Retrospective analysis of blunt force trauma associated with fatal road traffic accidents in Cape Town (South Africa) over a two-year period.

by

T. A Tiffany Majero
(MJRTIN002)

SUBMITTED TO THE UNIVERSITY OF CAPE TOWN
In partial fulfilment of the requirements for the degree

MPhil (Biomedical Forensic Science)

Faculty of Health Sciences
UNIVERSITY OF CAPE TOWN

November 2017
Supervisors: Calvin Mole
Department of Pathology
Division of Forensic Medicine and Toxicology
University of Cape Town
The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.
## TURNIT IN REPORT

**mjrtin002:T._A._Tiffany_Majero_-_Thesis_submission_for_turnitin.docx**

### ORIGINALITY REPORT

<table>
<thead>
<tr>
<th>Similarity Index</th>
<th>Internet Sources</th>
<th>Publications</th>
<th>Student Papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>4%</td>
<td>2%</td>
<td>7%</td>
</tr>
</tbody>
</table>

**MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)**

6%

★ Submitted to University of Cape Town

Student Paper

---

Exclude quotes: On
Exclude bibliography: On
Exclude matches: <12 words
DECLARATION

I, T. A. Tiffany Majero, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university. I empower the university to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

Signature : [Signed by candidate]

Date : February 2018
ABSTRACT

Road transportation systems are a global developmental achievement. However, with them comes increased morbidity and mortality rates in the form of road traffic accidents. In South Africa, there is a need to characterize road traffic accidents and the injuries associated with them, to determine the preventative mechanisms required to reduce their morbidity and mortality rates. A brief review of fatal road traffic accidents from a global perspective is presented, highlighting the current literature surrounding the prevalence, demographics and blunt force trauma injuries associated with road traffic accidents in South Africa. There is limited research regarding the prevalence and characteristics of road traffic accidents. The objective of this study was to determine the prevalence of fatal road traffic accidents, necessitating the need for research, particularly at the regional level.

A retrospective analysis was therefore conducted of all fatal road traffic accident related deaths autopsied at Salt River Mortuary (which services the West Metropole region of Cape Town, South Africa) from January 1st, 2013 to December 31st, 2014. The mean prevalence of road traffic accidents for the reviewed period was 15.9 / 100 000 population. The majority of road traffic accident victims were males who fell in the age group of 30 – 49 years. Over the two-year period, the majority of road traffic accident victims were pedestrians with elevated blood alcohol concentration levels.
The head and facial regions of victims commonly exhibited external injuries, while the majority of fractures and organ injury were seen in the head and chest regions. There are limited studies which have investigated the blunt force trauma injuries associated with road traffic accidents in South Africa, and there is a need for further research. Interventions are of paramount importance to decrease fatal road traffic accidents, particularly amongst pedestrians as a road user. This study presents recent data on road traffic accidents for the West Metropole region of Cape Town (South Africa).
# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TURNITIN ® REPORT</td>
<td>ii</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>iii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>iv</td>
</tr>
<tr>
<td>CONTENTS</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>viii</td>
</tr>
<tr>
<td>CHAPTER ONE: LITERATURE REVIEW</td>
<td>9</td>
</tr>
<tr>
<td>1.1 Introduction</td>
<td>10</td>
</tr>
<tr>
<td>1.2 Definition of a road traffic accident</td>
<td>10</td>
</tr>
<tr>
<td>1.3 The global impact of road traffic accidents</td>
<td>12</td>
</tr>
<tr>
<td>1.4 Trauma associated with road traffic accidents</td>
<td>17</td>
</tr>
<tr>
<td>1.5 Road traffic accidents in South Africa</td>
<td>18</td>
</tr>
<tr>
<td>1.5.1 Road traffic accident mortality and morbidity rates</td>
<td>19</td>
</tr>
<tr>
<td>1.5.2 Economic burden of road traffic accidents</td>
<td>19</td>
</tr>
<tr>
<td>1.5.3 Road traffic accident victim demographics</td>
<td>22</td>
</tr>
<tr>
<td>1.5.4 Risk factors</td>
<td>23</td>
</tr>
<tr>
<td>1.5.4.1 Road traffic accident and alcohol impairment</td>
<td>24</td>
</tr>
<tr>
<td>1.5.4.2 Road traffic accident and drug impairment</td>
<td>26</td>
</tr>
<tr>
<td>1.5.5 Road traffic accident preventative mechanisms</td>
<td>27</td>
</tr>
<tr>
<td>1.5.6 Road traffic accident associated blunt force trauma</td>
<td>28</td>
</tr>
<tr>
<td>1.6 Conclusion</td>
<td>30</td>
</tr>
<tr>
<td>1.7 Reference List</td>
<td>32</td>
</tr>
<tr>
<td>CHAPTER TWO: PUBLICATION READY MANUSCRIPT</td>
<td>37</td>
</tr>
<tr>
<td>2.1 ABSTRACT</td>
<td>39</td>
</tr>
<tr>
<td>2.2 INTRODUCTION</td>
<td>40</td>
</tr>
<tr>
<td>2.3 METHODS</td>
<td>42</td>
</tr>
<tr>
<td>2.3 RESULTS AND DISCUSSION</td>
<td>44</td>
</tr>
<tr>
<td>2.4.1 Prevalence of RTAs</td>
<td>44</td>
</tr>
</tbody>
</table>
2.4.2 Demographic distribution of RTAs ................................................................. 45
  2.4.2.1 Distribution of RTAs by age .................................................................. 45
  2.4.2.2 Distribution of RTAs by sex ................................................................. 47
  2.4.3 Distribution of RTAs by road user ............................................................ 47
  2.4.4 Temporal distribution of fatal RTAs .......................................................... 50
    2.4.4.1 Time of day ....................................................................................... 50
    2.4.4.2 Day of the week ................................................................................. 52
  2.4.5 Survival period ......................................................................................... 52
  2.4.6 Toxicology and RTAs ................................................................................ 54
    2.4.6.1 Alcohol intoxication ........................................................................... 54
    2.4.6.2 Drug intoxication ............................................................................... 57
  2.4.7 RTA associated injuries ............................................................................ 58
    2.4.7.1 Region of injury .................................................................................. 60
    2.4.7.2 External injuries .................................................................................. 62
    2.4.7.3 Hard tissue injuries ............................................................................. 64
    2.4.7.4 Head and spinal tissue injuries ............................................................ 70
    2.4.7.5 Visceral injuries .................................................................................. 73
  2.5 LIMITATION .................................................................................................. 75
  2.6 CONCLUSION .............................................................................................. 76
  2.7 REFERENCES ............................................................................................... 78

CHAPTER THREE: APPENDICES ......................................................................... 84
Appendix A: Acknowledgments ........................................................................ 85
Appendix B: Ethics approval letter ..................................................................... 86
Appendix C: Estimated population data for the West Metropole region of Cape Town (South Africa). ................................................................. 87
Appendix D: Instructions to Authors .................................................................. 89
LIST OF FIGURES

Figure 1.1 2012 global causes of injury-related deaths ................................................................. 12
Figure 1.2 2013 RTA associated fatalities in terms of income level ........................................... 13
Figure 1.3 2013 RTA associated fatalities per 100 000 population by region ........................... 14
Figure 1.4 Global age distribution of RTA associated fatalities in 2000 and 2012 .................... 15
Figure 2.1 West Metropole region of the city of Cape Town ..................................................... 42
Figure 2.2 Percentage age distribution of road users involved in RTAs .................................... 46
Figure 2.3 Percentage distribution of RTA fatalities by road user .......................................... 48
Figure 2.4 Comparison between time of death and pedestrian versus motor vehicle occupants .... 51
Figure 2.5 Place of death and survival period after admission .................................................. 53
Figure 2.6 Percentage distribution of RTA associated injuries according to body regions ........ 61
Figure 2.7 Mean percentage distribution of external injuries according to road user ............... 62

LIST OF TABLES

Table 1.1 Economic costs of RTAs ........................................................................................................... 16
Table 1.2 Road traffic accidents in South Africa .................................................................................. 21
Table 2.1 Distribution of the presence of alcohol, intoxication and BAC levels per road user .......... 55
Table 2.2 Distribution of type of injury per road user ......................................................................... 59
Table 2.3 Distribution of external injuries in RTA victims over different regions of the body ........ 63
Table 2.4 Distribution of hard tissue and visceral tissue injuries in RTA victims over different regions of the body ...... 66
CHAPTER ONE:
Literature Review
1.1 Introduction

Road transportation systems are a global developmental achievement. However, their establishment contributes to an increase in global morbidity and mortality rates. This review will discuss the global epidemiology of road traffic accidents (RTAs) as well as critically evaluate the literature surrounding RTAs in South Africa,

1.2 Definition of a road traffic accident

Collecting data on RTAs is important to monitor their contribution to morbidity and mortality rates. In addition to this RTA data assists in assessing if road safety mechanisms are required and if those that have been implemented are working. However, there is no universal definition of an RTA [1]. As a result, definitions vary from country to country which makes a comparative analysis of global RTA mortality and morbidity rates challenging [1]. Peden et al. [1] reports that since 2010, 100 countries now use the 30-day definition of RTAs. This means that police will follow up on the outcome of an RTA if death occurs within 30 days of the accident [1]. The death is recorded as an RTA fatality if it occurs within 30 days of the accident. The lack of follow up by police and the exclusion of deaths, which occur after 30 days facilitates a statistical under representation of the true extent of RTA fatalities.

There are a number of definitions for accidents involving transport related vehicles hierarchically organised according to a number of transport modes. These include
transportation related fatalities (these include all transport related fatalities from aircraft ships to motor vehicle occupants to cyclists to skate boarders to pedestrians), road traffic fatalities (these include all road users, from pedestrians to cyclists to bus users to skate boarders and motor vehicle related fatalities which only involve motorised registered vehicle statistics. Previous studies [1-4], define a RTA as a collision that occurs on a road between a moving motor vehicle and an object (such as a wall, tree, building or debris), an individual(s) (such as a pedestrian, a cyclist or motorcyclist), an animal or another motor vehicle. These studies did not include cases where the injury occurred on the road but did not involve a collision (e.g. a person falling out of a moving vehicle, a person slipping or falling on the road) or a stationary vehicle (e.g. a person sustaining an injury while for example washing or loading a vehicle). In their definition of an RTA Lehohla [5], include other land accidents such as animal riders, railway train accidents, water and air accidents. The inclusion of these other factors is a limitation when investigating transportation related fatalities.

It is important to establish a working definition of an RTA because issues may arise in the reporting of them within individual studies [1]. Inconsistent definitions within studies can result in inaccurate reports, which may underreport RTA’s, thus, affecting the analysis and appreciation of their severity. For the purpose of this literature review, studies were not excluded based on RTA definition. This was done to gain an understanding of RTA in South Africa. A RTA will be defined as an accident that occurred on any road (private or public) due to a collision between two or more objects, one of which must be a moving motor vehicle.
1.3 The global impact of road traffic accidents

Injuries account for 9% of the world’s deaths, claiming the lives of over 5 million people annually. In 2012, RTAs accounted for 24% of all injury-related deaths, globally [6] (Figure 1.1). Approximately, 1.2 million people died from fatal RTA associated injuries, while millions sustained debilitating injuries, affecting their way of life and in some cases inhibiting victims from working for extended periods of time or even permanently [1, 7].

![Figure 1.1](image-url) | 2012 global causes of injury-related deaths. [6]
If current trends continue, it has been predicted that the world will experience a 60% increase in RTA associated fatalities by 2020, making RTA a major contributor to the overall burden of disease [1, 8]. In 2002, RTAs were the 10th leading cause of death. However, Mathers & Loncar [9] suggest that RTAs will rise in rank, becoming the 8th leading cause of death by 2030.

Despite the fact that a minority of the population own motor vehicles, 90% of RTA associated fatalities and injuries occur in low- and middle-income countries [10-12] (Figure 1.2). According to data collected by the World Health Organization [7], in 2013, low-income countries had the highest road traffic fatality rates per 100,000 population, followed by middle-income and lastly high-income countries (Figure 1.2).

Figure 1.2 | 2013 RTA associated fatalities in terms of income level [7]
Of the low-income countries, African countries have some of the highest RTA associated mortality rates in the world [10-12]. In 2013 the African continent was found to be the region with the highest RTA associated mortality rates with a rate of 26.6 per 100,000 population [7] (Figure 1.3).

**Figure 1.3** | **2013 RTA associated fatalities per 100,000 population by region** [7]

RTA associated injuries and fatalities affect all age groups. However, data collected by the WHO [6, 13], suggests that this type of injury predominantly affects young people and people who are in their prime working years. In 2000, the age groups most affected by
RTAs were 15-29 years and 30-49 years (Figure 1.4). Furthermore, RTAs were found to be the second and third leading cause of death for these age groups, respectively [1]. By 2012, the age groups most affected by RTAs had not changed. However, RTAs became the number one leading cause of death for people aged 15-29 years [13].

**Figure 1.4** | Global age distribution of RTA associated fatalities in 2000 and 2012 [6]

The majority of RTA casualties are among the most economically productive young adults. This contributes to the inhibition of economic growth and development of a country and places additional financial, physical and psychological strain on those directly

---

15 | P a g e
affected by RTAs. Table 1.1, summarizes the economic burden of RTAs in some countries.

**Table 1.1 | Economic costs of RTAs**

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>YEAR</th>
<th>% GDP</th>
<th>REFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>2006</td>
<td>1.7</td>
<td>BITRE, 2009 [14]</td>
</tr>
<tr>
<td>India</td>
<td>2009</td>
<td>3.0</td>
<td>World Health Organization, 2015 [7]</td>
</tr>
<tr>
<td>South Africa</td>
<td>2010</td>
<td>7.8</td>
<td>World Health Organization, 2015 [7]</td>
</tr>
<tr>
<td>United States</td>
<td>2010</td>
<td>1.6</td>
<td>Blincoe et al., 2015 [15]</td>
</tr>
</tbody>
</table>

GDP: Gross domestic product

It is evident that the financial strain of RTAs varies from country to country and depends in part on the economic status, of the nation. Data collected by the Industrial Policy Action Plan [16] for 2010, suggests that the economic burden of RTAs is greater in developing than developed countries and it is expected that this burden will continue to increase with increased urbanisation and vehicle ownership [10-12].
1.4 Trauma associated with road traffic accidents

In forensic science, trauma is defined as any physical injury that results from a physical force or agent [17]. It is divided into three primary categories according to the mechanism of trauma; blunt force, sharp and ballistics trauma [18]. Blunt force trauma is the most common injury associated with RTAs. Blunt force trauma injuries are non-penetrating injuries, which are caused by rapid acceleration/deceleration and/or impact with a surface or object. In RTAs, blunt force results in external, hard tissue and visceral injuries. The severity of these injuries is dependent on the force applied to the tissue [19].

Typical external blunt force trauma injuries in RTAs include, include abrasions, contusions and lacerations. Knight’s Forensic Pathology [19] provides an overview and description of typical external injuries associated with blunt force trauma. Briefly, abrasions are superficial injuries to subcutaneous tissue, characterized by the appearance of scratches (linear marks) and grazes (brush abrasions) on the skin surface [19]. Different types of abrasions exist (e.g. brush, crushing, fingernail, pattern abrasions) and the abrasion formed depends on the mechanism of injury to the skin. A common form of abrasion associated with RTA is caused by seatbelts abrading the skin across the torso. Contusions are bruises that lie beneath the surface of an intact epidermis, formed by the collection of blood as a result of ruptured blood vessels caused by the mechanism of impact. Contusions are not exclusive to subcutaneous tissue, they can also present themselves on deep tissue and internal organs. Lacerations are characterized by complete penetration of the full thickness of the skins as a result of tearing. Lacerations
may be differentiated from incisions (sharp trauma) by tissue bridging and a jagged appearance. There is, unfortunately, limited consensus as to what the most common type of injury sustained during an RTA is. For example, Aggarwal et al. [20] reported that abrasions contributed to the highest percentage (86%) of blunt force external injuries sustained RTA victims, followed by lacerations (75%) and contusions (58%). Similar findings were observed by Farooqui et al. [21] and Das & Gogoi [22], although they are noted contusion to be more common than lacerations. A study [23] investigating injuries sustained by motor vehicle occupants, contradicted these findings by reporting that lacerations (38.28%) were the most common type of external injury sustained, followed by abrasions (38.15%) and contusions (19.20%).

In terms of typical visceral injuries and hard tissue injuries sustained in RTAs there is also limited consensus. However, associations exist in terms of the position of the individual in a motor vehicle [24] and the site of impact [25]. It is also evident that pedestrians sustain far more extensive trauma than other road users [26].

