FATAL PENETRATING INJURIES OF THE CHEST

Hendrik J Scholtz

Dissertation in partial fulfillment of the requirements for the degree M Med Path (Forens)

Supervisor: Dr K M De Groot
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PREFACE

The study for this dissertation was carried out in the Department of Forensic Medicine and Toxicology of the University of Cape Town.

The supervisor for this work was Dr K M De Groot of the Department of Cardiothoracic Surgery of the University of Cape Town at Groote Schuur Hospital.

This study represents original work by the author and has not been submitted in any form to any other University. Where use was made of the work of others, it has been duly acknowledged in the text.

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Signed

Hendrik J Scholtz

10 March 1996
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Hendrik J Scholtz
# Table of Contents

1. INTRODUCTION .................................................................................................................. 1

2. LITERATURE REVIEW ........................................................................................................... 3
  2.1 MECHANISM OF DEATH .................................................................................................... 3
    2.1.1 Haemorrhage ............................................................................................................... 3
    2.1.2 Cardiac Tamponade ...................................................................................................... 4
    2.1.3 Air Embolism ............................................................................................................... 4
    2.1.4 Pneumothorax ............................................................................................................ 6
    2.1.5 Aspiration of blood ...................................................................................................... 6
  2.2 AETIOLOGY ....................................................................................................................... 6
  2.3 AGE ..................................................................................................................................... 7
  2.4 SEX ..................................................................................................................................... 8
  2.5 INTRATHORACIC INJURIES .............................................................................................. 8
    2.5.1 Penetrating Vascular Injuries ...................................................................................... 8
    2.5.2 Penetrating Cardiac Injuries ....................................................................................... 12
    2.5.3 Penetrating Lung Injuries ........................................................................................... 13

3. METHOD ................................................................................................................................ 14
  3.1 DATA COLLECTED ............................................................................................................. 15
  3.2 DATA ANALYSIS ................................................................................................................. 15

4. RESULTS ................................................................................................................................ 16
  4.1 DEMOGRAPHIC DATA ......................................................................................................... 17
  4.2 SITE OF INJURY .................................................................................................................. 18
  4.3 NATURE OF INJURY ............................................................................................................ 20
  4.4 INTRATHORACIC INJURIES ............................................................................................... 22
    4.4.1 Fatal Penetrating Vascular Injuries ............................................................................. 23
    4.4.2 Fatal Penetrating Cardiac Injuries ............................................................................. 24
    4.4.3 Fatal Penetrating Lung Injury .................................................................................... 27
  4.5 BLOOD ALCOHOL CONCENTRATION ............................................................................. 27
  4.6 HOSPITAL TREATMENT ..................................................................................................... 28

5. DISCUSSION .......................................................................................................................... 29
  5.1 STUDY POPULATION .......................................................................................................... 29
  5.2 DEMOGRAPHIC DATA ......................................................................................................... 30
  5.3 SITE OF INJURY .................................................................................................................. 31
  5.4 NATURE OF INJURY ............................................................................................................ 32
  5.5 INTRATHORACIC INJURIES ............................................................................................... 33
    5.5.1 Fatal Penetrating Vascular Injuries ............................................................................. 33
    5.5.2 Fatal Penetrating Cardiac Injuries ............................................................................. 34
    5.5.3 Fatal Penetrating Lung Injuries ................................................................................. 36
  5.6 BLOOD ALCOHOL CONCENTRATION ............................................................................. 37
  5.7 HOSPITAL TREATMENT ..................................................................................................... 37

6. CONCLUSION ........................................................................................................................ 38

7. BIBLIOGRAPHY ..................................................................................................................... 40
1. INTRODUCTION

Fatal penetrating injuries of the chest are common. Mattox and Allen\(^1\) concluded that chest injury accounts for up to 50 per cent of deaths secondary to trauma. In Cape Town, penetrating incised wounds of the chest constituted 33% of all homicide victims admitted to the Salt River Medicolegal Laboratory in 1986.\(^2\)

A large volume of literature has been published on the subject of penetrating chest injuries, and high survival rates are recorded by most authors on patients presenting alive on arrival at hospital.

