Improving Forensic Casework Analysis and Interpretation of Gunshot Residue (GSR) Evidence

by

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A thesis
submitted for the degree of
Doctor of Philosophy

University of Technology, Sydney

2011

CERTIFICATE OF AUTHORSHIP / ORIGINALITY

I certify that this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Dedicated to the memory of

Robin Keeley

Without his efforts in the field of forensic gunshot residue evidence
and his contributions to scanning electron microscopy
this work would not have been possible.

Acknowledgements

When something takes up so much of your life there are a lot of people to thank. I truly appreciate the contribution of each and every one of them.

I thank my wonderful husband Paul who has supported me in so many ways through this journey. I thank my beautiful children, Ethan and Sophie, who I adore, for putting up with Mummy always being busy with 'PhD work'.

I thank my Mum and Dad and my sister Gerry for being my constant encouragement and motivation. I thank Carolynne and John for wanting a daughter-in-law they could call 'Dr' and doing everything they could to help.

I thank my supervisors, Professor Claude Roux, Professor Chris Lennard and Associate Professor Michael Dawson for their guidance and inspiration.

I thank the New South Wales Police Force (NSWPF) and Dr Tony Raymond for mentoring me and supporting me through providing study time for this research. I also thank the NSWPF Forensic Ballistics Investigation Section for providing ammunition samples.

I thank the Australian Federal Police (AFP) and Professor James Robertson for providing funding for the project as well as chemical standards, ammunition and access to AFP facilities. I also thank Dave Royds, Paul McFawn and Eric Davies for assistance with various areas of the research.

I thank Dr Ric Wuhrer and Professor Matthew Phillips for making me welcome in the University of Technology, Sydney (UTS) Centre of Expertise Microstructural Analysis and for their assistance and technical support with the scanning electron microscopy energy dispersive X-ray analysis (SEM/EDX) work.

I thank Jim Keegan and Dr Harry Rose for their assistance with the liquid chromatography tandem mass spectrometry research.

I thank Dr Sarah Benson for her assistance with the initial surveys, sampling and instrumentation for the gunshot residue background study research.

I thank Liz Chan, Dr Sonia Taflaga, Kate McCann and Joanna Maniago for their assistance with the ion mobility spectrometry research. I also thank Liz for helping me set-up the Forensic Microanalysis Laboratory and for being my 'fix-it' person and general sounding board.

I thank Professor Christophe Champod and Dr Simon Walsh for their assistance with the Bayesian statistical modelling.

I thank Glyn Smith and Ivan Sarvas of Forensic Science South Australia, Bernie Lynch of the Chemistry Centre Western Australia and Peter Ross and Harald Wrobel of the Victorian Police Forensic Science Centre for opening their laboratories and imparting their gunshot residue wisdom to me.

I thank the Sydney University Australian Centre for Microscopy and Microanalysis staff for their SEM/EDX technical assistance.

I thank all of the survey participants from around Australia. I thank the volunteer participants in the general population study and the NSWPF participants in the general duties, tactical response, crime scene and firearms examiner studies.

I thank Australian Defence Industries (now Thales Australia) for teaching me about the ammunition manufacturing process and providing component samples and analytical methods.

I thank Charlie Midkiff and Max Houck for providing literature and ideas at the inception of the research.

I also thank the original UTS Forensic Science Research Group; Karen Scott, Dr Susan Bennett, Steven Armitage and Dr Juuso Huttunen; for keeping me sane in those early days.

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AAS – atomic absorption spectrometry