1.5 Road traffic accidents in South Africa

Numerous studies, exploring RTAs have been conducted globally. In Africa, some of these studies have been conducted in countries such as Libya [27], Ghana [28] and Tanzania [29]. Although the information reported in these studies is useful, they cannot be used to make conclusions about RTAs in South Africa. To fully appreciate the impact
of RTAs in South Africa, studies need to be conducted in the nation. Such studies do exist and aid our understanding of RTAs in this country. These studies investigate various aspects of RTAs. However, there are limited studies regarding the injuries associated with RTA.

1.5.1 Road traffic accident mortality and morbidity rates

RTAs are a major contributor to the burden of disease in South Africa. In 2000, 12% of deaths were injury associated deaths attributed to RTAs, which was the 4th leading cause of years of life lost [30]. RTAs accounted for 27% of fatalities 1999 [31] and in 2001 and 2006, the number of RTA incidences and fatalities increased by 42% and 37%, respectively [32]. The most recent data released by Statistics South Africa [33] reported 6 300 RTAs in 2015 accounting for 12.1% of unnatural deaths (1.4% of all deaths) in the country. RTAs were the third leading cause of unnatural death in South Africa. Although statistics exist on RTAs, there are limited studies providing in-depth research on RTAs (Table 2.2).

1.5.2 Economic burden of road traffic accidents

Globally, it has been established that RTAs place an economic burden on countries. In 2000, the cost of RTAs amounted to R 13.8 billion [34]. In 2008/2009, it was reported that RTAs cost R 12 675 billion [35] and in 2010, they accounted for 7.8% of South Africa’s annual GDP [7]. However, the Road Traffic Management Corporation [36] reports a
higher figure. They reported that annually, RTA associated fatalities and injuries cost South Africa R 38 billion [36].

Other aspects of RTA costs have been investigated. A previous study, reported that pedestrian injuries accounted for 13% of the total cost of RTAs [37]. Harris & Olukonga [38] investigated how the use of preventative mechanisms can be used to reduce the economic burden of RTA. It was predicted that increasing the use of seatbelts in urban areas by an additional 16% from a baseline of 32%, could decrease the cost of RTAs by 9.5%, saving a single province R 35.36 million [38].

Although these studies and reports serve to highlight the significant burden of RTAs in South Africa, they are limited because they do not describe where these costs come from. Parkinson et al. [10] attempted to do this in a study investigating the hospital cost of RTAs. Using a bottom-up micro-costing approach, this study reported that over a ten-week period the cost of in-patient care amounted to approximately R 9 million [10]. The average cost for pedestrians and motor vehicle occupants was R 88 257 and R 92 651, respectively [10]. The authors report that upper extremity injuries were the most expensive injury per patient (R 137 930), followed by pelvic injuries (R 122 772) and neck injuries (R 105 066) [10]. There are numerous studies and reports investigating the cost of RTAs. However, it is difficult to compare these studies and therefore develop an understanding of the economic magnitude of RTAs in South Africa [39].
### Table 1.2 | Studies investigating RTAs in South Africa

<table>
<thead>
<tr>
<th>STUDY</th>
<th>REGION</th>
<th>PERIOD</th>
<th>FATAL/NON-FATAL RTAS</th>
<th>PREVALENCE</th>
<th>BLUNT FORCE TRAUMA INJURIES REPORTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peden et al. (1996) [34]</td>
<td>Cape Town</td>
<td>1993</td>
<td>Fatal &amp; non-fatal</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Sukhai et al. (2009) [37]</td>
<td>South Africa</td>
<td>2002-2006</td>
<td>Fatal</td>
<td>35.8/100 000</td>
<td>No</td>
</tr>
<tr>
<td>Reddy et al. (2013) [38]</td>
<td>eThekwini</td>
<td>5-year period</td>
<td>Fatal &amp; non-fatal</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Howlett et al. (2014) [39]</td>
<td>Pietermaritzburg</td>
<td>2011-2012</td>
<td>Fatal &amp; non-fatal</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Parkinson et al. (2014) [10]</td>
<td>Pietermaritzburg</td>
<td>2011-2012</td>
<td>Fatal</td>
<td>-</td>
<td>Yes</td>
</tr>
</tbody>
</table>
1.5.3 Road traffic accident victim demographics

During the period 2001-2006, RTAs predominantly affected individuals who fell within the age group 35-49 years, followed by 25-34 years [5]. Studies investigating different aspects of RTAs in South Africa, reported similar age groups in their findings, with some of the most affected age groups being 18-29 years [40] 21-30 years [41], 25-59 years [42] and 15-44 years [10, 11]. The loss of individuals in these age groups contributes to the economic burden of the country [6, 13]. This is because these individuals are typically young individuals who are in their most economically productive years [6, 13].

Globally, numerous studies [2, 4, 43-45] have reported that there is a greater percentage of males than females involved in RTAs. In 2002, it was reported that males made up 73% of RTA fatalities globally [46]. In Cape Town, RTAs were the fourth leading cause of death in 2001 (7.0%) and 2006 (6.7%) for males, compared to females where RTA associated death accounted for 3.8% and 3.1% in 2001 and 2006, respectively [47]. Similar findings are also reported in rural areas of South Africa. A study conducted in Mthatha reported a male to female ratio of 3:1 [41]. In other South African studies, the percentage distribution of males involved in RTAs ranges from 65 – 81%, however, in no cases were females found to be at a greater risk for RTAs than males [10, 40, 48]

It is suggested that the increased preponderance of males compared to females in RTAs can be attributed to the fact that males have a more active lifestyle with more mobility [43,
This is further agitated by increased risk-taking behaviour associated with males [49]. Other risk factors associated with RTAs include fatigue, increased alcohol/drug consumption and the use of cell phones while driving [49].

### 1.5.4 Risk factors

The risk factors associated with RTAs have been investigated extensively globally. These risk factors have been explored in South Africa. The University of Natal’s Accident Research Centre [50], reported that human factors (78%) were the main reason responsible for RTAs, followed by environmental factors (12%) and vehicle factors (10%). Human factors include speed, alcohol and drug use, driver fatigue, and cell phone use, while environmental factors include crash scene light, weather, location and road surface [1]. Similar findings were reported by Kyei & Masangu [51], where human factors such as high speed (47.3%), jaywalking (39.0%), unlawful/unsafe overtaking (7.2%), hit and run (6.5%), were also the main cause for RTAs (80.1%). Environmental and vehicle, related factors were reported to be responsible for 11.5% and 8.4% of RTAs, respectively [51].

Rural regions may, however, differ slightly in the attributed risk factors. A study investigating RTAs in Mthatha (semi-rural region in the Eastern Cape province of South Africa), attributed RTAs to poor roads, poor health and communication systems, reckless driving and unroadworthy vehicles [41]. Regions which are more economically stable
typically have improved infrastructure and better access to health care structure, both of which may result in fewer deaths associated with RTAs. Further risk factors include; jaywalking (particularly across major highways), speeding and the use of alcohol [52].

1.5.4.1 Road traffic accident and alcohol impairment

Alcohol consumptions is a global phenomenon and has been shown to lead to drunkenness and violence [53, 54]. South Africa has been described by Seggie [55] as a “hard drinking” country, consuming more than five billion litres of alcohol every year [56]. In 2009, 10-12% of the country’s gross domestic product was spent on the tangible and intangible costs of harmful alcohol use [56]. It was predicted in 2006, that the cost of alcohol-related RTAs would amount to R 7.9 billion [57]. In 2010, the Road Management Traffic Co-operation reported that alcohol-related RTAs cost South Africa R 180 billion [58].

The effect of alcohol misuse in South Africa is a growing public health concern and have had a huge impact on the justice system in the country [59, 60]. Studies have shown that an association exists between alcohol use and risk-taking behaviour [59, 60]. Alcohol use may also impair judgement and slow down the reaction times of an individual [61]. Such effects can have disastrous consequences for road users, including vehicle occupants as well as pedestrians. It has been reported that in South Africa alcohol was a contributing factor in 29.1% of non-fatally injured drivers [62] and in 47.4% of fatally injured drivers
[63]. A study predicted that 24% of fatal and non-fatal RTAs could be prevented if drivers were not behind the steering wheel while under the influence of alcohol [64]. A legal alcohol limit has been set for drivers in South Africa to discourage drinking and driving. Within South African legislation (National Road Traffic Act 92 of 1996), the legal limit for the presence of alcohol for professional drivers is set at 0.02 g/100 mL and for normal drivers at 0.05 g/100 mL. At BAC levels between 0.0 – 0.05 g/100 mL, the clinical signs and symptoms are normal behaviour, mild euphoria and reduced reaction time [65]. The clinical signs and symptoms at BAC levels between 0.05 – 0.01 g/100 mL include impaired coordination, slow reaction time, decreased judgment, slow reaction time and decreased sensory response to stimuli [65].

Previous studies have reported BAC levels in fatal RTAs in South Africa. BAC levels greater than 0.05 g/100 mL were reported in 57.2%, 30.7%, 46.5% and 35.6% for pedestrians, passengers, drivers and cyclists, respectively [1]. A recent study investigating the presence of alcohol in all medicolegal autopsies in Pretoria, reported that 37% of the cases analysed were RTAs [40]. Within these RTA cases, alcohol was present (BAC > 0.01 g/100 mL) in 52% of the cases. The average BAC for drivers and pedestrians was 0.17 ± 0.09 g per 100 mL and 0.22 ± 0.11 g per 100 mL, respectively, which is far above the South African legal limit of 0.05 g/100 mL.

Although pedestrians are often reported as the most intoxicated road user, the country’s legislation is directed at controlling driver impairment; there are no laws directly governing
alcohol use for pedestrians in South Africa. Such laws do exist in various states (such as Alabama, Idaho, Illionois, and Kansas) in United States of America.

A study investigating pedestrian fatalities across four cities in South Africa found that 58% of cases tested positive for alcohol, with 42% of these cases having a Bac greater than 0.24g/100ml [66]. Pedestrian safety education programs exist; however, these programs do not always communicate the risk of alcohol use and pedestrian behaviour [67]. Research suggests that alcohol limits for pedestrians should be introduced [67].

1.5.4.2 Road traffic accident and drug impairment

Alcohol is the most commonly abused drug and its effect has been researched extensively. However, research is now showing an increased prevalence of drug use in fatal and non-fatal RTAs. Out of treatment drug users (87%) reported driving immediately after taking illicit drugs, mainly heroin and cocaine [68]. Out of these drug users, 41.4% were involved in at least one RTA following drug consumption [68]. A United States-based study reported that drug positive prevalence in fatally injured drivers increased by 49% from 1999 - 2000 to 2009 - 2010 [69]. A study conducted in Sweden showed that 80 - 85% of samples collected from fatally injured drivers tested positive for at least one banned substance with amphetamine being the most detected drug [70]. In another study, illicit drugs were detected in 25% of drivers involved in RTAs [71]. Cannabis was the most detected drug, followed by benzodiazepines, cocaine, amphetamines and opioids [71].
Although limited, the epidemiology of drug abuse in South Africa has been investigated. A study conducted by Peltzer et al. [72] investigated the types of drugs seen in substance abuse treatment centres. The primary illicit substance reported was cannabis (16.9%), followed by methamphetamine (tik) (12.8%), crack cocaine (9.6%), heroine/opiates (9.2%), cannabis and mandrax (3.4%) and prescription/over the counter medication (2.6%). Another study based on admissions at substance abuse treatment centres, showed that after alcohol (51%), cannabis (21%) was the most abused drug. This was followed by crack cocaine (4.5%), prescription/over the counter medications (2.0%) and cannabis and mandrax (1.7%) [73]. There have however been no studies investigating the role of drugs in RTAs. One of the challenges faced is the lack of forensic toxicological data available. This is because, unless suspected, drugs are not routinely tested for in post-mortem RTA cases. The problem with this, as Mercer & Jeffrey [74] pointed out is that in RTA cases, alcohol and drug impairment is mistakenly interpreted as alcohol impairment only and drug impairment is identified as “driving without care and attention”. It is evident, there is a need to further investigate the use of drugs among victims of RTAs in South Africa.

1.5.5 Road traffic accident preventative mechanisms

Road transportation preventative mechanisms are put in place to reduce RTA mortality and morbidity rates. In South Africa, although limited, studies have been conducted investigating the efficiency of preventative mechanisms that have been put in place. Reddy & Knight [75] investigated the effect of traffic calming humps on pedestrian-vehicle
collisions in two different areas of eThekwini Municipality, Durban. This study reported that the introduction of traffic calming humps resulted in the reduction of non-fatal RTAs by 23% and 22%, while fatal RTAs dropped by 68% and 50% in Chatsworth and Kwamashu, respectively [75].

An in-depth review of traffic calming strategies was conducted in Cape Town. This review concluded that a significant decrease in traffic speeds (up to 30%), volumes (up to over 70%), resulted in a reduction of RTAs (by between 16% to 90%) from the base case. However, unlike the study conducted by Reddy & Knight [75], this study was not based on an extensive literature review. Nonetheless, the study provides valuable insight into the degree of success of road traffic calming strategies in Cape Town.

1.5.6 Road traffic accident associated blunt force trauma

Studies regarding RTAs are limited, especially when it comes to RTA associated injuries. The main issue with SA based studies regarding RTA associated blunt force trauma injuries, is that the research lacks depth and detail. A study carried out by Parkinson et al. [10], investigating the hospital cost of RTAs, reported that upper limb injuries were the most expensive injury to treat. However, this study did not provide insight into specifics about the types of injury (e.g. soft tissue versus hard tissue), the severity of injuries and the road user obtaining these injuries. In another study Parkinson et al. [11] provided more detail about the type of upper limb injuries observed in RTA victims. However, this
information is limited to hard tissue injuries, and in lower limb injuries even less information is provided. This is an issue with similar studies where fractures are often noted but not described in any great detail, or the mechanism of injury is not fully investigated.

Parkinson et al. [12] conducted another study in 2013 comparing the pattern of injuries obtained by pedestrians (PED) with those obtained by motor vehicle occupants. Their findings suggested that motor vehicle occupants sustained neck, abdominal and upper arm injuries, while pedestrians sustained injuries to the lower extremity, upper limbs, head and torso. Despite the fact that details of the mechanism of injury were not explored, the difference between the injuries observed, illustrate how the mechanism of injury informs the type of injuries obtained by RTA victims. This study provides valuable information to enhance the distinction between road users in RTAs, which may have forensic significance. However, with the exception of upper and lower extremities, the study did not investigate the types of injuries observed in the different regions. In addition to this, the study did not describe the differences in the injuries obtained by different people within a vehicle, such as the driver or passenger(s).

In comparison to Parkinson et al. [12], Bowely and Boffard [76] investigated injuries associated with RTA including an analysis of the mechanism of injury obtained by pedestrians. Their findings revealed that an upright adult pedestrian hit by the bumper of a motor vehicle was more likely to sustain injuries to the lower extremities [76]. If the
pedestrian was hit by the windscreen they were more likely to obtain injuries to the torso and head, while impact with the ground resulted in head, spinal and other injuries [76].

The injuries obtained by children has also been investigated. A study [77] conducted in Gauteng reported that lower limb fractures (33.5%) were the most frequent, followed by fractures to the upper extremities (5.5%) and pelvic fractures (4.1%). Visceral injuries were not reported; neither was the mechanism of injury investigated. Despite this, however, the study does provide useful insight into the type of injuries obtained by children. However, this type of research is limited in South Africa.

1.6 Conclusion

Road transportation systems are a developmental achievement. However, with them came increased global morbidity and mortality rates. In South Africa, RTAs pose a huge economic and psychological burden on the country. A greater preponderance of males to females are involved in RTAs, most of whom fall within the most economically productive age group. The use of alcohol and drugs in RTAs has been identified. However, the extent of alcohol and drug-impaired in RTAs has not been fully established. In addition to this, factors other than alcohol and drug use, are rarely quantified within literature. Many aspects of RTA associated blunt force trauma have been investigated internationally. However, very few studies exist in South Africa.
In South Africa, RTAs are a complicated issue to study. This can be attributed to the economically diverse population, varying road conditions and different road users, which make data collection both challenging and unique [78]. However, the burden of RTAs calls for more research and this research needs to pay particular attention to RTA associated injuries, the road user and the context in which these RTAs are occurring. The purpose of this study is to investigate the demography surrounding RTAs in a region of Cape Town and the injuries associated with them. This information can then be used in the identification of the mechanism of injury, which will then inform the road safety mechanisms and the traffic laws required to reduce the prevalence of RTAs in South Africa.
1.7 Reference List


[52] I.P. Ojungu-Omara, Ways of reducing accidents on South African roads, Faculty of Engineering and the Built Environment, Department of Civil Engineering, University of Cape Town South Africa, 2006.