Patients in these series are often divided into groups such as lifeless, agonal, shocked and stable,\(^3\) or variations on the theme\(^4,5\) based on the condition of the patient on arrival. The prognosis of these patients can be directly correlated to their clinical condition on admission. Generally, the true impact of penetrating chest injuries is unknown, as an important group of cases is usually left out of the series, namely the group of cases who die at the scene or en route to a hospital. The importance of this group is highlighted in a clinical and autopsy profile by Kulshrestha\(^6\) which showed that only 10% of patients who sustained cardiac injuries, reached hospital alive.
In the Republic of South Africa, an autopsy is required in all cases of unnatural death, or in cases where the cause of death is unknown, in terms of the Inquest Act of 1959. These are performed at the Salt River Medicolegal Laboratory by Forensic Pathologists and Registrars of the Department of Forensic Medicine and Toxicology of the University of Cape Town. The Salt River Medicolegal Laboratory serves the greater Cape Town area with a population of approximately 2.5 million, including the magisterial districts of Cape Town, Wynberg, Mitchell’s Plain and Simonstown.

Cape Town has one of the world’s highest homicide rates and in 1986 the incidence was 56.9/100,000 population per annum. In contrast, Singapore has a homicide rate of only 2.5/100,000, while the United States has an overall homicide rate of 7.7/100,000 population.

In order to document the true impact of penetrating chest injuries, and to place mortality data in perspective, a retrospective descriptive study of all cases with fatal penetrating chest injuries admitted to the Salt River Medicolegal Laboratory in Cape Town during 1990 was undertaken.

In 1990, a total of 5,758 cases was admitted to the Salt River Medicolegal Laboratory of which 1,834 cases (39%) were the result of homicide. Of the homicide cases, 408 (22%) were the result
of firearm injuries. A total of 2044 (35.5%) cases admitted was deemed to have died of natural causes.

This study identified a total of 841 cases of fatal penetrating injuries of the chest admitted during 1990, which constituted 22.6% of all non-natural cases admitted.

2. LITERATURE REVIEW

A number of publications in the English language literature exists on the subject of penetrating chest injury and its treatment. Several publications deal with specific injuries to cardiovascular and pulmonary organs and structures. Only one autopsy series⁶ and three combined clinical and autopsy series⁹-¹¹ were found.

2.1 Mechanism of death

2.1.1 Haemorrhage

The main mechanism of death in penetrating chest injuries is haemorrhage with resultant circulatory shock. The large potential volume of the chest cavity allows for unimpeded haemorrhage to occur from injured vessels or the heart into the chest cavity without necessarily
showing much external haemorrhage. Loss of several litres of blood, usually as a mixture of blood and clot, may occur. Irreversible shock is stated to occur with the rapid loss of more than 40% of the circulating volume, but Robbins et al advise guarded use of the term as “it's not over until it's all over.”

According to Pate and Casini, the treatment of haemorrhage due to penetrating vascular injuries can in itself lead to complications. These include pulmonary oedema, acute heart failure, and irreversible ischaemia of the brain, spinal cord, kidneys and viscera.

2.1.2 Cardiac Tamponade
In cardiac tamponade relatively little loss of blood needs to occur into the pericardial sac to cause death. An amount of 250 ml is considered to be sufficient to cause pericardial tamponade if the accumulation of fluid occurs rapidly.

2.1.3 Air Embolism
Venous air embolism may cause rapid death as the result of an effective airlock forming in the right ventricle of the heart. Arterial air embolism, also known as systemic air embolism or systemic pulmonary venous air embolism, from penetrating trauma to the lung, is discussed by Meier et al in a publication based on experimentation on dogs. This work shows that arterial air
embolism only occurs in cases where the intratracheal pressure is raised higher than 65 mmHg. In dogs with a stab to the lung, the average amount of arterial air embolism was double that of dogs without lung injury. These findings are also consistent with the findings of Waldo et al. They showed that no animals developed arterial air embolism at normal intratracheal pressures.

