RS06	586	531	34	16
RS07	856	705	141	10

TABLE 3—*Summary of the areas of highest and lowest contamination.*

Sample set:	**Area of highest contamination (i)**	**Number of characteristic particles in (i)**	**Area of lowest contamination (ii)**	**Number of characteristic particles in (ii)**
RS01	Right rear passenger seat back	315	Drivers, right and left rear outside door handles	0
RS02	Passengers seat base	190	Left rear passenger seat back	3
RS03	Right rear passenger seat base	12	Passengers seat base; Dashboard; Driver's seat well; Driver's seatbelt; left rear passengers inside door handle; drivers, passengers and left rear outside door handles	0
RS04	Trunk left	72	Drivers and right rear passengers outside door handles	0
RS05	Trunk left	15	Driver's seatbelt; Glove box; Drivers, passengers and left rear passengers inside door handles and all outside door handles	0
RS06	Left rear passenger seat base	105	All outside door handles	0
RS07	Trunk left	265	Drivers and right rear passengers inside door handle	1

Figure Legends

FIG. 1—*Recreational shooter vehicle RS01 showing sample locations A-P, and both an inside and outside door handle.*

FIG. 2—*Visual representation of GSR contamination in 7 recreational vehicles, RS01-RS07 (a-g).*