[57] L. London, Mazok, C., Adam, H., Parry, C., If the alcohol doesn't get you, then the toxins will: The health impacts of bulk wine provision in the Western Cape province of South Africa, American Public Health Association Conference, Boston, 2006.


CHAPTER TWO:

Publication Ready Manuscript
RETROSPECTIVE ANALYSIS OF BLUNT FORCE TRAUMA ASSOCIATED
WITH FATAL ROAD TRAFFIC ACCIDENTS IN CAPE TOWN (SOUTH
AFRICA) OVER A TWO-YEAR PERIOD.

T. A. Tiffany Majero*

*Department of Pathology, Division of Forensic Medicine and Toxicology, Faculty of
Health Sciences, University of Cape Town.

*Correspondence to: T. A. Tiffany Majero, Department of Pathology, Division of Forensic Medicine and
Toxicology, Faculty of Health Sciences, University of Cape Town, P.O. Box 13914, Mowbray, 7705,
South Africa. E-mail: tiffanymajero@icloud.com
Currently, in South Africa, there is limited information regarding the prevalence of road traffic accidents and the blunt force trauma injury patterns associated with them. The purpose of this study was to determine the prevalence of fatal road traffic accidents and the characteristics of associated blunt force trauma injuries in the West Metropole region of Cape Town (South Africa). A retrospective analysis was conducted of all fatal road traffic accidents autopsied at Salt River Mortuary (which serves the West Metropole region of Cape Town), from January 1st, 2013 to December 31st, 2014. All deaths that were not determined to be due to road traffic accident associated blunt force trauma by the pathologist were excluded. The prevalence of fatal road traffic accidents for 2013 and 2014 were 16.2/100 000 and 15.5/100 000, respectively. The majority of road traffic accident victims were males who fell in the age group of 30 – 49 years. Over the two-year period, the majority of road traffic accident victims were pedestrians with elevated blood alcohol concentration levels. The body regions which presented the most associated blunt force trauma were the head and face for external injuries and the head and chest for hard tissue and visceral injuries. It was determined that pedestrians were the most vulnerable road user and that in order to develop appropriate preventative mechanisms, further research is required in order to determine what factors make them more vulnerable.
2.2 INTRODUCTION

Road transportation systems are a global development. However, this achievement may be responsible for increasing global mortality and morbidity rates around the world. Approximately, 1.2 million people die annually in road traffic accidents (RTAs), while millions of survivors sustain debilitating injuries [1]. It has been predicted that RTA associated fatalities will increase by 2020, making RTAs the lead contributor to the overall burden of disease [1, 2].

90 % of RTA associated fatalities occur in low- and middle- income countries, with Africa having some of the highest mortality rates in the world [3-5]. It has been predicted that these rates will continue to increase with increased urbanisation and vehicle ownership [3-5]. In Africa studies investigating this phenomenon have been conducted in Libya [6], Ghana [7] and Tanzania [8].

In South Africa, the economic burden of RTAs has also been investigated. The incidence of RTA and associated fatalities increased by 42% and 37%, respectively, from 2001 – 2006 [9]. In 2006, RTAs were responsible for the loss of an average of 27 people daily [9]. In 2008/2009, it was estimated that RTAs cost the economy R12 675 billion [10]. Other South African based studies have investigated the hospitalisation cost of RTAs [5], the relationship between alcohol and RTAs [11] and in general, the injury patterns sustained by RTA victims [4]. These studies highlight the severe and increasing burden of RTAs,
however, it is still necessary to conduct further research particularly relating to the prevalence of RTA associated fatalities and the injuries associated with such deaths.

Blunt force trauma injuries are characteristic of RTAs and are the primary type of injury seen in such cases. Studies investigating RTA associated blunt force trauma injuries in South Africa have been conducted [4, 5, 12]. However, these studies are limited to regions of the body injured and the fractures sustained. These studies do not provide an in-depth analysis of the injuries observed. In addition to this, they do not investigate the relationship between the type of injuries observed and road user. No studies characterizing the pattern of injury observed in RTA, exist for the Western Cape. In order to reduce the morbidity and mortality rates of RTAs, an understanding of the types of injuries obtained needs to be established.

Therefore, the aim of this study was to investigate RTA associated blunt force trauma injuries, the road user and the context in which these RTAs occur. This information can then be used in identifying the mechanism of injury, which can then inform the road safety mechanisms and the traffic laws required to reduce the prevalence of RTAs in South Africa.
2.3 METHODS

A retrospective investigation of all fatal road traffic accident (RTA) autopsied at Salt River Mortuary (Cape Town, South Africa) from 1 January 2013 to 31 December 2014 was conducted. Salt River Mortuary is classified as a level six academic facility, which serves the West Metropole region of the city of Cape Town (Figure 2.1). It receives in excess of 3 000 cases per year [13].

Figure 2.1 | Map of the greater Cape Town area indicating the service region of Salt River mortuary (West Metropole of the city of Cape Town)
For the purposes of this study, a RTA was defined as a collision between two or more objects (one of which had to be a motor vehicle). Cases were excluded if injuries occurred on the road but did not involve at least one motor vehicle (a motor vehicle was defined as a self-propelled device that is used as a means of transport for passengers or cargo on roads) RTA cases were also excluded if death was not determined by the pathologist as due to RTA associated blunt force trauma injuries. In addition to this, cases were excluded from further analysis when the injuries described by the pathologist were challenging to interpret.

Information was extracted from the original autopsy files and was recorded in a Microsoft® Office Excel® 2013 (Microsoft, Redmond, Washington, USA) database. The data was exported into Stata Version 13.1 (StataCorp, Texas, USA), where descriptive statistical analysis was carried out. Associations between different variables were analysed using the Pearson’s Chi-Squared ($\chi^2$) test. Population Data was obtained from the 2011 National Census Data from Statistics South Africa [14]. A summary list of the suburbs forming part of the service area and their relevant population sizes can be found in Appendix C.

Ethical approval for this study was granted by the Human Research Ethics Committee (HREC) of the Faculty of Health Sciences at the University of Cape Town (HREC REF: 165/2016).
2.3 RESULTS AND DISCUSSION

2.4.1 Prevalence of RTAs

RTAs form a substantial proportion of deaths worldwide. A study utilizing data from the National Injury Mortality Surveillance System (NIMSS), suggested that the road traffic mortality rate in South is double the global rate of 26.7% of injury-related deaths accredited to road traffic injuries [15].

At Salt River Mortuary, a total of 3,346 and 3,461 autopsies were conducted in 2013 and 2014, respectively. Of these deaths, 314 (9.4%) and 301 (8.7%) were as a result of RTAs. Based on population data from the 2011 national census, the prevalence of fatal RTAs for 2013 and 2014 were 16.2/100,000 and 15.5/100,000, respectively. Comparison of these values to previous studies conducted in the Western Cape, was challenging, because such studies are limited. However, when compared to other regions in South Africa the prevalence of RTAs observed in these study were considerably less than the prevalence reported study that investigated fatal RTAs in Mthatha, Eastern Cape South Africa (57/100,000) [16]. This study used medico-legal autopsy files to collect its data. In contrast to the West metropole region of the city of Cape Town (predominantly mid- to high socio-economic status), the Mthatha region is a largely impoverished rural area. It has previously been demonstrated that the prevalence of RTAs is inflated in poorer, rural regions [17, 18]. This is as a result of poor roads, poor health and communications
system, reckless driving and unroadworthy vehicles [16]. When compared to other provinces in the country, the prevalence of RTAs in this study was less than the prevalence (18.1/100 000) reported for Limpopo, but greater than the prevalence (5.9/100 000) reported for Gauteng between 2001 and 2006 [19]. Differences in the prevalence of RTAs are expected between countries and within a country because of the differences that exist in terms of the volume of vehicles, the density of road networks, road safety mechanism and the behaviour of road users.

2.4.2 Demographic distribution of RTAs

2.4.2.1 Distribution of RTAs by age

Figure 2.2 illustrates the age distribution of RTAs. The age ranges used are the same as those used by the WHO. According to data collected by the WHO, in 2000 and 2012, the age groups most affected by RTAs were 30 - 49 years, followed by 15 – 29 years [20]. These were the same age groups most affected by RTAs in the current study (Figure 2.2). The mean age group of individuals involved in RTAs was 34 years (SD = 16.80; range 1 – 87 years). The highest incidence of fatalities occurred in the age group of 30 - 49 years (44.95%), followed by 15 – 29 years (25.08%). It is important to note, that further analysis is needed to more accurately define exactly who is at risk.
The findings in this study concur that globally over 50% of RTAs involve individuals who are aged between 15 – 44 years [21]. Individuals who form part of this age group are in their most active and productive years. The loss of these individuals has a huge economic impact on family members and the nation [22, 23]. It is, therefore, important to implement appropriate preventative and safety mechanisms in order to reduce the risk of these age groups to RTAs. However, before this can be done, more research investigating the risk factors (e.g. use of restraint methods, experience behind the wheel, drugs and alcohol, etc.) specifically associated with these age groups needs to be conducted.
The findings in this study showed that the proportion of RTAs in the age groups that were less than 15 years and greater than 50 years were low. This is because individuals who fall within these age groups are presumed to be less mobile and are therefore less likely to be exposed to RTAs [22].

2.4.2.2 Distribution of RTAs by sex

In this study, there was a higher percentage of males (82.60%) than females (17.40%) involved in RTAs (ratio = 4.75: 1). The male predominance observed in this study is in accordance with other studies of this nature [22, 24]. It is suggested that males are more exposed to RTA as studies suggest that males have a more active outdoor lifestyle with more mobility [24]. In addition to this, when compared to women, men have a greater risk-taking attitude on the road [1].

2.4.3 Distribution of RTAs by road user

In the current study, RTA victims were divided into five categories according to road user, namely: cyclist, driver, motorcyclist, passenger and pedestrian. It is important to note that further classification of road users (e.g. sub-classification of passengers according to their seating position) would be beneficial in conducting a more in-depth analysis of the type of injuries obtained by various road users. However, the information required in order to conduct this type of analysis is often not reported in medicolegal autopsy files.
In this study, the greatest percentage of RTA deaths were among pedestrians (58.21%), followed by drivers (17.24%), passengers (14.63%), motorcyclists (8.29%) and cyclists (1.63%) (Figure 2.3). Similar findings were reported by Matzopoulos et al. [18], where pedestrian fatalities accounted for 40%, of RTAs followed by drivers (22.9%) and passengers (32.6%).

Figure 2.3 | Percentage distribution of RTA fatalities by road user

Previous studies [25-27] conducted in developing countries, substantiate the increased susceptibility of pedestrians to RTAs. The vulnerability of pedestrians could be attributed to the lack of awareness of road safety mechanisms and practices. A Kenyan based study
[8], reported that 92% of police respondents felt that the lack of awareness of the highway code by pedestrians was one of the reasons why they were the most vulnerable road user. In South Africa, research investigating pedestrian behaviour is limited. However, the high percentage of deaths occurring among pedestrians observed in this study, suggests that the current laws regulating pedestrians may be inefficient. In order to reduce the exposure of pedestrians to RTAs, research investigating pedestrian behaviour is required, so that reasonable pedestrian laws can be created and enforced [28]. In addition to this, there is a need for campaigns designed to educate and encourage pedestrians to adopt good road safety practices.

Comparison of the findings in this study with studies conducted in other African countries such as Cote d’Ivoire [25], Ethiopia [25], Kenya [26] and Nairobi [27] revealed that the highest proportion of RTA deaths were also among pedestrians. However, in countries in South-East Asia, motorcyclists contributed the most to RTA fatalities, while in the United States of America, drivers were the most vulnerable road user [29]. Studies investigating the distribution of road users in RTA fatalities have shown that it varies dramatically between different countries [30]. The difference between countries is due to differences in the type of traffic, the proportion of road users, and the nature of RTA [1].
2.4.4 Temporal distribution of fatal RTAs

2.4.4.1 Time of day

Odero et al. [31] reported that in developing countries between 60-80 % of RTA fatalities occurred during the day with only a third of them occurring at night between 1800-2400 hrs. A similar observation was made in a Jamaican based study conducted by Crawford & McGrowder [22] where the greatest incidence of RTA fatalities occurred between 0600-1800 hrs. The reason for the increased incidence of RTAs during the day may be attributed to an increased traffic load of individuals travelling to and from work or school [31]. The majority of studies report elevated levels of RTAs during the day, however, a few studies do report a greater incidence of RTAs at night [31, 32], as was the case in the current study.

In the current study, the majority of fatal RTAs occurred between 1800-2400 hrs. (37.52%) followed by 0000-0559 (22.13%). Although traffic density at night is less, poor visibility, increased speed, fatigue and increased risk-taking behaviour escalates the risk of RTAs [31, 33, 34]. Delays in injury reporting and less efficient medical services at night [31] may also contributed to increased risk of RTAs occurring at night, where adequate infrastructure and medical support are not readily available.
Differences were noted in the time of death of different road users (Figure 2.3). Motor vehicle occupant fatalities had two substantial peaks at 0000 – 0559 and 0600 – 1159. In contrast pedestrian fatalities gradually increased throughout the day, with the highest percentage of deaths (65.71%) occurring between 1800-2359. After which the number of fatalities decreased (Figure 2.4). A significant difference ($p = 0.0001$) between road user and time of death was observed between pedestrian and motor vehicle occupant fatalities. The difference observed could be attributed to the differences in the density of these road users during these time zones. However, the relationship between road user density and time of death has not been fully explored.

**Figure 2.4 | Comparison between time of death and pedestrian versus motor vehicle occupants.**
2.4.4.2 Day of the week

Over the two-year period, 50.56% RTAs occurred during the week (Monday – Friday), while 49.44% of RTAs occurred during the weekend (00h00 Saturday morning to 24h00 Sunday night). The greatest number of RTAs was observed on Saturday (26.67%), followed by Sunday (22.78%). In studies conducted in Ethiopia [35] and India [36] the greatest incidence of RTAs was also observed on Saturday. Even though, there is a decrease in traffic density during the weekend, the risk of RTAs is high because of other factors such as alcohol and drug intoxication [31].

2.4.5 Survival period

Over the two-year period, 58.37% of RTA victims died at the scene, 38.70% died after hospitalisation and 2.93% died en route to the hospital. Of the hospitalised RTA victims, 34.21% survived less than 24 hours and 65.78% survived more than 24 hours (Figure 2.5). The mean survival time after admission to hospital was 4.84 hours (min < 1 hour; max 21.0 hours) in the < 24-hour group and 11.78 days (min: 1 day; max: 178 days) in the > 24-hour group. Survival time is linked to the severity and extent of injuries as well as the quality of treatment a patient receives. However, post-operative complications and infections may further compromise an individual’s chance of survival. Furthermore, the longer a RTA victim stays in hospital, the greater the risk of developing complications that may lead to death [37]. Thus, it is not surprising that the majority of hospitalised patients
in fatal RTAs, succumb to their injuries after 24hrs of hospitalisation. Increased mortality rates of RTAs in third world countries are often attributed to insufficient and poor emergency medical services [32, 38]

Figure 2.5 | Place of death and survival period after admission
2.4.6 Toxicology and RTAs

2.4.6.1 Alcohol intoxication

South Africa has been described as a “hard-drinking country” consuming more than 5 billion litres of alcohol annually [39]. Matzopoulou et al. [40] reported that in 2009 the tangible and intangible costs of harmful use of alcohol to the economy amounted to R300 billion, which was 10-12% of the country’s gross domestic product. A strong correlation exists between intoxication and RTAs.