Arterial air embolism is potentially fatal due to air embolisation into the coronary vasculature and other vital organs such as the brain. In arterial air embolism, a much smaller amount of air is required to cause lethal damage than in venous air embolism. As little as 0.5 ml of arterial air embolism is required to cause embolisation to the coronary vasculature with subsequent fatal ventricular fibrillation.

Knight points out that arterial air embolism is rarely seen at autopsy. This can be due to several reasons. (1) Autopsies are rarely performed anaerobically, and any intravascular air found at autopsy is usually discounted. (2) A small volume of air, even though fatal, can easily be overlooked macroscopically. (3) Air may be absorbed into the tissues during the post mortem interval prior to autopsy. (4) No specific tests exist to detect the presence of arterial air embolism. (5) Histological findings of ischaemia that develop as result of arterial air embolism are not distinguishable from ischaemia due to other causes.
2.1.4 Pneumothorax

In cases of bilateral pneumothorax, acute respiratory embarrassment with terminal anoxia may lead to death. Pneumothorax is not usually fatal, but may cause death, presumably by some vagal cardio-inhibitory mechanism.\textsuperscript{12} Tension pneumothorax is relatively uncommon,\textsuperscript{20} but may lead to death as a result of mediastinal shift and subsequent neurogenic cardiac arrest.

2.1.5 Aspiration of blood

Aspiration of blood in cases with penetrating lung injury or combined vascular and tracheobronchial injury may lead to anoxic anoxia as a mechanism of death, but in most cases relatively little functional impairment occurs.\textsuperscript{21}

2.2 Aetiology

Knives and firearms are cited most frequently as the causative agents of penetrating chest injuries.

Other instruments used include glass, scissors, chisels, swords and bayonets.\textsuperscript{22}
Table 1. Aetiology

<table>
<thead>
<tr>
<th>Author</th>
<th>Knives</th>
<th>Firearms</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandal(1989)</td>
<td>607 (55%)</td>
<td>502 (45%)</td>
<td>1109</td>
</tr>
<tr>
<td>Borlase(1986)</td>
<td>119 (62%)</td>
<td>74 (38%)</td>
<td>193</td>
</tr>
<tr>
<td>Penetrating chest injuries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symbas(1974)</td>
<td>20 (56%)</td>
<td>16 (44%)</td>
<td>36</td>
</tr>
<tr>
<td>Penetrating vascular injuries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symbas(1976)</td>
<td>54 (59%)</td>
<td>37 (41%)</td>
<td>91</td>
</tr>
<tr>
<td>Naughton(1989)</td>
<td>28 (39%)</td>
<td>44 (61%)</td>
<td>72</td>
</tr>
</tbody>
</table>

Baillot et al\textsuperscript{27} grouped cases of penetrating chest injuries by site and aetiology. In cases of centrally situated or mediastinal injuries, there was a preponderance of injury due to sharp instruments. Laterally situated wounds showed a preponderance of firearm related injuries.

Overall, almost two thirds of the injuries were firearm related\textsuperscript{27}.

Cases with recurrent injuries were studied by Morrissey, who showed that 32.6\% of 389 patients had sustained two or more documented episodes of penetrating trauma\textsuperscript{28}.

2.3 Age

Although penetrating injuries of the chest occur in all age groups, the average age in all studies is between the ages of 25 and 30 years. The average age in Mandal’s series was 28.1 years\textsuperscript{23}, and
that of Marshall's series was 31 years.\textsuperscript{29} Baillot states that the majority of their cases was younger than 30 years.\textsuperscript{27}

2.4 \textit{Sex}

The general article "Murder by stabbing", authored by Hunt,\textsuperscript{22} shows a preponderance of male victims as is also true for the article by Duflou et al\textsuperscript{2} on homicide in Cape Town. Mavroudis' series of cervico-thoracic vascular injuries included 89\% males,\textsuperscript{30} the series by Naughton of penetrating cardiac injuries included 86\% males,\textsuperscript{10} and the series by Marshall of penetrating cardiac injuries showed a similar figure of 83\% males.\textsuperscript{29}

