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Gunshot residue preservation in seawater

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ABSTRACT

Little is known about the persistence of gunshot residue (GSR) in soft tissue and bones during decomposition in marine environments. For a better understanding, qualitative and quantitative data were obtained on GSR retention on soft tissue and bony gunshot wounds (GSWs). A quantity of 36 fleshed and 36 defleshed bovine ribs were shot at contact range with 0.22 calibre hollow point ammunition using a Stirling 0.22 calibre long rifle. Bone specimens in triplicate were placed in three environments: submerged, intertidal and in supralittoral zone. Sets of triplicates were recovered on day 3, 10, 24 and 38, and analysed with scanning electron microscopy with energy dispersive X-ray spectrometry (SEM–EDX), and inductive coupled plasma mass spectrometry (ICP-MS). The SEM–EDX recorded GSR-indicative particles surrounding the bullet entrance on all bone types (fleshed and defleshed) in all environments throughout the study. GSR-unique particles were only detected on the supralittoral bones. The ICP-MS analysis showed faster GSR loss on submerged than intertidal and supralittoral defleshed specimens. Fleshed specimens showed a faster GSR loss on intertidal than submerged and supralittoral specimens. In conclusion, the GSR disappeared faster from submerged and intertidal than non-submerged specimens. The difference of detection of GSR between analysed specimens (defleshed versus fleshed) disappeared upon defleshing. This study highlights the potential of finding evidence of GSR in a submerged body and the potential of microscopic and analytical methods for examining suspected GSW in highly decomposed bodies in marine habitats.

1. Introduction

Gunshot residue (GSR) consists of burnt and unburnt residue, derived from the primer, propellant, the bullet or the firearm itself [1,2], which normally can be differentiated by their chemical composition and morphology. Particles characterized as GSR have normally a spherical shape of molten and cold matter with a diameter of 0.1 to 10 μm. In casework involving shootings, inorganic residues originating from the primer, bullet and cartridge are analysed. Pb, Ba and Sb are considered unique to GSR and can be found in different combinations and concentrations [3,4]. They can be divided into GSR-unique (i.e. Pb–Ba–Sb) and GSR-indicative (i.e. Pb–Ba or Ba–Ca–Si–Pb) particles of the ammunition used during a shooting incident [5]. Indicative particles are particles that may originate from a cartridge but may also originate from other objects such as industrial tools. SEM–EDX cannot always distinguish between GSR-indicative particles originating from a discharged gun and other inorganic particles that come from other sources such as brake linings [6], fireworks [7] or paints [8]. This can lead to false positive identification of GSR particles.

One of the unsolved puzzles of GSR is the question of how long it persists in tissues during the process of decomposition, particularly in different environments [9]. There may be a link between the postmortem interval and the retention of GSR [10], but testing this relationship is challenging because of postmortem factors such as decomposition, burial conditions and scavengers. When

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analysing GSR, time requirements, high cost per sample or limitations of the sophisticated techniques used may also be an issue. These techniques include proton-induced X-ray emission (PIXE) [11], computer tomography [12], scanning electron microcopy with energy dispersive X-ray spectrometry (SEM–EDX) [13], neutron activation analysis (NAA) [14], inductive coupled plasma mass spectrometry (ICP-MS) [15] and time-of-flight secondary ion mass spectrometry [16].

Studies on GSR in decomposed remains have been conducted on soft tissue [17,18], as well as on skeletonized remains [4,10,11]. A study by LaGoo et al. [18], used microwave digestion prior to ICP-MS to detect GSR of Pb, Ba and Sb in pigs shot multiple times. One pig was allowed to decompose in summer and one in winter for a sampling period of 37 days and 60 days correspondingly. They showed that GSR could be retrieved up to at least 37 days during the summer period, and that in winter it could be retrieved up to 60 days. Gibelli et al. [14] showed survival of Sb up to 16 weeks of decomposition on putrefied pigskin and on buried samples by using NAA analysis. Cecchetto et al. [17] used micro-CT to compare the amount and distribution of solid objects with a density higher than 1000 HU (Hounsfield Units) on human skin specimens that were allowed to decompose in a cowshed for 15 days. Evidence of high-density particles referred to as GSR particles were found in the dermis layer throughout the study, but not in the exit wounds.