ABS – Australian Bureau of Statistics

ADI – Australian Defence Industries

2-A-4,6-DNT – 2-amino-4,6-dinitrotoluene

4-A-2,6-DNT – 4-amino-2,6-dinitrotoluene

2-ADPA – 2-amino-diphenylamine

4-ADPA – 4-amino-diphenylamine

AFP – Australian Federal Police

Al – aluminium

APCI – atmospheric pressure chemical ionisation

API – Atmospheric Pressure Ionisation

ASV – anodic stripping voltammetry

Ba – barium

BC – butyl centralite

BN – Bayesian network

BSE – back scattered electron

Ca – calcium

CAD – collision activated dissociation

CCI – Cascade Cartridge Industries

CE – capillary electrophoresis

CF – Clean-fire

CSI – crime scene investigator

CSSB – Crime Scene Services Branch

Cu – copper

DAL – Division of Analytical Laboratories

DBP – dibutylphthalate

DDNP, diazol – 2-diazo-4,6-dinitrophenol

DEP – diethylphthalate

DFA – Delta Frangible Ammunition

DMP – dimethylphthalate

DNA – deoxyribonucleic acid

DNB – 1,3-dinitrobenzene

2,4-DNDPA – 2,4-dinitrodiphenylamine

DNT – dinitrotoluene

DPA – diphenylamine

DTA – differential thermal analysis

EC – ethyl centralite

EDX – energy dispersive x-ray analysis

FA – firearm activity

FBIS – Forensic Ballistics Investigation Section

FCC – fired cartridge case

FDR – firearms discharge residue

FIA – flow injection analysis

FMJ – full metal jacket

FML – Forensic Microanalysis Laboratory

FSG – Forensic Services Group

FSSA – Forensic Science South Australia

FTIR – Fourier transform infrared

FWHM – full width half maximum

GC – gas chromatography

GCMS – gas chromatography mass spectrometry

1,2-GDN – 1,2-glycerol dinitrate

1,3-GDN – 1,3-glycerol dinitrate

GSR – gunshot residue

HEPA – high efficiency particle arrestors

HMF – heavy metal free

HMX – octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine

HPLC – high performance liquid chromatography

HPLC-MS – high performance liquid chromatography mass spectrometry

ICP-AES – inductively coupled plasma - atomic emission spectrometry

IMS – ion mobility spectrometry

K – potassium

LC – liquid chromatography

LC-MS/MS – liquid chromatography tandem mass spectrometry

LF – lead free

LHS – left hand side

LR – likelihood ratio

MC – methyl centralite

m-cresol – 1-hydroxy-3-methylbenzene

MRM – multiple reaction monitoring

MS – mass spectrometry

MSDS – material safety data sheets

Na – sodium

NA – not applicable

NAA – neutron activation analysis

NATA – National Association of Testing Authorities

NB – nitrobenzene

NC – nitrocellulose

2-NDPA – 2-nitrodiphenylamine

4-NDPA – 4-nitrodiphenylamine

NG – nitroglycerine

NGU – nitroguanidine

NIFS – National Institute of Forensic Sciences

N-NDPA – N-nitrosodiphenylamine

NSW – New South Wales

NSWPF – New South Wales Police Force

NT – nitrotoluene

Pb – lead

PDA – photo diode array

PE – Perkin-Elmer

PETN – pentaerythritol tetranitrate

PMDE – pendant mercury drop electrode

QA – quality assurance

RDX – 1,3,5-trinitro-1,3,5-triazacyclohexane

RHS – right hand side

ROI – region of interest

RWS – Dynamit-Nobel

S – sulphur

Sb – antimony

SE – secondary electron

SEM – scanning electron microscopy

SEM/EDX – scanning electron microscopy/energy dispersive X-ray analysis

Si – silicon

SIM – selected ion monitoring

SMANZFL – Senior Managers of Australian and New Zealand Forensic Laboratories

Sn – tin

SOPs – standard operating procedures

SPC – Sydney Police Centre

SPG – State Protection Group

Sr – strontium

Tetracene – 1-(5-tetrazolyl)-4-guanyltetrazene hydrate

Tetryl – 2,4,6-N-tetranitro-N-methylaniline

Ti – titanium

TIC – total ion chromatogram

TLC – thin layer chromatography

TMJ – total metal jacket

TNB – 1,3,5-trinitrobenzene

TNT – 2,4,6-trinitrotoluene

TOU – Tactical Operations Unit

Triacetin – glyceryl triacetate

UHP – ultra high purity

US – United States

USA – United States of America

UTS – University of Technology, Sydney

VPFSC – Victorian Police Forensic Science Centre

W – tungsten

XRD – X-ray diffraction

XRF – X-ray fluorescence

z – stage height

Z – atomic number

Zn – zinc

List of Conference Presentations

Characteristics of Lead / Heavy Metal –Free Ammunition

Stephanie Hales, BSc; Claude Roux, PhD; Michael Dawson, PhD; Chris Lennard, PhD; Eric Davies

Presented at the 18th International Symposium on the Forensic Sciences, Fremantle WA, Australia, April 2006 (National ANZFSS Scholarship winner)

A Bayesian Model for GSR Evidence Interpretation

Stephanie Hales, BSc; Claude Roux, PhD; Simon Walsh, PhD; Chris Lennard, PhD

Presented at the 18th International Symposium on the Forensic Sciences, Fremantle WA, Australia, April 2006 (National ANZFSS Scholarship winner)

Contamination Prevention Procedures and Their Effect on Laboratory Background Levels of GSR

Stephanie Hales, BSc; Chris Lennard, PhD; Claude Roux, PhD

Presented at the 17th International Symposium on the Forensic Sciences, Wellington, New Zealand, March 2004

Use of Ion Mobility Spectrometry (IMS) for Detection of GSR in Shooting Investigations

Stephanie Hales, BSc; Elizabeth Chan, BSc; Sonia Casamento, BSc; Kate McCann, BSc; Joanna Maniago, BSc

Presented at the 17th International Symposium on the Forensic Sciences, Wellington, New Zealand, March 2004

Use of the Environmental Scanning Electron Microscope for the Analysis of Gunshot Residue

Joanna Maniago, BSc; Claude Roux, PhD; Stephanie Hales, BSc; Matthew Phillips, PhD; Richard Wuhrer, PhD