2.5 \textit{Intrathoracic injuries}

2.5.1 Penetrating Vascular Injuries

Penetrating vascular injuries are well described in the literature, particularly as to vessels injured and the treatment of these injuries. Publications discussing large series reflecting the military experience\textsuperscript{31} and the civilian experience\textsuperscript{32} exist. The following table\textsuperscript{33} provides a summary of the relative incidence of thoracic vascular injuries:
Table 2: Breakdown of Thoracic Vascular Injuries:

Relative Incidence Observed in 1094 Injuries (From: Pickard RL, Beall AC.33)

<table>
<thead>
<tr>
<th></th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart</td>
<td>516</td>
<td>47.2</td>
</tr>
<tr>
<td>Subclavian vessel</td>
<td>155</td>
<td>14.2</td>
</tr>
<tr>
<td>Descending thoracic aorta</td>
<td>89</td>
<td>8.1</td>
</tr>
<tr>
<td>Pulmonary artery</td>
<td>78</td>
<td>7.1</td>
</tr>
<tr>
<td>Thoracic vena cava</td>
<td>54</td>
<td>4.9</td>
</tr>
<tr>
<td>Innominate vein</td>
<td>42</td>
<td>3.8</td>
</tr>
<tr>
<td>Pulmonary vein</td>
<td>39</td>
<td>3.6</td>
</tr>
<tr>
<td>Innominate artery</td>
<td>37</td>
<td>3.4</td>
</tr>
<tr>
<td>Ascending aorta</td>
<td>33</td>
<td>3.0</td>
</tr>
<tr>
<td>Aortic Arch</td>
<td>22</td>
<td>2.0</td>
</tr>
<tr>
<td>Azygous vein</td>
<td>16</td>
<td>1.5</td>
</tr>
<tr>
<td>Coronary artery</td>
<td>13</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Mortality due to injuries to the intrathoracic great vessels is high and few patients survive long enough to receive medical attention.34 This appears to be related to rapid exsanguination prior to hospital therapy.34-37

In adults, injuries to the aorta are rare but often fatal.25,38-40 Mortality for aortic injuries is usually in excess of 85%36. In children, however, the aorta is the most frequently injured vessel.35

Survival time prior to therapy is not recorded in the literature scrutinised, apart from a mean time of survival of 195 minutes from the injury until surgery in 12 cases of carotid arterial injury.41
2.5.1.1 Penetrating wounds of the carotid arteries

The main mechanism of death in patients with carotid arterial injury is exsanguination. Patients with these injuries who have a neurological defect including coma also have a poor prognosis. Mavroudis describes 17 cases of which 3 suffered from persistent postoperative neurological deficit. In one case this was the result of a shotgun pellet embolus to the middle cerebral artery.

2.5.1.2 Penetrating wounds of the innominate artery

A case report and review by McLean and McManus note that these are uncommon. Rich et al in their series of 1000 Vietnam cases attribute the low incidence to the fact that the majority of patients exsanguinate before being able to receive treatment. Table 3 is a summary of the incidence of reported innominate artery injury in the more recent literature.

Table 3: Innominate Artery Injuries

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Cases</th>
<th>Years reviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lim et al</td>
<td>1979</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Pate and Casini</td>
<td>1980</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>Graham et al</td>
<td>1980</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>Bladergroen et al</td>
<td>1989</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Weaver et al</td>
<td>1989</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>
This also confirms the incidence of less than 1% as reported by Rich et al. Graham et al. in a subsequent publication note that survivors of innominate artery injuries are seen with increasing frequency.

2.5.1.3 Penetrating injuries of the subclavian vessels

Subclavian vessel injuries are rare in both military and civilian experience. Injury to the vessels on the left predominate. Injuries where both artery and vein were injured, were similarly situated on the left side.

Demetriades et al. do include patients who were dead on arrival in their study of 228 patients with penetrating injuries of the subclavian vessels. The overall mortality was 66% in contrast with 15.5% in the group which underwent surgery. The vein was involved in 44% of cases and the artery in 39% of cases. Both vessels were involved in 17% of cases.