In the current study, it was noted that alcohol analysis was requested in 66.55% of the autopsies reviewed. The reason why blood alcohol analysis was not conducted in all cases is because in South Africa, specimens for analysis are collected at the pathologists’ discretion. Blood was the most common specimen taken for alcohol analysis (66.02%) and vitreous humour was used as a specimen in 0.53% of the cases. At the time of writing BAC results were present in 69.74% of the cases. The blood alcohol concentration (BAC) was expressed in grams per 100 millilitres (g/100 mL). A BAC of ≥ 0.01 g/100 mL was considered a positive detection of alcohol. Of the cases where alcohol analysis was conducted, and results were available, alcohol was detected in 50.18% of the victims with a mean BAC of 0.091 g/100 mL. Findings in this study are comparable to other South African based studies conducted by Ehmke et al. [41] and du Plessis et al. [42] where 52.0% and 50.3% respectively, of RTA victims tested positive for alcohol.
Table 2.1 | Distribution of the presence of alcohol, intoxication and BAC levels per road user

<table>
<thead>
<tr>
<th>PRESENCE OF ALCOHOL</th>
<th>Cyclist</th>
<th>Driver</th>
<th>Motorcyclist</th>
<th>Passenger</th>
<th>Pedestrian</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive *</td>
<td>1 (33.33)</td>
<td>30 (52.63)</td>
<td>12 (46.15)</td>
<td>20 (46.51)</td>
<td>72 (51.06)</td>
<td>121</td>
</tr>
<tr>
<td>Negative *</td>
<td>2 (66.67)</td>
<td>27 (47.37)</td>
<td>14 (53.85)</td>
<td>23 (53.49)</td>
<td>69 (48.94)</td>
<td>149</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>57</td>
<td>26</td>
<td>43</td>
<td>141</td>
<td>270</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PREVALENCE OF INTOXICATION</th>
<th>Cyclist</th>
<th>Driver</th>
<th>Motorcyclist</th>
<th>Passenger</th>
<th>Pedestrian</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intoxicated *</td>
<td>1 (33.33)</td>
<td>25 (43.86)</td>
<td>10 (38.43)</td>
<td>18 (41.86)</td>
<td>67 (47.52)</td>
<td>121</td>
</tr>
<tr>
<td>Not intoxicated *</td>
<td>2 (66.67)</td>
<td>32 (56.14)</td>
<td>16 (61.54)</td>
<td>25 (58.14)</td>
<td>74 (52.48)</td>
<td>149</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>57</td>
<td>26</td>
<td>43</td>
<td>141</td>
<td>270</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BAC LEVELS</th>
<th>Cyclist</th>
<th>Driver</th>
<th>Motorcyclist</th>
<th>Passenger</th>
<th>Pedestrian</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.34</td>
<td>0.153 ± 0.08</td>
<td>0.148 ± 0.07</td>
<td>0.154 ± 0.08</td>
<td>0.206 ± 0.09</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0.34-0.34</td>
<td>0.02-0.31</td>
<td>0.03-0.26</td>
<td>0.04-0.34</td>
<td>0.02-0.41</td>
<td></td>
</tr>
</tbody>
</table>

* BAC ≥ 0.01 g/100 mL  
* BAC 0.00 g/100 mL  
* BAC ≥ 0.05 g/100 mL  
* BAC < 0.05 g/100 mL  
* Indicates significant difference (p < 0.05)

The distribution of the presence of alcohol according to road user was investigated (Table 2.1). Drivers (52.63%) were the most prevalent road user with the highest percentage of fatalities with a positive BAC. Pedestrians (51.06%) were found to have the second highest percentage of fatalities with positive BAC results. Drivers involved in fatal RTAs were more likely to have positive BAC results than pedestrians (p = 0.0001).
The results demonstrated that in cases where alcohol was detected, 44% of the victims’ BAC levels were over the South African legal driving limit (0.05 g/100 mL), as governed by the National Road Traffic Act (92 of 1996). The mean BAC of these cases was 0.192 ± 0.08 g/100 mL ranging between 0.05-0.41 g/100 mL.

Table 2.1 indicates that the mean BAC for each road user group was far greater than 0.05 g/100 mL. The same observation was made by du Plessis et al. [42]. Cyclists had the overall highest mean BAC (0.34 g/100 mL). However, this group only contained three cases, only one of which was positive for the presence of alcohol. Pedestrians had the second highest mean BAC (0.206 ± 0.09 g/100 mL) followed by drivers and passengers who both had a mean BAC of 0.15 g/100 mL.

The high mean BAC level among pedestrians in this study is a major concern, especially considering that as discussed previously, pedestrians made up the majority of RTA victims (Figure 2.1). In South Africa, the National Road Traffic Act 92 of 1996 governs the use of alcohol by drivers, however, no laws or interventions exist explicitly governing the use of alcohol by pedestrians. It is evident from these findings that to reduce the risk of pedestrians to RTAs, more needs to be done to limit drunk pedestrians.

The findings in this study show that alcohol consumption by these different road user groups, especially by pedestrians and drivers is a major problem. The legal BAC in South
Africa for driving was reduced in 1996 from 0.08 g/100 mL to 0.05 g/100 mL and 0.02 g/100 mL for professional drivers. Since this reduction there has not been a huge improvement in the number of alcohol-related RTA fatalities [41]. Further reduction of the legal limit might not the solution to reducing RTA related deaths [42]. Instead there might be a need for the establishment of alcohol-related preventative mechanism targeted at specific road users and perhaps stricter enforcement of blood alcohol laws and penalties for non-compliance with the relevant laws in South Africa [42]. In addition to this, there is a need for the implementation of education programs focused on increasing awareness on road safety.

2.4.6.2 Drug intoxication

Similar to alcohol, previous research has shown that there is an association between the use of psychoactive substances and an increased risk of RTAs [43-45]. However, a clear concentration-effect-relationship between the parent drug (and its metabolites), RTA risk and the severity of injury has to date not been established [46]. Unfortunately, relatively few regions routinely conduct investigations to determine the presence of psychoactive drugs in victims of RTA’s. Studies which have been conducted revealed the prevalence of cannabis (3.5-27%), cocaine (33%), amphetamine (4.6-14%), opioids (19%) and benzodiazepines (3-12%) in drivers involved in RTAs [47-52]. The presence of antihistamines (2%), sedative cough suppressant (0.7%), mitragynine (0.9%) and
morphine (0.1%) have also been detected in drivers [53]. There are, however, limited studies on the detection of psychoactive drugs in other road users.

In South Africa, specimens for toxicological analysis (other than alcohol) are not routinely collected. Therefore, the presence of psychoactive substances could not be investigated in this study. Over the two-year period of this study, samples for drug analysis were only collected from 12 (2.10%) cases and results for these cases were not yet available. The epidemiology of drug abuse in South Africa has been studied previously [54, 55]. However, there is a limited number of studies investigating drugs in the context of RTAs. The role of drugs in RTAs is underestimated and it is important that drug analysis in such cases be made mandatory to fully appreciate their involvement.

2.4.7 RTA associated injuries

Investigating RTA associated injuries can assist in predicting the pattern of injuries obtained by RTA victims. The information produced by such studies can be used by medical services to reduce mortality rates by decreasing the diagnosis time and subsequent patient management [23]. This information can also be used by policymakers to make improvements to emergency services [23, 56]. In addition to this, analysing injuries obtained in RTAs is a useful way of assessing if current road safety mechanisms are working and what can be done to improve them [23]. With regards to forensic investigations, understanding RTA associated injuries can assist pathologists, law enforcement and the court in reconstructing the circumstances surrounding the RTA.
In this study, injuries were divided into two main categories: external and internal injuries. Internal injuries were further subdivided into those affecting hard tissue (e.g. bone fractures) and visceral injuries. Pedestrians were found to have the highest percentage of all these injuries, followed by drivers and passengers (Table 2.2). However, it is important to note that 58% of autopsied cases involved pedestrians (Figure 2.1). The distribution of injuries is similar to the distribution of road users. No significant difference was observed between the proportion of road users and the presence of external (p = 0.089), hard tissue (p = 0.567) and visceral (p = 0.736) injuries as a result of RTA. Similarly, there is also no significant difference in the number of external, hard tissue and visceral injuries (p = 0.77).

**Table 2.2 | Distribution of type of injury per road user**

<table>
<thead>
<tr>
<th>Road User</th>
<th>Distribution of road user (%)</th>
<th>Injury n (%)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>External</td>
<td>Hard</td>
<td>Visceral</td>
<td></td>
</tr>
<tr>
<td>Cyclist</td>
<td>1.63</td>
<td>9 (1.61)</td>
<td>8 (1.47)</td>
<td>9 (1.58)</td>
<td></td>
</tr>
<tr>
<td>Driver</td>
<td>17.24</td>
<td>98 (17.56)</td>
<td>95 (17.46)</td>
<td>100 (17.61)</td>
<td></td>
</tr>
<tr>
<td>Motorcyclist</td>
<td>8.29</td>
<td>47 (8.42)</td>
<td>45 (8.27)</td>
<td>47 (8.27)</td>
<td></td>
</tr>
<tr>
<td>Passenger</td>
<td>14.63</td>
<td>79 (14.16)</td>
<td>83 (15.26)</td>
<td>85 (14.96)</td>
<td></td>
</tr>
<tr>
<td>Pedestrian</td>
<td>58.21</td>
<td>325 (58.24)</td>
<td>313 (57.54)</td>
<td>327 (57.57)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>558</td>
<td>544</td>
<td>568</td>
<td></td>
</tr>
</tbody>
</table>
2.4.7.1 Region of injury

Figure 2.6 demonstrates the distribution of injuries according to the region of injury. Overall, most external injuries were observed on the face (70.19%), followed by lower (65.25%) and upper (64.05%) extremities. Pedestrians were more likely to suffer external injuries to the head (0.023), neck (0.032) and back (0.021). Motor vehicle occupants (driver/passenger) exhibited external injuries to the neck (41.98%), followed by upper extremities (31.91%) and the chest (31.13%).

The head (hard tissue: 43.69%; visceral: 40.78%) and the chest (hard tissue: 77.55%; visceral: 68.54%) were the most common regions affected by hard tissue and visceral injuries in this current study. Pedestrians were at greater risk of obtaining hard tissue injuries to the lower extremities. It is evident, that pedestrians are the most vulnerable road user, with minimum to little protection against RTAs. There is a need for preventative and protective mechanisms specifically tailored to protect this type of road user from RTAs.
Figure 2.6 | Percentage distribution of RTA associated injuries according to body regions
2.4.7.2 External injuries

In this study, abrasions (66.51%) were the most common type of external injury followed by lacerations (22.23%) and contusions (11.27%) (Table 2.3). Abrasions contributed to the highest percentage of external injuries in all road users in this study (Figure 2.7). Abrasions are typically noted as the most common form of external injury in RTAs [23, 57, 58]. However, a study conducted in India on the injuries sustained by motor vehicle occupants noted, where lacerations were the most common type of external injury (38.28%), followed by abrasions (38.15%), and contusions (19.20%) [59].

![Figure 2.7](image_url)  
**Figure 2.7** | Mean percentage distribution of external injuries according to road user
Table 2.3 | Distribution of external injuries in RTA victims over different regions of the body

<table>
<thead>
<tr>
<th>REGION OF BODY</th>
<th>Abrasion (n)</th>
<th>Contusion (n)</th>
<th>Laceration (n)</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face</td>
<td>349</td>
<td>72</td>
<td>184</td>
<td>605 (26.32)</td>
</tr>
<tr>
<td>Head</td>
<td>119</td>
<td>10</td>
<td>63</td>
<td>192 (8.35)</td>
</tr>
<tr>
<td>Neck</td>
<td>62</td>
<td>10</td>
<td>10</td>
<td>82 (3.57)</td>
</tr>
<tr>
<td>Chest</td>
<td>164</td>
<td>30</td>
<td>9</td>
<td>203 (8.83)</td>
</tr>
<tr>
<td>Back</td>
<td>99</td>
<td>1</td>
<td>3</td>
<td>103 (4.48)</td>
</tr>
<tr>
<td>Pelvis</td>
<td>112</td>
<td>9</td>
<td>27</td>
<td>148 (6.44)</td>
</tr>
<tr>
<td>Abdomen</td>
<td>131</td>
<td>16</td>
<td>13</td>
<td>160 (7.00)</td>
</tr>
<tr>
<td>Upper extremities</td>
<td>227</td>
<td>49</td>
<td>100</td>
<td>376 (16.35)</td>
</tr>
<tr>
<td>Lower extremities</td>
<td>266</td>
<td>62</td>
<td>102</td>
<td>430 (18.70)</td>
</tr>
<tr>
<td>Total</td>
<td>1 529</td>
<td>259</td>
<td>511</td>
<td>2 299 (100)</td>
</tr>
</tbody>
</table>

Degloving injuries are characterized by avulsion or detachment of subcutaneous tissue from underlying muscle and tissue [60], RTAs have been reported to be the most common cause of degloving injuries, frequently involving the lower extremities [61-63]. In this study degloving injuries were the most common injury observed to the upper (71.43%) and lower (53.85%) extremities. Degloving injuries have been reported to be common in pedestrians [64]. In the current study, no significant difference was observed ($p = 0.287$).
between degloving injuries to the lower extremities of pedestrians and motor vehicle occupants. For upper extremities, the was insufficient data to determine which road user was at greater risk of obtaining degloving injuries.

2.4.7.3 Hard tissue injuries

The distribution of hard and visceral tissue injuries is summarised in Table 2.4. Hard tissue injuries of the skull occurred in 53.25% of cases. These injuries consisted of various fractures (96.25%), followed by suture diastasis (3.54%). In a study conducted by Soni et al. [65] and Menon & Nagesh [66], linear fractures were the most common head fractures amongst victims of RTA. However, a review of head fractures in the current study, showed that comminuted fractures (75%) were the most common type of fracture. This is consistent with a study conducted in Fiji where comminuted fractures were also the most common type of head fracture [67]. Pedestrians had the highest percentage of fractures to the head (59.61%), followed by drivers (18.56%) and passengers (13.5%). The cause of pedestrians’ increased head injury has been attributed to impact with the windscreen or impact to the A-pillar region of the car [68].

The neck is another commonly injured region in RTAs. Hard tissue injuries to the neck were observed in 19.11% of cases. These injuries consisted of dislocations (49.17%) and fractures (50.83%). The majority of dislocations and fractures were observed on the atlanto-occipital joint (64.5%) and the majority of fractures were observed on the cervical
vertebrae (83.6%). Typically, atlanto-occipital dislocation accounts for less than 1% of all cervical spine injuries, however, in RTAs, it is the most commonly noted cervical spine injury, with a prevalence as high as 35% [69]. Partial dislocations (75%) and fracture dislocations (63.16%) were commonly present in the current study. Pedestrians had the highest percentage of dislocations (64.5%) and fractures (60.66%), followed by drivers.

Hard tissue injuries to the thoracic region were observed in 40.78% of cases. These injuries were in the form of fractures (94.91%), with relatively few dislocations (5.09%). The chances of obtaining fractures in this region of the body were significantly greater in pedestrians than in motor vehicle occupants (drivers and passengers) (P = 0.001). Most of the fractures involved the ribs (60.53%), followed by the vertebral column (13.56%) and the clavicle (12.35%) respectively. In a previous study, rib fractures (63.3%) were also the most common injury observed in the thorax [70]. A total of 54.85% of rib fractures were observed in pedestrians followed by drivers (17.76%) and passengers (16.39%). The frequency of rib fractures in RTA victims is important because it can be a good indicator of underlying visceral injuries to the thorax [70].
Table 2.4 | Relative distribution of hard tissue and visceral tissue injuries in RTA victims over different regions of the body