Presented at the 18th Australian Conference on Microscopy and Microanalysis, Geelong VIC, Australia, February 2004

Presented at the 17th International Symposium on the Forensic Sciences, Wellington, New Zealand, March 2004

Presented at the Microscopy and Microanalysis Conference, Savannah, USA, August 2004

Gunshot Residue (GSR) Evidence Interpretation Issues

Stephanie Bull, BSc; Sarah Benson, BSc; Claude Roux, PhD; Chris Lennard, PhD

Presented at the 16th International Symposium on the Forensic Sciences, Canberra ACT, Australia, May 2002 (National ANZFSS Scholarship winner)

Propellant & Explosives Analysis by LC/MS/MS

Stephanie Bull, BSc; Claude Roux, PhD; Michael Dawson, PhD; Chris Lennard, PhD

Presented at the 16th International Symposium on the Forensic Sciences, Canberra ACT, Australia, May 2002 (National ANZFSS Scholarship winner)

Presented at the INTERPOL Symposium, Lyon, France, October 2001

Barringer GC-Ionscan: A Field Instrument for Clan Lab Investigations

Karen Scott, BSc; Greg Cook; Stephanie Bull, BSc; Priscilla Barsenbach, BSc

Presented at the 16th International Symposium on the Forensic Sciences, Canberra ACT, Australia, May 2002 (National ANZFSS Scholarship winner)

Presented at Clandestine Laboratory Investigating Chemists 2001
– A Technical Training Seminar, Monterey, California, USA, September 2001

Application of Analytical Chemistry to Forensic Science Problems – an Overview of Method Development and Validation

Claude Roux, PhD; Stephanie Bull, BSc; et al

Presented at Pittcon 2001, New Orleans, LA, USA, March 2001

Investigation Into the Possibility for Secondary Transfer of Gunshot Residue to a Suspect During an Arrest

Stephanie Bull, BSc; Sarah Benson, BSc; Claude Roux, PhD; Chris Lennard, PhD

Presented at the CrimTrac 15th International Symposium on the Forensic Sciences, Gold Coast QLD, Australia, March 2000
(NIFS/SMANZFL Younger Practitioner Award)

Organic Propellant and Explosives Analysis by LC/MS/MS – Preliminary Results

Stephanie Bull, BSc; Claude Roux, PhD; Michael Dawson, PhD; Chris Lennard, PhD

Presented at the CrimTrac 15th International Symposium on the Forensic Sciences, Gold Coast QLD, Australia, March 2000
(NIFS/SMANZFL Younger Practitioner Award)

Presented at the International Association of Forensic Sciences 15th Triennial Meeting, LA, California, USA, August 1999

Abstract

There are two main challenges to gunshot residue (GSR) evidence.

The first concerns analysis. The lack of screening techniques complicates sampling and analysis of large areas or numbers of exhibits. Also, lead or heavy metal free ammunitions present limitations to the technique for confirmatory detection of residues – scanning electron microscopy/energy dispersive X-ray analysis (SEM/EDX).

A screening technique was developed to detect GSR components from all ammunition types. Ion mobility spectrometry (IMS) was proven to allow sensitive and effective screening before proceeding to confirmatory analysis.

Lead and heavy metal free ammunitions were examined and a technique developed for detecting components in the organic portion of the residue. Liquid chromatography tandem mass spectrometry (LC-MS/MS) was extremely effective, detecting twenty seven components. The technique is sensitive (to around 1 ppb), selective, rapid and cost effective. The combination of IMS, SEM/EDX and LC-MS/MS, with visual, physical and microscopic examination, is proposed as a complete protocol for GSR analysis from all ammunition types.

The second challenge involves interpretation. Factors that lead to positive and negative findings must be considered and the weight of evidence assessed. Both background data and application of an interpretive framework have been inadequate.

Background levels of GSR in the NSW general population and NSW Police Force were studied and the chances of random presence on a suspect and of contamination during arrest and sampling process determined.

Nil GSR was detected on hands of the NSW general population or the sample of general duties police officers. A moderate probability was demonstrated for low levels of GSR on hands of crime scene investigators. GSR was detected on hands of all forensic firearms examiners tested, however their role limits access to suspects and items

sampled for GSR, limiting the chance of contamination. Significantly, one high risk area for contamination was identified, the tactical response officers.

Background levels of GSR in the Australian Federal Police laboratories were compared before and after implementing contamination controls. The configuration of the original laboratory along with the lack of controls lead to GSR being detected on almost every sample. The newer laboratory was extremely clean, only one GSR particle being detected, demonstrating the importance of effective contamination controls during sample collection and analysis.

A statistical interpretive framework was developed. The model utilises Bayesian networks to consider existing data relating to transfer and persistence, and new data from this research, providing more objective assessment and allowing broader application of the Bayesian framework.