2.5.1.4 Intercostal vessel injuries

These injuries are not commonly described in the literature due to their usually innocuous nature. Moar does however describe 19 injuries to these vessels occurring in 52 patients in his study on fatal penetrating incised wounds of the chest.
2.5.2 Penetrating Cardiac Injuries

A high overall survival rate in cases of penetrating cardiac injuries is reported in the literature in patients who have survived long enough to reach hospital. Mortality due to penetrating cardiac injuries varies between 20% and 25%.\(^29\) Attar et al\(^3\) review 109 cases of penetrating cardiac trauma with a survival rate of 61%. A similar survival rate of 63% is reported in a wartime study from Lebanon by Jebara et al.\(^48\) However, Kulshrestha et al,\(^6\) in their study which included autopsy cases, note that only 10% of cases reach hospital alive.

Survival time prior to hospital treatment varies between 15 and 30 minutes,\(^49\) but is not generally reported in the literature.\(^24,26,29,50\) Several factors that affect the survival time are identified in the literature and include time taken to reach hospital, type of weapon used, size of injury, the cardiac chamber injured, the presence of coronary artery injury, the presence of tamponade, and the presence of associated injuries.\(^48\)

Firearm related penetrating cardiac injuries overall carry a worse prognosis than stab wounds.\(^3,29,49\) Injuries to the right ventricle predominate, with atrial injuries and great vessel injuries being present in the minority of cases.\(^26,49,51,52\) Aggressive management of penetrating
cardiac injuries is recommended and survival rates of 70% are recorded. Increase in the survival rate from 20% to 67% is recorded due to resuscitation and immediate evaluation for thoracotomy. The role of pericardiocentesis in the diagnosis of these injuries is regarded as limited.

Cardiac tamponade was recorded in 57% of 47 cases by Marshall et al. Five cases of ventricular septal defects and two cases of aortic valvular injuries were described by Cha et al in eleven patients who had slow recovery postoperatively.

2.5.3 Penetrating Lung Injuries

Few publications focus on this aspect. This is related to the low mortality and well established treatment with intercostal thoracostomy. In an extensive study of 7,283 patients with trauma, Thompson et al report 388 patients with pulmonary or tracheobronchial injury requiring thoracotomy and note that pneumonectomy should be the operation of last resort in critically ill patients as a result of pulmonary injury, as lobectomy and pneumonorrhaphy are better tolerated.

Lerer and Knottenbelt surprisingly found that 19% of prehospital deaths could be attributed to patients with single unilateral lung wounds in a study of 722 cases of sharp penetrating chest injuries.
trauma. This was a study which included autopsy cases and 231 cases of patients who died before reaching hospital.

3. METHOD

A retrospective review of all cases of fatal penetrating chest injuries admitted to the Salt River Medicolegal Laboratory during the period 1 January 1990 to 31 December 1990 was undertaken.

These cases were identified from the cause of death as stated in the official Death Register. In order to ensure that no cases were missed due to sometimes vague death certification, all cases with causes of death stated either as undetermined at autopsy or multiple injuries, as well as cases of injury to adjacent structures such as neck and abdomen, were reviewed. Demographic data including sex, race, age and employment were also obtained from the Death Register.

The corresponding autopsy reports were then obtained from the Department of Forensic Medicine and Toxicology at the University of Cape Town and reviewed. Those autopsies showing no sign of fatal penetrating chest injuries were excluded. Data was entered and processed on a personal computer using dBASE IV version 1.5 (Borland International Inc.).
3.1 Data collected

The autopsy reports of cases with fatal penetrating chest injuries were studied and data collected as to site of injury, volume of haemothoraces, mechanism of injury and structures injured. Special attention was paid to cardiac and vascular injuries. Single associated injuries were noted and cases of multiple injuries and bilateral injuries were placed in separate groups. Blood alcohol concentration in specimens taken from the femoral veins was recorded.