<table>
<thead>
<tr>
<th></th>
<th>CYCLIST</th>
<th>DRIVER</th>
<th>MOTORCYCLIST</th>
<th>PASSENGER</th>
<th>PEDESTRIAN</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASES</td>
<td>10 (1.63 %)</td>
<td>106 (17.24 %)</td>
<td>51 (8.29 %)</td>
<td>90 (14.63 %)</td>
<td>358 (58.21 %)</td>
<td></td>
</tr>
<tr>
<td><strong>HARD TISSUE INJURIES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HEAD</td>
<td>7 (1.49 %)</td>
<td>85 (18.05 %)</td>
<td>33 (7.01 %)</td>
<td>64 (13.59 %)</td>
<td>282 (59.87 %)</td>
<td>0.782</td>
</tr>
<tr>
<td>NECK</td>
<td>1 (0.83 %)</td>
<td>20 (16.53 %)</td>
<td>8 (6.61 %)</td>
<td>13 (10.74 %)</td>
<td>79 (65.29 %)</td>
<td>0.522</td>
</tr>
<tr>
<td>THORAX</td>
<td>7 (1.42 %)</td>
<td>80 (16.19 %)</td>
<td>47 (9.51 %)</td>
<td>72 (14.57 %)</td>
<td>288 (58.30 %)</td>
<td>0.854</td>
</tr>
<tr>
<td>Clavicle</td>
<td>2 (3.28 %)</td>
<td>8 (13.11 %)</td>
<td>1 (1.64 %)</td>
<td>6 (9.84 %)</td>
<td>44 (72.13 %)</td>
<td>0.097</td>
</tr>
<tr>
<td>Ribs</td>
<td>4 (1.38 %)</td>
<td>53 (17.73 %)</td>
<td>29 (9.36 %)</td>
<td>49 (16.39 %)</td>
<td>164 (54.85 %)</td>
<td>0.713</td>
</tr>
<tr>
<td>Sternum</td>
<td>1 (1.85 %)</td>
<td>11 (20.37 %)</td>
<td>8 (14.81 %)</td>
<td>10 (18.52 %)</td>
<td>24 (44.44 %)</td>
<td>0.248</td>
</tr>
<tr>
<td>UPPER EXTREMITIES</td>
<td>1 (0.62 %)</td>
<td>21 (12.96 %)</td>
<td>26 (16.05 %)</td>
<td>21 (12.96 %)</td>
<td>93 (57.41 %)</td>
<td>0.006</td>
</tr>
<tr>
<td>Humerus</td>
<td>1 (1.25 %)</td>
<td>9 (11.25 %)</td>
<td>4 (5.00 %)</td>
<td>12 (15.00 %)</td>
<td>54 (67.5 %)</td>
<td>0.410</td>
</tr>
<tr>
<td>Radius</td>
<td>0 (0.00 %)</td>
<td>6 (14.63 %)</td>
<td>11 (26.83 %)</td>
<td>4 (9.76 %)</td>
<td>20 (48.78 %)</td>
<td>0.001</td>
</tr>
<tr>
<td>Ulnar</td>
<td>0 (0.00 %)</td>
<td>6 (13.63 %)</td>
<td>11 (25.00 %)</td>
<td>5 (11.36 %)</td>
<td>22 (50.00 %)</td>
<td>0.002</td>
</tr>
<tr>
<td>PELVIS</td>
<td>1 (0.45 %)</td>
<td>21 (9.46 %)</td>
<td>12 (5.41 %)</td>
<td>28 (12.61 %)</td>
<td>160 (72.07 %)</td>
<td>0.001</td>
</tr>
<tr>
<td>LOWER EXTREMITIES</td>
<td>1 (0.36 %)</td>
<td>26 (9.32 %)</td>
<td>30 (10.75 %)</td>
<td>38 (13.62 %)</td>
<td>184 (65.95 %)</td>
<td>0.001</td>
</tr>
<tr>
<td>Femur</td>
<td>0 (0.00 %)</td>
<td>9 (10.84 %)</td>
<td>11 (13.25 %)</td>
<td>18 (21.69 %)</td>
<td>45 (54.22 %)</td>
<td>0.065</td>
</tr>
<tr>
<td>Fibula</td>
<td>1 (1.09 %)</td>
<td>8 (8.70 %)</td>
<td>10 (10.87 %)</td>
<td>10 (10.87 %)</td>
<td>63 (68.48 %)</td>
<td>0.118</td>
</tr>
<tr>
<td>Tibia</td>
<td>0 (0.00 %)</td>
<td>9 (8.65 %)</td>
<td>9 (8.65 %)</td>
<td>10 (9.62 %)</td>
<td>76 (73.08 %)</td>
<td>0.118</td>
</tr>
</tbody>
</table>

| **VISCERAL INJURIES** |               |               |               |               |               |          |
| BRAIN             | 27 (1.93 %)   | 235 (16.79 %) | 96 (6.86 %)   | 189 (13.5 %)  | 853 (60.93 %) | 0.116    |
| THORAX            | 15 (1.50 %)   | 170 (17.03 %) | 85 (8.52 %)   | 142 (14.23 %) | 586 (58.72 %) | 0.987    |
| Heart             | 6 (2.40 %)    | 43 (17.20 %)  | 21 (8.40 %)   | 30 (12 %)     | 150 (60.00 %) | 0.693    |
| Lungs             | 2 (0.63 %)    | 56 (17.72 %)  | 28 (8.86 %)   | 47 (14.87 %)  | 183 (57.91 %) | 0.715    |
| Spinal cord       | 0 (0.00 %)    | 13 (20.00 %)  | 8 (12.31 %)   | 4 (6.15 %)    | 40 (61.54 %)  | 0.205    |
| ABDOMEN           | 17 (1.94 %)   | 132 (15.05 %) | 76 (8.67 %)   | 151 (17.22 %) | 501 (57.13 %) | 0.121    |
| Kidneys           | 2 (1.46 %)    | 19 (13.87 %)  | 9 (6.57 %)    | 27 (19.71 %)  | 80 (58.39 %)  | 0.429    |
| Liver             | 5 (1.97 %)    | 43 (16.93 %)  | 22 (8.66 %)   | 42 (16.54 %)  | 142 (55.91 %) | 0.895    |
| Spleen            | 3 (2.86 %)    | 15 (14.29 %)  | 13 (12.38 %)  | 19 (18.10 %)  | 55 (52.38 %)  | 0.278    |
| BLOOD VESSELS     | 0 (0.00 %)    | 33 (18.86 %)  | 14 (9.14 %)   | 26 (14.86 %)  | 100 (57.14 %) | 0.507    |
| Aorta             | 0 (0.00 %)    | 7 (30.43 %)   | 0 (0.00 %)    | 0 (0.00 %)    | 16 (69.57 %)  | 0.076    |
| Ascending aorta   | 0 (0.00 %)    | 3 (12.5 %)    | 1 (4.17 %)    | 6 (25.00 %)   | 14 (58.33 %)  | 0.564    |
| Descending thoracic aorta | 0 (0.00 %) | 18 (19.35 %) | 10 (10.75 %) | 17 (18.28 %) | 48 (51.61 %) | 0.409    |

*p-value denotes significance of the distribution of injuries according to road user compared to relative case numbers for each road use
Sternal fractures are a rare injury, however, the incidence of sternal fractures in RTAs has increased over time. A study conducted over a three-year (1991 – 1993) period showed that the incidence of sternal fractures in RTAs increased from 0.7% to 4% [71]. Studies have associated this increase with increased utilisation of seatbelts [71-74]. In the present study, sternal fractures occurred in 11% of RTA victims. Pedestrians had the highest percentage of sternal fractures (44.44%), followed by drivers (20.37%) and passengers (18.52%). No significant difference was observed between the number of sternal fractures obtained and road users (p = 0.248). With regards to motor vehicle occupants, information on how many were wearing seatbelts at the time of the RTA was lacking. Thus, the association between sternal fractures and seat belt usage could not be established.

A study conducted by Ooi et al. [75] showed that RTAs (52%) were the most common mechanism of injury for pelvic fractures. To date in South Africa, there is poor documentation of RTA associated injuries. This is unfortunate, considering that pelvic fractures are a major cause of death and disability in RTAs [76]. Previous studies [37, 77] have reported that approximately 25% of RTA victims sustain injuries to the pelvis. In the current study, hard tissue injuries to the pelvis occurred in 25.43% of cases. The most common injury to this region was fractures (72.20%), followed by diastasis (21.52 %) and dislocation (5.83%). Pedestrians had the highest percentage of pelvic fractures (71.97%), followed by passengers (14.65%) and drivers (9.55%). No significant difference (p = 0.653) between the number of drivers and the number of passengers that had pelvic fractures was observed. This finding was also noted by Daffner et al. [78]. However, when
compared to motor vehicle occupants, pedestrians had a significantly greater chance \( (p = 0.0012) \) of sustaining fractures to the pelvis. This is because pedestrians are the least protected road user. As a result, they receive the full impact of the kinetic energy transfer during a motor vehicle collision, resulting in severe injuries to the pelvic region [75]. Open book fractures accounted for 42.3% of pelvic fractures. This was followed by non-displaced fractures (23.08%) and comminuted fractures (19.23%). Spitz & Fischer [79] also reported that open book fractures were the most common type of pelvic fracture. However, in the current study all open book fractures were sustained by pedestrians, compared to previous where motor vehicle occupants who were in close proximity to the steering wheel (drivers) and the dashboard (front seat passengers).

Hard tissue injuries to the upper extremities were observed in 20.14% of cases. Fractures were the only hard tissue injury observed. The most common type of fracture was closed (54.72%), followed by compound (26.42%) and comminuted (11.32%). A previous study conducted in India showed that humeral fractures accounted for the greatest percentage of injuries to the upper extremities (31.25%), followed by fractures to the ulnar (15.63%) and radius (12.5%) [70]. In the current study, humeral fractures (48.48%) were also the most common injury to the upper extremities, followed by fractures of the ulnar (26.67%) and radius (24.85%). Pedestrians had the highest percentage of fractures to the upper extremities (57.4%), followed by motorcyclists (16.05%) and motor vehicle occupants (drivers: 12.96%; passenger: 12.98%). A study investigating upper extremity fractures to pedestrians revealed that humeral fractures were observed in 11% of the cases followed by fractures to the ulnar (7%) and radius (6%) [80]. In the current study, humeral fractures
were more prevalent amongst pedestrians. Fractures of the humerus were observed in 67.5% of pedestrians. Fractures of the ulna and radius were noted in 50% and 48.8% of pedestrian cases, respectively. When compared to motor vehicle occupants, pedestrians had a greater chance of sustaining fractures to the upper extremities (p = 0.001) and of sustaining humeral fractures (p = 0.038). No significant difference was observed in the number of fractures of the radius (p = 1.0) or ulnar (p = 1.0) between drivers and passengers.

Lower extremity injuries have been described as the most frequent type of injury in RTAs. In the current study, injuries to the lower extremities were observed in 27.47% of cases. The majority of these injuries were fractures (99.64%). There was only a single case where a dislocation was observed. Most of the fractures observed were closed (61%), followed by compound (33.60%) and comminuted (12.8%) fractures. The greatest percentage of lower limb fractures were sustained by pedestrians (70%), followed by passengers (13.72%) and motorcyclists (10.83%). A study investigating RTA associated injuries in motor vehicle occupants showed that fractures to the lower extremities were the most common in drivers and front seat passengers [81]. However, previous studies have shown that injuries to the lower extremities are more common in pedestrians than in motor vehicle occupants [82-84]. The findings in this study have also shown that the chances of obtaining injuries to the lower extremities are significantly greater in pedestrians than in motor vehicle occupants (P ≤ 0.001).
Previous analysis of lower limb injuries associated with RTAs showed that femoral fractures were the most frequent injury accounting for 18.6% of injuries to the lower extremities [85]. In a South African based study investigating RTA associated orthopaedic injuries in children, femoral fractures made up the majority of fractures (35.4%) [86]. Another study showed that fractures to the femur accounted for the highest percentage (31.99%) of fractures in motor vehicle occupants, more so in drivers than passengers [87]. It was, therefore, expected that in the current study the femur would have the greatest percentage of injuries. However, fractures of the tibia (37.28%), were the most frequent injury to the lower extremities, followed by fractures to the fibula (32.97%) and the femur (29.75%). Similar observations were made by Landy et al. [80] where the tibia and fibula accounted for 44% of injuries followed by femoral fractures (13%). When compared to drivers, passengers had the greatest chance of obtaining injuries to the femur ($p = 0.006$), fibula ($p = 0.0018$) and tibia ($p = 0.003$). However, pedestrians had the greatest risk of obtaining fractures to the femur ($p = 0.0016$), fibula ($p = 0.0045$) and tibia ($p = 0.0008$).

### 2.4.7.4 Head and spinal tissue injuries

Head injuries have been reported to be very common in RTAs [88]. In a study conducted by Yattoo & Tabish [89], RTAs were the main cause of head injuries accounting for 44.44% of the cases. In another study [90], investigating head trauma in children, RTAs (58.3%) were reported to be the main cause of head trauma. Emejulu & Malomo [91] also reported that a great percentage of head trauma resulted from RTAs (67.5%). Farooqui
et al. [23] attributes this increased percentage of RTA associated head trauma to the lack of helmet use by two-wheel users and the lack of seatbelt use by motor vehicle occupants. Emejulu & Malomo [91] argues that the poor state of roads and poor compliance with traffic regulations is the reason for increases in RTA associated head trauma.

In the current study, injuries to the head were observed in 77.55% of the cases. These injuries were observed on the brain (75.57%). In a previous study [23], the brain was reported as the most frequently injured organ. In this present study, pedestrians had a greater chance of sustaining injuries to the brain (p = 0.001) than motor vehicle occupants. Similar findings were found by Toro et al. [37], who reported that pedestrians and cyclists were more likely to obtain RTA associated head injuries. Kraus et al. [92] contradicts these findings by reporting that the majority of head injuries (62%) were observed in motor vehicle occupants.

In the current study, intracranial injuries were predominantly made up of haemorrhages (50.4%), followed by lacerations (13.14%), and contusions (9.83% of the brain). Subarachnoid haemorrhages were most commonly reported (75.9%) followed by subdural haemorrhages (42.41%). In the current study, pedestrians had the highest percentage of haemorrhages (63.79%), followed by drivers (14.95%) and passengers (12.48%). The findings in this study showed that the chances of obtaining haemorrhages was significantly greater in pedestrians than in drivers (p = 0.001) and passengers (p = 0.001).
injuries to the neck were observed in 13.95% of the cases. These injuries were predominantly haemorrhages (69.18%) and transections (19.86%). Visceral haemorrhages made up 87.23% of the haemorrhages. All the transections were complete transections of the spinal cord. Pedestrians had the highest percentage of haemorrhages (57.43%) and transections (62.07%), followed by drivers (haemorrhages: 18.81%; transections: 20.69%) and passengers (haemorrhages: 13.86%; transections: 13.79%). When compared to motor vehicle occupants, pedestrians had a greater chance of obtaining injuries to the neck ($p = 0.001$). In addition to this, pedestrians had a greater chance of obtaining haemorrhages ($p = 0.0189$) and transections ($p = 0.001$) than motor vehicle occupants.

Injuries to the back were observed in 9.03% of cases. These injuries involved the spinal cord (84.42%) and the spinal column (15.58%). Pedestrians had the greatest percentage of injuries to the spinal column (41.67%), followed by drivers (25%) and passengers (25%). Pedestrians also had the highest percentage of injuries to the spinal cord (61.54%), followed by drivers (20%) and motorcyclists (12.30%). No significant difference was observed between the injuries to the spinal column ($p = 0.2612$) and spinal cord ($p = 0.17$) of pedestrians and motor vehicle occupants. Visceral injuries to the back were made up of transections of the spinal column and or spinal cord (33.77%) and haemorrhages (33.77%), followed by lacerations (20.78%). Pedestrians had a significantly greater chance of obtaining transections ($p = 0.0187$) and haemorrhages ($p = 0.0016$) to the back than motor vehicle occupants.
2.4.7.5 Visceral injuries

Visceral injuries to the thoracic region were observed in 68.54% of the cases. The majority of these injuries were in the form of haemorrhages (30.46%) and contusions (22.02%). Hemothoracies were noted in 21.03% of cases. Most of the injuries to the thoracic region were observed on the lungs (31.66%) and the heart (25.05%). Pedestrians had a greater chance of obtaining injuries to the lungs (p = 0.001) and heart (p = 0.001) than motor vehicle occupants. A previous study [70], investigating the pattern of thoraco-abdominal injuries in fatal RTAs, reported that the lungs (92.3%) were the most frequently injured organs in the thoracic region, mostly exhibiting lacerations (79.1%). In contradiction to this, the current study mostly observed contusion (70.72 %), followed by laceration (44.21%) and haemorrhage (17.97%) of the lungs.

In the current study, injuries to blood vessels were observed in 19.02% of cases. Similar observations were made in another SA based study, where 20.5% of RTA victims sustained injuries to blood vessels [88]. Previous studies have reported that injury to the aorta is the second most common cause of death in RTAs [88]. In the current study, it was found that the aorta was the most injured blood vessel (86.29%), followed by the inferior vena cava (6.29%). The region of the aorta that was mostly affected was the descending thoracic aorta (61.59%), followed by the ascending aorta (15.89%). The descending thoracic aorta was also reported to have sustained the most injuries in a previous study (11.8%), although no injuries to the ascending aorta were observed [88].
Injuries to blood vessels were predominantly in the form of lacerations (50.29%), followed by transections (24.86%) and haemorrhages (12.72%). Of the lacerations described, 64.28% were transverse lacerations and 28.57% were described as step ladder lacerations. The majority of these lacerations (82.75%) were observed on various regions of the aorta. Lacerations of the aorta were described by Prahlow [93] as a “classic” injury in RTA victims. In the current study, 88.37% of the transections to blood vessels were observed on the aorta. Pedestrians had an increased chance of obtaining injuries to the aorta ($p = 0.001$) and haemorrhages ($p = 0.0056$) than motor vehicle occupants.