Studies on GSR or bullet residue in skeletonized remains [4,10,11,19] have found evidence of GSR up to 90 years decomposition. Fischbeck et al. [11] showed the presence of Pb in a finger bone of a murder victim by using PIXE analysis when soft tissue was absent. As an attempt to identify bullet wipe on bone, Berryman et al. [13] showed evidence of GSR on defleshed bone samples, deep within the bony wound tract after removal of the periosteum. Recently, Taborelli et al. [10] presented evidence of GSR on bone lesions from the mandible and forehead of fully skeletonized animal models up to four years of decomposition in terrestrial environments (buried in pots and in open air). All samples were kept indoors to avoid eventual modification by weather conditions. The samples were completely skeletonized after 16 to 20 weeks. They also examined human bone specimens that underwent simulated decomposition in distilled water, where GSR could still be detected after one week. The question then arises whether the GSR originally came from the bone or soft tissue after decomposition. Most studies have been conducted in terrestrial environments. Little is known about the effect of a marine environment on GSR, which is important knowledge since it may provide information for diagnosis of a suspected gunshot wound.

Currently SEM–EDX is one of the most commonly used techniques for detection of GSR [10,13,20,21], because it can provide qualitative elementary as well as morphological information [15]. The ICP-MS demonstrated its usefulness for detecting and accurately quantifying Pb, Ba and Sb in GSR [22] and for differentiating bullet types [15]. As far as the authors in this present study are aware, only a small number of studies on decomposed material using ICP-MS analysis have been conducted [15,18]. Udey et al. [15] detected GSR on porcine tissue shot with jacketed and nonjacketed bullets of which samples were collected during early decomposition up to 49 days. The elements investigated were Sb, Ba, Pb, Cu and Fe. Cu and Pb were useful for differentiating bullet types during decomposition.

Understanding how GSR is distributed in bony wounds and subsequently lost during decomposition will provide valuable forensic reference data. In the present study, SEM–EDX and ICP-MS were used to detect and quantify GSR in experimentally produced bony GSWs that were allowed to decompose in three contrasting marine environments over a 38 days period.

2. Materials and methods

2.1. Experimental design

The study involved 93 young adult bovine rib specimens purchased from local suppliers used for the experiments as shown in Table 1. The specimens were subdivided into seven subgroups: (i) 36 shot defleshed; (ii) 36 shot fleshed; (iii) six unshot defleshed controls; (iv) six unshot fleshed controls; (v) three shot defleshed controls; (vi) three shot fleshed controls and (vii) three unshot controls. Group one to four were exposed to marine environments. The remaining groups (five to seven) were unexposed samples. Ribs were shot at contact range with a CCI Sub-Sonic 0.22 calibre long rifle with lead hollow point bullets (1050 FPS 40 Grain).

In preparation of being shot each rib was placed on a custom made jig consisting of a thick wooden baseplate, a sandbag filled with wet sand, and rod fitted with a spirit level to ensure a 90° shot. In our study, ribs were placed on a sandbag saturated with water, to simulate the poroelastic nature of the thoracic soft tissue.

Specimens except the non-exposed controls were exposed to marine environments within 24 h of being shot. The shot specimens were allowed to decompose at the Portobello Marine Research Center, University of Otago, Dunedin, New Zealand during the spring period (September–October). The non-shot samples were allowed to decompose during summer (January–February). There were three conditions of exposure: submerged at a minimum depth of 1.5 m at low tide; in the intertidal zone and in the supralittoral zone. The specimens were placed, unbound, in triplicate in perforated plastic cages, within which specimens could move naturally. Defleshed and fleshed specimens were held in separate cages. The specimens were free-floating in the cages when immersed. After 3, 10, 24 and 38 days, triplicates of each group were recovered from the different environments. To avoid any disturbance of the decomposition process, the specimens were only attended on recovery. The specimens were skeletonized due to effects from the surrounding environments. Possible contamination during the workflow starting at time of butchering the

Table 1
Number of samples for each experimental group versus environmental exposure.

	Submerged	Intertidal	Supralittoral	Not exposed	Total
Shot (test) defleshed[a]	12	12	12		36
Shot (test) fleshed[b]	12	12	12		36
Unshot (control) defleshed	2	2	2		6
Unshot (control) fleshed	2	2	2		6
Shot (control) defleshed				3	3
Shot (control) fleshed				3	3
Unshot (control)				3	3
					93
Analysed with SEM–EDX	28	28	28	9	93
Analysed with ICP-MS	28	28	28	9	93

[a] With periosteum.
[b] 15 mm thick layer of soft tissue.