Blunt force trauma injuries to the abdomen are seen in 2-5% of all accidents, accounting for 51.6% of fatal accidents [94]. A study conducted in India argued that RTAs are the most common mechanism of injury for blunt force abdominal injuries. In the current study, visceral injuries to the abdomen were observed in 57.89% of cases. These injuries were predominantly made up of lacerations (41.44%), and haemorrhages (22.72%). A consequence of these injuries was hemoperitoneum, which was observed in 10.50% of the cases. A previous study [8] reported that the spleen (46.8%) was the most common organ injured, followed by the intestines (19.4%) and the liver (16.1%). The current study found the liver to be the most commonly injured abdominal organ (28.96%), followed by kidneys (15.62%). Pedestrians were at a great risk of obtaining blunt force injuries to the liver ($p = 0.001$) and kidneys ($p = 0.001$) than motor vehicle occupants. Compared to other regions of the body, the abdomen is susceptible to injuries because these regions of the body have minimal bony protection for underlying organs.
2.5 LIMITATION

A limitation of this study is that the data collected was obtained from autopsy files and a database that was not compiled by the author. As a result, assumptions were made about some of the injuries described in this manuscript, as pathologists often use different nomenclature to describe the injuries they observed. Another limitation of this study is that it only includes RTAs with a fatal outcome. The exclusion of non-fatal RTAs is a limitation because it does not provide insight into RTA associated injuries obtained by RTA survivors and therefore limits our appreciation of RTA associated injuries as a whole.
2.6 CONCLUSION

Research investigating various aspects of RTAs has been conducted in South Africa. However, studies investigating RTA associated blunt force trauma injuries are limited. In the West Metropole region of Cape Town (South Africa), during the two-year period (1 January 2013 to 31 December 2014), pedestrians were the most vulnerable road user, followed by drivers, passengers, motorcyclists and cyclists.

Abrasions contributed to the highest percentage of external injuries in all road users. This was followed by lacerations and contusions for all road users, except motorcyclists, where the opposite was found. Pedestrians had the highest percentage of head, rib, pelvic, upper extremity and lower extremity fractures. Fractures to these regions were also observed in motor vehicle occupants (drivers and passengers). There was a high incidence of visceral injuries to the brain, where the most common intracranial injuries (haemorrhages, lacerations and contusions) were observed in pedestrians, followed by motor vehicle occupants.

Further studies investigating the relationship between severity of injury, pre-, during and post hospitalisation need to be conducted as these factors have a huge influence on the survival rates of RTA victims. Improvements in these areas may result in a decrease in RTA fatalities. In addition to this, this information can also be used to direct research towards other areas in RTAs that need further investigations. Research like this is very
important because it can be used by various organisations to inform educational programs and develop preventive mechanisms that can increase the safety of all road users.
2.7 REFERENCES


Abrahams, N., Msemburi, W., Lombard, C., Bradshaw, D., Injury-related mortality in South Africa: a retrospective


[22] T. Crawford, McGrowder, D., Road traffic injury epidemic in Jamaica: Implications for Governance and public policy,

Kalakoti, P., Pattern of injury in fatal road traffic accidents in a rural area of western Maharashtra, India,


[25] I.A. Sayer, Palmer, C. J, Pedestrian accidents and road safety education in selected developing countries, 3rd

Evans, Whitehead, M., Diderichsen, F., Bhuiya, A., Wirth, M. (Ed.), Challenges inequalities: from ethics to action,


[28] J. Mwakalonge, Siuhi, S., White, J., Distracted walking: Examining the extent to pedestrian safety problems,

2015.


[32] A. Chandrasekharan, Nanavati, A. J., Prabhakar, S., Prabhakar, S., Factors impacting mortality in the pre-
hospital period after road traffic accidents in urban India, Trauma Monthly 21(3) (2016) e 22456.


[34] M. Taylor, Lynam, D., Baruya, A., The effect of driver's speed on the frequency of road accidents, UK:
Transport Research Laboratory, Berkshire, 2000.


[88] C. Lewis, Injury patterns in motor accident victims from a sample taken at the southern cluster Forensic Pathology Services, Division of Forensic Medicine, University of Witwatersrand, South Africa, 2012.


CHAPTER THREE:
Appendices
Appendix A: Acknowledgments

Prima facie, I would like to thank God for providing me with the strength, I needed to complete this thesis. I would like to express my sincere gratitude to my supervisor, Calvin Mole for his continuous support, guidance, and patience throughout the research and writing process. He had an open-door policy and was always available to answer questions and provide assistance. Finally, I would like to thank my mother, Patricia. D. Majero for supporting me spiritually and encouraging me throughout the writing process.
Appendix B: Ethics approval letter

The letter was removed to avoid exposing the authority's signature.
Appendix C: Estimated population data for the West Metropole region of Cape Town (South Africa).

The estimated population data for the individual suburbs for the west metropole region of Cape Town were obtained from the 2011 Census, which is available here: [http://www.capetown.gov.za/Family%20and%20home/education-and-research-materials/data-statistics-and-research/cape-town-census](http://www.capetown.gov.za/Family%20and%20home/education-and-research-materials/data-statistics-and-research/cape-town-census)

<table>
<thead>
<tr>
<th>Suburb</th>
<th>Population</th>
<th>Suburb</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia Park 817</td>
<td>817</td>
<td>Green Point</td>
<td>9 301</td>
</tr>
<tr>
<td>Athlone</td>
<td>45 048</td>
<td>Gugulethu</td>
<td>98 468</td>
</tr>
<tr>
<td>Atlantis Non-Urban</td>
<td>2 479</td>
<td>Hanover Park</td>
<td>45 497</td>
</tr>
<tr>
<td>Atlantis</td>
<td>67 491</td>
<td>Hazendal</td>
<td>4 995</td>
</tr>
<tr>
<td>Bergvliet</td>
<td>4 428</td>
<td>Heathfield</td>
<td>7 226</td>
</tr>
<tr>
<td>Bishopscourt</td>
<td>1 603</td>
<td>Heideveld</td>
<td>21 288</td>
</tr>
<tr>
<td>Bloubergstrand</td>
<td>11 179</td>
<td>Hout Bay</td>
<td>17 329</td>
</tr>
<tr>
<td>Bonteheuvel</td>
<td>52956</td>
<td>Imizamo Yethu</td>
<td>15 538</td>
</tr>
<tr>
<td>Bothasig</td>
<td>11 790</td>
<td>Joe Slovo Park</td>
<td>12 629</td>
</tr>
<tr>
<td>Brooklyn</td>
<td>10 941</td>
<td>Kalk Bay</td>
<td>700</td>
</tr>
<tr>
<td>Camps Bay</td>
<td>4 982</td>
<td>Kennilworth</td>
<td>10 872</td>
</tr>
<tr>
<td>Cape Peninsula National Park</td>
<td>286</td>
<td>Kensington</td>
<td>24 161</td>
</tr>
<tr>
<td>Cape Town CBD</td>
<td>5 647</td>
<td>Kirstenhof</td>
<td>4 515</td>
</tr>
<tr>
<td>Capri</td>
<td>30 61</td>
<td>Kleine Zout Rivier Small Holdings</td>
<td>283</td>
</tr>
<tr>
<td>Capricorn</td>
<td>4 458</td>
<td>Knole Park</td>
<td>2 961</td>
</tr>
<tr>
<td>Castle Rock</td>
<td>5 595</td>
<td>Kommetjie</td>
<td>3 341</td>
</tr>
<tr>
<td>Century City</td>
<td>4 239</td>
<td>Lakeside</td>
<td>3 801</td>
</tr>
<tr>
<td>Claremont</td>
<td>17 198</td>
<td>Langa</td>
<td>52 401</td>
</tr>
<tr>
<td>Clifton</td>
<td>5 07</td>
<td>Lansdowne</td>
<td>18 650</td>
</tr>
<tr>
<td>Clowelly</td>
<td>5 59</td>
<td>Lavenderhill</td>
<td>32 598</td>
</tr>
<tr>
<td>Coniston Park</td>
<td>1 833</td>
<td>Llandudno</td>
<td>571</td>
</tr>
<tr>
<td>Constantia</td>
<td>12 454</td>
<td>Lotus River</td>
<td>38 143</td>
</tr>
<tr>
<td>Crossroads</td>
<td>36 043</td>
<td>Maitland Garden Village</td>
<td>1 834</td>
</tr>
<tr>
<td>Da Gama Park</td>
<td>2 346</td>
<td>Maitland</td>
<td>9 782</td>
</tr>
<tr>
<td>Diep River</td>
<td>2 515</td>
<td>Mammre</td>
<td>9 048</td>
</tr>
<tr>
<td>Dreyersdal</td>
<td>2 130</td>
<td>Manenberg</td>
<td>61 615</td>
</tr>
<tr>
<td>Edgewemead</td>
<td>9 884</td>
<td>Marconi Beam</td>
<td>37</td>
</tr>
<tr>
<td>Epping Industria</td>
<td>50</td>
<td>Marina da Gama</td>
<td>3 390</td>
</tr>
<tr>
<td>Fairways</td>
<td>2 952</td>
<td>Masiphumelele</td>
<td>21 904</td>
</tr>
<tr>
<td>Fish Hoek</td>
<td>9 052</td>
<td>Meadowridge</td>
<td>3 194</td>
</tr>
<tr>
<td>Foreshore</td>
<td>7 62</td>
<td>Melkbosstrand</td>
<td>11 303</td>
</tr>
<tr>
<td>Gardens</td>
<td>7 960</td>
<td>Milnerton Non-Urban</td>
<td>3 293</td>
</tr>
<tr>
<td>Glencairn</td>
<td>1 574</td>
<td>Milnerton</td>
<td>14 306</td>
</tr>
<tr>
<td>Grassy Park</td>
<td>19 212</td>
<td>Mitchells Plain</td>
<td>310 485</td>
</tr>
<tr>
<td>Suburb</td>
<td>Population</td>
<td>Suburb</td>
<td>Population</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------</td>
<td>-------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Montague Gardens</td>
<td>22</td>
<td>Sea Point</td>
<td>16 164</td>
</tr>
<tr>
<td>Monte Vista</td>
<td>7 023</td>
<td>Sheraton Park</td>
<td>3 111</td>
</tr>
<tr>
<td>Mowbray</td>
<td>4 726</td>
<td>Silvertown</td>
<td>27 146</td>
</tr>
<tr>
<td>Muizenberg</td>
<td>5 537</td>
<td>Simons Town</td>
<td>2 649</td>
</tr>
<tr>
<td>Ndabeni</td>
<td>1 014</td>
<td>Southfield</td>
<td>7 106</td>
</tr>
<tr>
<td>Newlands</td>
<td>5 100</td>
<td>St James</td>
<td>4 91</td>
</tr>
<tr>
<td>Noordhoek</td>
<td>4 424</td>
<td>Steenberg Estate</td>
<td>796</td>
</tr>
<tr>
<td>Nyanga</td>
<td>57 996</td>
<td>Steenberg</td>
<td>4 168</td>
</tr>
<tr>
<td>Observatory</td>
<td>9 207</td>
<td>Stonehurst Mountain Estate</td>
<td>678</td>
</tr>
<tr>
<td>Ocean View</td>
<td>13 569</td>
<td>Summer Greens</td>
<td>6 275</td>
</tr>
<tr>
<td>Oranjezicht</td>
<td>3 580</td>
<td>Sun Valley</td>
<td>4 869</td>
</tr>
<tr>
<td>Ottery</td>
<td>17 942</td>
<td>Sunningdale</td>
<td>5 299</td>
</tr>
<tr>
<td>Oude Molen Village</td>
<td>530</td>
<td>Sybrand Park</td>
<td>1 613</td>
</tr>
<tr>
<td>Paarden Eiland</td>
<td>11</td>
<td>Table Mountain Nature Reserve</td>
<td>114</td>
</tr>
<tr>
<td>Parklands</td>
<td>24 614</td>
<td>Table View</td>
<td>25 977</td>
</tr>
<tr>
<td>Parkwood</td>
<td>11 870</td>
<td>Tamboerskloof</td>
<td>2 984</td>
</tr>
<tr>
<td>Pelikan Park</td>
<td>12 552</td>
<td>Thornton</td>
<td>5 862</td>
</tr>
<tr>
<td>Pella</td>
<td>1 681</td>
<td>Tiijgerhof/Sanddrift</td>
<td>6 178</td>
</tr>
<tr>
<td>Philippi</td>
<td>191 025</td>
<td>Tokai</td>
<td>3 664</td>
</tr>
<tr>
<td>Philippi Small Holdings</td>
<td>6 618</td>
<td>University of Cape Town</td>
<td>471</td>
</tr>
<tr>
<td>Phoenix</td>
<td>4 219</td>
<td>V &amp; A Waterfront</td>
<td>1 570</td>
</tr>
<tr>
<td>Pinelands</td>
<td>14 198</td>
<td>Vissershok</td>
<td>323</td>
</tr>
<tr>
<td>Plumstead</td>
<td>20 178</td>
<td>Vredehoek</td>
<td>5 415</td>
</tr>
<tr>
<td>Polismoor</td>
<td>2 161</td>
<td>Vrygrond</td>
<td>18 498</td>
</tr>
<tr>
<td>Red Hill</td>
<td>1 016</td>
<td>Westlake</td>
<td>6 452</td>
</tr>
<tr>
<td>Retreat</td>
<td>35 709</td>
<td>Wingfield</td>
<td>3 129</td>
</tr>
<tr>
<td>Robben Island</td>
<td>116</td>
<td>Woodstock</td>
<td>12 656</td>
</tr>
<tr>
<td>Rondebosch/Rosebank</td>
<td>19 554</td>
<td>Wynberg</td>
<td>14 472</td>
</tr>
<tr>
<td>Rugby</td>
<td>4 431</td>
<td>Youngsfield</td>
<td>887</td>
</tr>
<tr>
<td>Ruyterwacht</td>
<td>10 773</td>
<td>Ysterplaat Airbase</td>
<td>838</td>
</tr>
<tr>
<td>Salt River</td>
<td>6 577</td>
<td>Zeekoei Vlei</td>
<td>421</td>
</tr>
<tr>
<td>Scarborough</td>
<td>1 075</td>
<td>Zonnebloem</td>
<td>5 122</td>
</tr>
<tr>
<td>Schotschekloof</td>
<td>3 203</td>
<td>Estimated population total</td>
<td>1 937 139</td>
</tr>
</tbody>
</table>
FORENSIC SCIENCE INTERNATIONAL
An international journal dedicated to the applications of medicine and science in the administration of justice.

AUTHOR INFORMATION PACK

DESCRIPTION
Forensic Science International publishes original contributions in the many different scientific disciplines pertaining to the forensic sciences. Fields include forensic pathology and histochemistry, chemistry, biochemistry and toxicology (including drugs, alcohol, etc.), biology (including the identification of hairs and fibres), serology, odontology, psychiatry, anthropology, the physical sciences, firearms, and document examination, as well as investigations of value to public health in its broadest sense, and the important marginal area where science and medicine interact with the law.

The journal publishes: Original Research Papers (Regular Papers) Review Articles Rapid Communications Technical Notes Forensic Anthropology Population Data Case Reports Preliminary Communications Letters to the Editor Book Reviews The journal covers all legal aspects of the general disciplines listed above, as well as specialist topics of forensic interest that are included in, or are related to, these disciplines, e.g.: Biochemical and chemical analyses, and the forensic application of advanced analytical, physical, chemical and instrumental techniques Bitemark evidence Battered child syndrome Questioned documents Ballistics, projectiles and wounds Fingerprints and identification Tool marks Contact traces Poisoning Breath analysers Accident investigation and mass disasters

AUDIENCE
Pathologists, Anthropologists, Psychiatrists, Biologists, Serologists, Odontologists, Physical Scientists, Toxicologists, Scientists in Legal and Social Medicine, Questioned Documents and Jurisprudence

IMPACT FACTOR
2016: 1.989 © Thomson Reuters Journal Citation Reports 2017
ABSTRACTING AND INDEXING

Bulletin Signalétique
Cambridge Scientific Abstracts
Chemical Abstracts
Criminology, Penology and Police Science Abstracts
Current Contents
MEDLINE®
EMBASE
National Criminal Justice Reference Service
Science Citation Index
Biological Abstracts
Current Awareness in Biological Sciences
Scopus

EDITORIAL BOARD

Co Editors-in-Chief

C. Cattaneo, Dipart. di Scienze Biomediche per la Salute, Sezione di Medicina Legale, Università degli Studi di Milano, via L. Mangiagalli 37, 20133, Milano, Italy (for: Forensic anthropology and odontology, clinical forensic medicine [eg. child abuse, sexual violence, torture, other forms of ill treatment], humanitarian forensic medicine, animal maltreatment and forensic issues concerning the environment)

C. Jackowski, Institute of Forensic Medicine, Universität Bern, Bühlstr. 20, CH 3012, Bern, Switzerland (for: Forensic pathology, forensic radiology, traffic medicine, ballistics, physics and biomechanics)

Consulting Editor-in-Chief

P. Saukko, University of Turku, Turku, Finland

Associate Editors

A. Carracedo, (for: Forensic Genetics), Institute of Legal Medicine, Universidade de Santiago de Compostela, Pedrueca 1, 39003 Santander - Cantabria, Spain

O.H. Drummer, (for: Toxicology), Dept. of Forensic Medicine, Monash University, Victoria, Australia

P. Margot, (for: Questioned Documents and Physical Science: ballistics, tool marks, contact traces, drugs analysis, fingerprints and identification etc.), Ecole des Sciences criminelles, School of Criminal Science, Université de Lausanne, bâtiment BCH, 1015 Lausanne, Switzerland

S. Matuszewski, (for: Forensic Entomology), Adam Mickiewicz University of Poznan, Św. Marcin 90, Poznań, Poland
Assistant Editors

A. Bécue, (for P. Margot) Lausanne, Switzerland
D. Deangelis, (for C. Cattaneo) Milan, Italy
Z. Obertova, (for C. Cattaneo) Milan, Italy
C. Weyermann, (for P. Margot) Lausanne, Switzerland

Editorial Board

J. Amendt, Frankfurt, Germany
P. Beh, Hong Kong, China
P. Buzzini, Huntsville, Texas, USA
C. Campobasso, Campobasso, Italy
H. Chung, Seoul, The Republic of Korea
J.G. Clement, Melbourne, VIC, Australia
S.D. Cohle, Grand Rapids, MI, USA
S. Cordner, South Melbourne, VIC, Australia
G.L. de la Grandmaison, Garches, France
P. Dickens, Buxton, UK
H. Druid, Stockholm, Sweden
A. Eriksson, Umea, Sweden
J.A.J. Ferris, Auckland, New Zealand
M.C. Fishbein, Los Angeles, CA, USA
M.J. Hall, London, England, UK
C. Henssge, Essen, Germany
M.A. Huestis, Baltimore, MD, USA
H. Ikegaya, Kyoto, Japan
A.W. Jones, Stockholm, Sweden
H. Kalimo, Helsinki, Finland
Y. Katsumata, Chiba, Japan
B. Kneubuehl, Thun, Switzerland
G. Lau, Singapore
S. Leadbeatter, Cardiff, Wales, UK
C. Lennard, Canberra, NSW, Australia
A. Luna Maldonado, Murcia, Spain
B. Madea, Bonn, Germany
H. Maeda, Osaka, Japan
D. Meuwly, The Hague, Netherlands
C. Neumann, University Park, PA, USA
S. Pollak, Freiburg, Germany
M.S. Pollanen, Toronto, ONT, Canada
D.J. Pounder, Dundee, Scotland, UK
K. Püschel, Hamburg, Germany
G. Quatrehomme, Nice, France
R. Ramotowski, Washington, DC, USA
GUIDE FOR AUTHORS

Your Paper Your Way

We now differentiate between the requirements for new and revised submissions. You may choose to submit your manuscript as a single Word or PDF file to be used in the refereeing process. Only when your paper is at the revision stage, will you be requested to put your paper in to a 'correct format' for acceptance and provide the items required for the publication of your article. To find out more, please visit the Preparation section below.

INTRODUCTION

Forensic Science International is a peer-reviewed, international journal for the publication of original contributions in the many different scientific disciplines comprising the forensic sciences. These fields include, but are not limited to, forensic pathology and histochemistry, toxicology (including drugs, alcohol, etc.), serology, chemistry, biochemistry, biology (including the identification of hairs and fibres), odontology, psychiatry, anthropology, the physical sciences, firearms, and document examination, as well as the many other disciplines where science and medicine interact with the law.

Types of paper

1. Original Research Articles (Regular Papers)
2. Review Articles
3. Rapid Communications
4. Technical Notes
5. Forensic Anthropology Population Data
6. Case Reports
7. Preliminary Communications
8. Letters to the Editor
9. Book Reviews

Please note that all contributions of type 4 to 7 will be published as e-only articles. Their citation details, including e-page numbers, will continue to be listed in the relevant print issue of the journal's Table of Contents.

**Announcement of Population Data:** these types of articles will be published in Forensic Science International: Genetics, only. Please submit these articles via [http://www.ees.elsevier.com/fsigen/](http://www.ees.elsevier.com/fsigen/).

**Preliminary Communications** (where brief accounts of important new work may be announced with less delay than is inevitable with major papers) may be accepted after correspondence with the appropriate Associate Editor.

**Review Articles** may be regularly submitted or invited by Editors. However, they will undergo the normal review process of the journal.

**Forensic Anthropology Population Data**: Although the main focus of the anthropology section of the journal remains on the publication of original research, authors are invited to submit their forensic anthropology population data articles by selecting the "Forensic Anthropology Population Data" article type on the online submission system. When submitting a Forensic Anthropology Population data article, please assure that "Forensic Anthropology Population Data" is included as one of the keywords. These forensic anthropology population data articles involve the application of already published and standardised methods of aging, sexing, determination of ancestry and stature and other well known diagnoses on different populations. This is at the heart of applied forensic anthropology. For example, in order to correctly assess age, stature or even sex of individuals of different ancestry or from different populations, it is fundamental that the method be tested on the specific population one is working on. In building the biological profile of a skeleton in order to aid identification, one needs to calibrate such techniques on the population of interest before applying them. The same may be true in a completely different scenario of anthropology, for example identifying criminals taped on video surveillance systems and aging victims of juvenile pornography. This section is dedicated to forensic anthropological population data and other types of updates (state of the art of particular issues, etc.), particularly concerning the following:

- Sexing
- Aging sub adult skeletal remains
- Aging adult skeletal remains
- Aging living sub adults and adults
- Determining ancestry
- Stature estimation
- Facial reconstruction
- Non metric trait distribution, pathology and trauma
- Positive identification of human skeletal remains
- Positive identification of the living
Forensic Anthropology Population Data articles will be published in abridged form in print (a clear, descriptive summary taken from the abstract), and the full length article will be published online only. Full citation details and a reference to the online article, including e-page numbers, will be published in the relevant print issue of the journal. All submitted manuscripts will be evaluated by a strict peer review process.

**Case Reports** will be accepted only if they contain some important new information for the readers.

**Rapid Communications** should describe work of significant interest, whose impact would suffer if publication were not expedited. They should not be longer than 5 printed journal pages (about 10 submitted pages). Authors may suggest that their work is treated as a Rapid Communication, but the final decision on whether it is suitable as such will be taken by the handling Editor. Rapid Communications requiring revision should be resubmitted as a new submission.

**Technical Notes** report new developments, significant advances and novel aspects of experimental and theoretical methods and techniques which are relevant for scientific investigations within the journal scope. Manuscripts of this type should be short (a few pages only). Highly detailed and specific technical information such as computer programme code or user manuals can be included as electronic supplements. The manuscript title must start with "Technical Note:"

**Revisions deadline**

Please note that articles that are sent to the author for revision need to be returned within 60 days (and within 20 days for subsequent revisions). A reminder will be sent in the second month. Any articles that are sent after the two month period of revision will be considered a re-submission.

**Contact details for submission**

Papers for consideration should be submitted by topic. Editors and their topic specialty are listed below.

- **C. Cattaneo** (Co Editors-in-Chief):
  Tel: +39 02503 15679
  E-mail: cristina.cattaneo@unimi.it

- **C. Jackowski** (Co Editors-in-Chief):
  Tel: +41 (0)31 631 84 12
  E-mail: Christian.Jackowski@irm.unibe.ch

- **A. Carracedo**: Forensic Genetics. Please note only review articles on this topic should be submitted to FSI. All non-review papers should be submitted to the FSI daughter journal devoted to this subject Forensic Science International: Genetics, via [http://ees.elsevier.com/fsigen/](http://ees.elsevier.com/fsigen/)
  Fax:+34 981 580336
  E-mail: angel.carrafsi@usc.es
P. Margot: Questioned Documents and Physical Science: ballistics, tool marks, contact traces, drugs analysis, fingerprints and identification, etc.
Tel: +41 21 692 4605
Fax: +41 21 692 4605
E-mail: pierre.margot@unil.ch

O.H. Drummer: Toxicology
Tel: +61 3 9684 4334
Fax: +61 3 9682 7353
E-mail: olaf.drummer@vifm.org

S. Matuszewski: Entomology
Tel: +48 61 82 94 292
E-Mail: szymmat@amu.edu.pl
Submission checklist

You can use this list to carry out a final check of your submission before you send it to the journal for review. Please check the relevant section in this Guide for Authors for more details.

Ensure that the following items are present:

One author has been designated as the corresponding author with contact details:

- E-mail address
- Full postal address

All necessary files have been uploaded:

Manuscript:

- Include keywords
- All figures (include relevant captions)
- All tables (including titles, description, footnotes)
- Ensure all figure and table citations in the text match the files provided
- Indicate clearly if color should be used for any figures in print

Graphical Abstracts / Highlights files (where applicable)
Supplemental files (where applicable)

Further considerations

- Manuscript has been 'spell checked' and 'grammar checked'
- All references mentioned in the Reference List are cited in the text, and vice versa
- Permission has been obtained for use of copyrighted material from other sources (including the Internet)
- A competing interests statement is provided, even if the authors have no competing interests to declare
- Journal policies detailed in this guide have been reviewed
- Referee suggestions and contact details provided, based on journal requirements

For further information, visit our Support Center.

BEFORE YOU BEGIN

Ethics in publishing
Please see our information pages on Ethics in publishing and Ethical guidelines for journal publication.

Declaration of interest

All authors must disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert
testimony, patent applications/registrations, and grants or other funding. Authors must disclose any interests in two places: 1. A summary declaration of interest statement in the title page file (if double-blind) or the manuscript file (if single-blind). If there are no interests to declare then please state this: 'Declarations of interest: none'. This summary statement will be ultimately published if the article is accepted. 2. Detailed disclosures as part of a separate Declaration of Interest form, which forms part of the journal's official records. It is important for potential interests to be declared in both places and that the information matches. More information.

Additional information

Multiple submissions is not acceptable to the Editor, and any such papers, together with future submissions from the authors, will be rejected outright. Submission also implies that all authors have approved the paper for release and are in agreement with its content.

Submission declaration and verification

Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see 'Multiple, redundant or concurrent publication' section of our ethics policy for more information), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. To verify originality, your article may be checked by the originality detection service CrossCheck.

Contributors

Each author is required to declare his or her individual contribution to the article: all authors must have materially participated in the research and/or article preparation, so roles for all authors should be described. The statement that all authors have approved the final article should be true and included in the disclosure.

Changes to authorship

Authors are expected to consider carefully the list and order of authors before submitting their manuscript and provide the definitive list of authors at the time of the original submission. Any addition, deletion or rearrangement of author names in the authorship list should be made only before the manuscript has been accepted and only if approved by the journal Editor. To request such a change, the Editor must receive the following from the corresponding author: (a) the reason for the change in author list and (b) written confirmation (e-mail, letter) from all authors that they agree with the addition, removal or rearrangement. In the case of addition or removal of authors, this includes confirmation from the author being added or removed. Only in exceptional circumstances will the Editor consider the addition, deletion or rearrangement of authors after the manuscript has been accepted. While the Editor considers the request, publication of the manuscript will be suspended. If the manuscript has already been published in an online issue, any requests approved by the Editor will result in a corrigendum.
Article transfer service

This journal is part of our Article Transfer Service. This means that if the Editor feels your article is more suitable in one of our other participating journals, then you may be asked to consider transferring the article to one of those. If you agree, your article will be transferred automatically on your behalf with no need to reformat. Please note that your article will be reviewed again by the new journal. More information.

Copyright

Upon acceptance of an article, authors will be asked to complete a 'Journal Publishing Agreement' (see more information on this). An e-mail will be sent to the corresponding author confirming receipt of the manuscript together with a 'Journal Publishing Agreement' form or a link to the online version of this agreement.

Subscribers may reproduce tables of contents or prepare lists of articles including abstracts for internal circulation within their institutions. Permission of the Publisher is required for resale or distribution outside the institution and for all other derivative works, including compilations and translations. If excerpts from other copyrighted works are included, the author(s) must obtain written permission from the copyright owners and credit the source(s) in the article. Elsevier has preprinted forms for use by authors in these cases.

For open access articles: Upon acceptance of an article, authors will be asked to complete an 'Exclusive License Agreement' (more information). Permitted third party reuse of open access articles is determined by the author's choice of user license.

Author rights

As an author you (or your employer or institution) have certain rights to reuse your work. More information.

Elsevier supports responsible sharing

Find out how you can share your research published in Elsevier journals.

Role of the funding source

You are requested to identify who provided financial support for the conduct of the research and/or preparation of the article and to briefly describe the role of the sponsor(s), if any, in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication. If the funding source(s) had no such involvement then this should be stated.

Funding body agreements and policies

Elsevier has established a number of agreements with funding bodies which allow authors to comply with their funder’s open access policies. Some funding bodies will reimburse the author for the Open Access Publication Fee. Details of existing agreements are available online. After
acceptance, open access papers will be published under a noncommercial license. For authors requiring a commercial CC BY license, you can apply after your manuscript is accepted for publication.

Open access

This journal offers authors a choice in publishing their research:

Subscription

- Articles are made available to subscribers as well as developing countries and patient groups through our universal access programs.
- No open access publication fee payable by authors.

Open access

- Articles are freely available to both subscribers and the wider public with permitted reuse.
- An open access publication fee is payable by authors or on their behalf, e.g. by their research funder or institution.

Regardless of how you choose to publish your article, the journal will apply the same peer review criteria and acceptance standards.

For open access articles, permitted third party (re)use is defined by the following Creative Commons user licenses:

Creative Commons Attribution-NonCommercial-NoDerivs (CC BY-NC-ND)

For non-commercial purposes, lets others distribute and copy the article, and to include in a collective work (such as an anthology), as long as they credit the author(s) and provided they do not alter or modify the article.

The open access publication fee for this journal is USD 2500, excluding taxes. Learn more about Elsevier's pricing policy: http://www.elsevier.com/openaccesspricing

Green open access

Authors can share their research in a variety of different ways and Elsevier has a number of green open access options available. We recommend authors see our green open access page for further information. Authors can also self-archive their manuscripts immediately and enable public access from their institution's repository after an embargo period. This is the version that has been accepted for publication and which typically includes author-incorporated changes suggested during submission, peer review and in editor-author communications. Embargo period: For subscription articles, an appropriate amount of time is needed for journals to deliver value to subscribing customers before an article becomes freely available to the public. This is the embargo period and it begins from the date the article is formally published online in its final and fully citable form. Find out more.

This journal has an embargo period of 12 months.
Elsevier Publishing Campus

The Elsevier Publishing Campus (www.publishingcampus.com) is an online platform offering free lectures, interactive training and professional advice to support you in publishing your research. The College of Skills training offers modules on how to prepare, write and structure your article and explains how editors will look at your paper when it is submitted for publication. Use these resources, and more, to ensure that your submission will be the best that you can make it.

Language (usage and editing services)

Please write your text in good English (American or British usage is accepted, but not a mixture of these). Authors who feel their English language manuscript may require editing to eliminate possible grammatical or spelling errors and to conform to correct scientific English may wish to use the English Language Editing service available from Elsevier's WebShop.

Submission

Our online submission system guides you stepwise through the process of entering your article details and uploading your files. The system converts your article files to a single PDF file used in the peer-review process. Editable files (e.g., Word, LaTeX) are required to typeset your article for final publication. All correspondence, including notification of the Editor's decision and requests for revision, is sent by e-mail.

Submit your article

Please submit your article via http://ees.elsevier.com/fsi.

PREPARATION

NEW SUBMISSIONS

Submission to this journal proceeds totally online and you will be guided stepwise through the creation and uploading of your files. The system automatically converts your files to a single PDF file, which is used in the peer-review process.

As part of the Your Paper Your Way service, you may choose to submit your manuscript as a single file to be used in the refereeing process. This can be a PDF file or a Word document, in any format or layout that can be used by referees to evaluate your manuscript. It should contain high enough quality figures for refereeing. If you prefer to do so, you may still provide all or some of the source files at the initial submission. Please note that individual figure files larger than 10 MB must be uploaded separately.

References

There are no strict requirements on reference formatting at submission. References can be in any style or format as long as the style is consistent. Where applicable, author(s) name(s), journal title/book title, chapter title/article title, year of publication, volume number/book chapter and the pagination must be present. Use of DOI is highly encouraged. The reference style used by the journal will be applied to the accepted article by Elsevier at the proof stage. Note that missing data will be highlighted at proof stage for the author to correct.
**Formatting requirements**

There are no strict formatting requirements but all manuscripts must contain the essential elements needed to convey your manuscript, for example Abstract, Keywords, Introduction, Materials and Methods, Results, Conclusions, Artwork and Tables with Captions. If your article includes any Videos and/or other Supplementary material, this should be included in your initial submission for peer review purposes.

Divide the article into clearly defined sections.

**Figures and tables embedded in text**

Please ensure the figures and the tables included in the single file are placed next to the relevant text in the manuscript, rather than at the bottom or the top of the file. The corresponding caption should be placed directly below the figure or table.

**Peer review**

This journal operates a double blind review process. All contributions will be initially assessed by the editor for suitability for the journal. Papers deemed suitable are then typically sent to a minimum of two independent expert reviewers to assess the scientific quality of the paper. The Editor is responsible for the final decision regarding acceptance or rejection of articles. The Editor's decision is final. More information on types of peer review.

**REVISED SUBMISSIONS**

Use of word processing software

Regardless of the file format of the original submission, at revision you must provide us with an editable file of the entire article. Keep the layout of the text as simple as possible. Most formatting codes will be removed and replaced on processing the article. The electronic text should be prepared in a way very similar to that of conventional manuscripts (see also the Guide to Publishing with Elsevier). See also the section on Electronic artwork.

To avoid unnecessary errors you are strongly advised to use the 'spell-check' and 'grammar-check' functions of your word processor.

**Article structure**

**Introduction**

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

**Material and methods**

Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized, and indicated by a reference. If quoting directly from a previously published method, use quotation marks and also cite the source. Any modifications to existing methods should also be described.
Results

Results should be clear and concise.

Discussion

This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusions

The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

Essential title page information

• Title. Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.

• Author names and affiliations. Please clearly indicate the given name(s) and family name(s) of each author and check that all names are accurately spelled. You can add your name between parentheses in your own script behind the English transliteration. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lowercase superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.

• Corresponding author. Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. This responsibility includes answering any future queries about Methodology and Materials. Ensure that the e-mail address is given and that contact details are kept up to date by the corresponding author.

• Present/permanent address. If an author has moved since the work described in the article was done, or was visiting at the time, a 'Present address' (or 'Permanent address') may be indicated as a footnote to that author's name. The address at which the author actually did the work must be retained as the main, affiliation address. Superscript Arabic numerals are used for such footnotes.

Abstract

A concise and factual abstract is required. The abstract should state briefly the purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

Graphical abstract

Although a graphical abstract is optional, its use is encouraged as it draws more attention to the online article. The graphical abstract should summarize the contents of the article in a concise,
pictorial form designed to capture the attention of a wide readership. Graphical abstracts should be submitted as a separate file in the online submission system. Image size: Please provide an image with a minimum of 531 × 1328 pixels (h × w) or proportionally more. The image should be readable at a size of 5 × 13 cm using a regular screen resolution of 96 dpi. Preferred file types: TIFF, EPS, PDF or MS Office files. You can view Example Graphical Abstracts on our information site. Authors can make use of Elsevier's Illustration Services to ensure the best presentation of their images and in accordance with all technical requirements.

**Highlights**

Highlights are mandatory for this journal. They consist of a short collection of bullet points that convey the core findings of the article and should be submitted in a separate editable file in the online submission system. Please use 'Highlights' in the file name and include 3 to 5 bullet points (maximum 85 characters, including spaces, per bullet point). You can view example Highlights on our information site.

**Keywords**

Immediately after the abstract, provide a maximum of 6 keywords, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and', 'of'). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

**Acknowledgements**

Please provide Acknowledgements as a separate file and remove this from the manuscript. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof reading the article, etc.).

**Formatting of funding sources**

List funding sources in this standard way to facilitate compliance to funder's requirements:

Funding: This work was supported by the National Institutes of Health [grant numbers xxxx, yyyy]; the Bill & Melinda Gates Foundation, Seattle, WA [grant number zzzz]; and the United States Institutes of Peace [grant number aaaa].

It is not necessary to include detailed descriptions on the program or type of grants and awards. When funding is from a block grant or other resources available to a university, college, or other research institution, submit the name of the institute or organization that provided the funding.

If no funding has been provided for the research, please include the following sentence:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

**Footnotes**

Footnotes should be used sparingly. Number them consecutively throughout the article. Many word processors build footnotes into the text, and this feature may be used. Should this not be
the case, indicate the position of footnotes in the text and present the footnotes themselves separately at the end of the article.

Artwork

Electronic artwork

General points

- Make sure you use uniform lettering and sizing of your original artwork.
- Preferred fonts: Arial (or Helvetica), Times New Roman (or Times), Symbol, Courier.
- Number the illustrations according to their sequence in the text.
- Use a logical naming convention for your artwork files.
- Indicate per figure if it is a single, 1.5 or 2-column fitting image.
- For Word submissions only, you may still provide figures and their captions, and tables within a single file at the revision stage.
- Please note that individual figure files larger than 10 MB must be provided in separate source files.

A detailed guide on electronic artwork is available.

You are urged to visit this site; some excerpts from the detailed information are given here.

Formats

Regardless of the application used, when your electronic artwork is finalized, please 'save as' or convert the images to one of the following formats (note the resolution requirements for line drawings, halftones, and line/halftone combinations given below):

EPS (or PDF): Vector drawings. Embed the font or save the text as 'graphics'.
TIFF (or JPG): Color or grayscale photographs (halftones): always use a minimum of 300 dpi.
TIFF (or JPG): Bitmapped line drawings: use a minimum of 1000 dpi.
TIFF (or JPG): Combinations bitmapped line/halftone (color or grayscale): a minimum of 500 dpi is required.

Please do not:

- Supply files that are optimized for screen use (e.g., GIF, BMP, PICT, WPG); the resolution is too low.
- Supply files that are too low in resolution.
- Submit graphics that are disproportionately large for the content.

Color artwork

Please make sure that artwork files are in an acceptable format (TIFF (or JPEG), EPS (or PDF), or MS Office files) and with the correct resolution. If, together with your accepted article, you submit usable color figures then Elsevier will ensure, at no additional charge, that these figures will appear in color online (e.g., ScienceDirect and other sites) regardless of whether or not these illustrations are reproduced in color in the printed version. For color...
reproduction in print, you will receive information regarding the costs from Elsevier after receipt of your accepted article. Please indicate your preference for color: in print or online only. Further information on the preparation of electronic artwork.

Figure captions
Ensure that each illustration has a caption. A caption should comprise a brief title (not on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used.

Tables
Please submit tables as editable text and not as images. Tables can be placed either next to the relevant text in the article, or on separate page(s) at the end. Number tables consecutively in accordance with their appearance in the text and place any table notes below the table body. Be sparing in the use of tables and ensure that the data presented in them do not duplicate results described elsewhere in the article. Please avoid using vertical rules and shading in table cells.

References
Citation in text
Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Any references cited in the abstract must be given in full. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either 'Unpublished results' or 'Personal communication'. Citation of a reference as 'in press' implies that the item has been accepted for publication.

Reference links
Increased discoverability of research and high quality peer review are ensured by online links to the sources cited. In order to allow us to create links to abstracting and indexing services, such as Scopus, CrossRef and PubMed, please ensure that data provided in the references are correct. Please note that incorrect surnames, journal/book titles, publication year and pagination may prevent link creation. When copying references, please be careful as they may already contain errors. Use of the DOI is encouraged.

A DOI can be used to cite and link to electronic articles where an article is in-press and full citation details are not yet known, but the article is available online. A DOI is guaranteed never to change, so you can use it as a permanent link to any electronic article. An example of a citation using DOI for an article not yet in an issue is: VanDecar J.C., Russo R.M., James D.E., Ambeh W.B., Franke M. (2003). Aseismic continuation of the Lesser Antilles slab beneath northeastern Venezuela. Journal of Geophysical Research, https://doi.org/10.1029/2001JB000884. Please note the format of such citations should be in the same style as all other references in the paper.

Data references
This journal encourages you to cite underlying or relevant datasets in your manuscript by citing them in your text and including a data reference in your Reference List. Data references should include the following elements: author name(s), dataset title, data repository, version (where available), year, and global persistent identifier. Add [dataset] immediately before the reference so we can properly identify it as a data reference. The [dataset] identifier will not appear in your published article.

Reference management software
Most Elsevier journals have their reference template available in many of the most popular reference management software products. These include all products that support Citation Style Language styles, such as Mendeley and Zotero, as well as EndNote. Using the word processor plug-ins from these products, authors only need to select the appropriate journal template when preparing their article, after which citations and bibliographies will be automatically formatted in the journal’s style. If no template is yet available for this journal, please follow the format of the sample references and citations as shown in this Guide.

Users of Mendeley Desktop can easily install the reference style for this journal by clicking the following link:
http://open.mendeley.com/use-citation-style/forensic-science-international
When preparing your manuscript, you will then be able to select this style using the Mendeley plugins for Microsoft Word or LibreOffice.

Reference formatting
There are no strict requirements on reference formatting at submission. References can be in any style or format as long as the style is consistent. Where applicable, author(s) name(s), journal title/book title, chapter title/article title, year of publication, volume number/book chapter and the pagination must be present. Use of DOI is highly encouraged. The reference style used by the journal will be applied to the accepted article by Elsevier at the proof stage. Note that missing data will be highlighted at proof stage for the author to correct. If you do wish to format the references yourself they should be arranged according to the following examples:

Reference style
Text: Indicate references by number(s) in square brackets in line with the text. The actual authors can be referred to, but the reference number(s) must always be given.
Example: '..... as demonstrated [3,6]. Barnaby and Jones [8] obtained a different result ....'
List: Number the references (numbers in square brackets) in the list in the order in which they appear in the text.
Examples:
Reference to a journal publication:
Reference to a book:
Reference to a chapter in an edited book:
Reference to a website:

**Video**
Elsevier accepts video material and animation sequences to support and enhance your scientific research. Authors who have video or animation files that they wish to submit with their article are strongly encouraged to include links to these within the body of the article. This can be done in the same way as a figure or table by referring to the video or animation content and noting in the body text where it should be placed. All submitted files should be properly labeled so that they directly relate to the video file’s content. In order to ensure that your video or animation material is directly usable, please provide the files in one of our recommended file formats with a preferred maximum size of 150 MB in total. Any single file should not exceed 50 MB. Video and animation files supplied will be published online in the electronic version of your article in Elsevier Web products, including ScienceDirect. Please supply 'stills' with your files: you can choose any frame from the video or animation or make a separate image. These will be used instead of standard icons and will personalize the link to your video data. For more detailed instructions please visit our video instruction pages.
Note: since video and animation cannot be embedded in the print version of the journal, please provide text for both the electronic and the print version for the portions of the article that refer to this content.

**Supplementary material**
Supplementary material such as applications, images and sound clips, can be published with your article to enhance it. Submitted supplementary items are published exactly as they are received (Excel or PowerPoint files will appear as such online). Please submit your material together with the article and supply a concise, descriptive caption for each supplementary file. If you wish to make changes to supplementary material during any stage of the process, please make sure to provide an updated file. Do not annotate any corrections on a previous version. Please switch off the 'Track Changes' option in Microsoft Office files as these will appear in the published version.

**RESEARCH DATA**
This journal encourages and enables you to share data that supports your research publication where appropriate, and enables you to interlink the data with your published articles. Research data refers to the results of observations or experimentation that validate research findings. To facilitate reproducibility and data reuse, this journal also encourages you to share your software, code, models, algorithms, protocols, methods and other useful materials related to the project.
Below are a number of ways in which you can associate data with your article or make a statement about the availability of your data when submitting your manuscript. If you are sharing data in one of these ways, you are encouraged to cite the data in your manuscript and reference list. Please refer to the "References" section for more information about data citation. For more information on depositing, sharing and using research data and other relevant research materials, visit the research data page.

*Data linking*

If you have made your research data available in a data repository, you can link your article directly to the dataset. Elsevier collaborates with a number of repositories to link articles on ScienceDirect with relevant repositories, giving readers access to underlying data that gives them a better understanding of the research described.

There are different ways to link your datasets to your article. When available, you can directly link your dataset to your article by providing the relevant information in the submission system. For more information, visit the database linking page.

For supported data repositories a repository banner will automatically appear next to your published article on ScienceDirect.

In addition, you can link to relevant data or entities through identifiers within the text of your manuscript, using the following format: Database: xxxx (e.g., TAIR: AT1G01020; CCDC: 734053; PDB: 1XFN).

*Mendeley Data*

This journal supports Mendeley Data, enabling you to deposit any research data (including raw and processed data, video, code, software, algorithms, protocols, and methods) associated with your manuscript in a free-to-use, open access repository. Before submitting your article, you can deposit the relevant datasets to Mendeley Data. Please include the DOI of the deposited dataset(s) in your main manuscript file. The datasets will be listed and directly accessible to readers next to your published article online.

For more information, visit the Mendeley Data for journals page.

*Data in Brief*

You have the option of converting any or all parts of your supplementary or additional raw data into one or multiple data articles, a new kind of article that houses and describes your data. Data articles ensure that your data is actively reviewed, curated, formatted, indexed, given a DOI and publicly available to all upon publication. You are encouraged to submit your article for Data in Brief as an additional item directly alongside the revised version of your manuscript. If your research article is accepted, your data article will automatically be transferred over to Data in Brief where it will be editorially reviewed and published in the open access data journal, Data in Brief. Please note an open access fee of 500 USD is payable for publication in Data in Brief. Full details can be found on the Data in Brief website. Please use this template to write your Data in Brief.
Data statement
To foster transparency, we encourage you to state the availability of your data in your submission. This may be a requirement of your funding body or institution. If your data is unavailable to access or unsuitable to post, you will have the opportunity to indicate why during the submission process, for example by stating that the research data is confidential. The statement will appear with your published article on ScienceDirect. For more information, visit the Data Statement page.

AudioSlides
The journal encourages authors to create an AudioSlides presentation with their published article. AudioSlides are brief, webinar-style presentations that are shown next to the online article on ScienceDirect. This gives authors the opportunity to summarize their research in their own words and to help readers understand what the paper is about. More information and examples are available. Authors of this journal will automatically receive an invitation e-mail to create an AudioSlides presentation after acceptance of their paper.

AFTER ACCEPTANCE
Availability of accepted article
This journal makes articles available online as soon as possible after acceptance. This concerns the accepted article (both in HTML and PDF format), which has not yet been copyedited, typeset or proofread. A Digital Object Identifier (DOI) is allocated, thereby making it fully citable and searchable by title, author name(s) and the full text. The article’s PDF also carries a disclaimer stating that it is an unedited article. Subsequent production stages will simply replace this version.

Online proof correction
Corresponding authors will receive an e-mail with a link to our online proofing system, allowing annotation and correction of proofs online. The environment is similar to MSWord: in addition to editing text, you can also comment on figures/tables and answer questions from the Copy Editor. Web-based proofing provides a faster and less error-prone process by allowing you to directly type your corrections, eliminating the potential introduction of errors. If preferred, you can still choose to annotate and upload your edits on the PDF version. All instructions for proofing will be given in the e-mail we send to authors, including alternative methods to the online version and PDF. We will do everything possible to get your article published quickly and accurately. Please use this proof only for checking the typesetting, editing, completeness and correctness of the text, tables and figures. Significant changes to the article as accepted for publication will only be considered at this stage with permission from the Editor. It is important to ensure that all corrections are sent back to us in one communication. Please check carefully before replying, as inclusion of any subsequent corrections cannot be guaranteed. Proofreading is solely your responsibility.

Offprints
The corresponding author will, at no cost, receive 25 free paper offprints, or alternatively a customized Share Link providing 50 days free access to the final published version of the article on ScienceDirect.
The Share Link can be used for sharing the article via any communication channel, including email and social media. For an extra charge, paper offprints can be ordered via the offprint order form which is sent once the article is accepted for publication. Both corresponding and co-authors may order offprints at any time via Elsevier’s Webshop. Corresponding authors who have published their article open access do not receive a Share Link as their final published version of the article is available open access on ScienceDirect and can be shared through the article DOI link.

**Author orders**
When your article is published, you can commemorate your publication with printed author copies of the journal issue, customized full-color posters, extra offprints, and more. Please visit [http://webshop.elsevier.com](http://webshop.elsevier.com) to learn more.

**AUTHOR INQUIRIES**
Visit the Elsevier Support Center to find the answers you need. Here you will find everything from Frequently Asked Questions to ways to get in touch. You can also check the status of your submitted article or find out when your accepted article will be published.