3.2 Data Analysis

Cases were divided into the following subsections:

- Single fatal penetrating incised wounds
- Single fatal penetrating incised wounds with one other significant injury
- Single fatal rifled firearm injuries
- Single fatal rifled firearm injuries with one other significant injury
- Single fatal shotgun injuries
- Single fatal shotgun injuries with one other significant injury
- Bilateral single penetrating chest injuries
- Multiple fatal penetrating chest injuries.
A significant other injury was deemed to be a penetrating injury of a body cavity or deep injury of
the neck or limbs which in itself would not have been fatal. Cases with three or more penetrating
injuries of the chest were included in the multiple injuries group.

The cases as a group were also divided into subsections according to the underlying intrathoracic
injuries:

- Cases with single fatal vascular injury,
- Cases with single fatal cardiac injury, and
- Cases with single fatal lung injury.

4. RESULTS

During the period 1 January 1990 to 31 December 1990, a total of 841 cases with fatal
penetrating injuries of the chest was identified. Of these 841 cases, 837 were cases of homicide
and 4 cases were alleged suicide cases. The latter were all cases of single contact firearm injuries
to the left chest with underlying injury to the heart.

During the same period, the total number of cases admitted to the Salt River Medicolegal
Laboratory was 5758. Of these, a total of 2044 (35.5%) cases were deemed to have died as
result of natural causes. Non-natural causes of death accounted for the remaining 3614 cases.
The total number of homicide related cases was 1834. Of the homicide related cases, 408 (22%) were related to firearm injuries. The 841 cases of fatal penetrating injuries of the chest constituted 22.6% of all non-natural cases admitted.

4.1 Demographic Data

Greater Cape Town is a metropolitan area with a population, according to the 1991 Census, of approximately 2.5 million. About 54% of the population consist of so-called Coloured people, 26% are White, 19% are Black and 1% are Asian. Male persons constitute 49% of the population and female persons constitute 51% of the population.

Male victims predominated with 793 (94.3%) males and 48 (5.7%) females included in the study.

Of the cases, 446 (52.75%) were Black, 385 (46%) were Coloured, 8 (1%) were White and 2 (0.25%) were Asian. The four suicide victims included in the study were all white males aged between 20 and 40 years. The average age of cases in the study was 28 years with the oldest person being 78 years old.
### Table 4: Age

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>n</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 19</td>
<td>137</td>
<td>16%</td>
</tr>
<tr>
<td>20 - 39</td>
<td>587</td>
<td>70%</td>
</tr>
<tr>
<td>40 - 59</td>
<td>109</td>
<td>13%</td>
</tr>
<tr>
<td>60+</td>
<td>8</td>
<td>1%</td>
</tr>
</tbody>
</table>

A total of 491 of the 841 deceased were employed, with employment simply stated as “Labourer” in 347. Six per cent or 51 cases were scholars. Eleven cases were security or police personnel.

Of this latter group, 9 were injured in the central chest anteriorly and 2 on the left side of the back.

### 4.2 Site of Injury

The site of the fatal chest injury was recorded and coded according to Figure 1. The anterior and lateral chest was divided into four horizontal zones by lines at the level of the 2nd rib/2nd intercostal space interface, the 5th rib/intercostal space interface and the 8th rib/intercostal space interface. These zones were further divided into two lateral regions and a central region by the vertical nipple lines. A total of 742 cases with single injuries was recorded.
Figure 1: Number of Injuries

RIGHT BACK = 35

LEFT BACK = 54
Only 89 (12%) of single fatal penetrating injuries were situated on the back. Injuries to the left central areas predominated. There were 463 (62%) injuries situated in these areas, compared with the 156 (21%) in the right central areas.

Of the injuries situated in the superior central portion (including the chest above the Angle of Louis, and the neck), 83 were situated above the clavicle and penetrated the chest by passing behind the clavicle.

In 51 of the 75 cases with multiple wounds, the wounds were situated bilaterally. Cases with multiple injuries (n=75) or bilateral injuries (n=24) were excluded. This was done as it could not be accurately determined which was the fatal wound in these cases.

4.3 Nature of injury

The 841 cases with penetrating chest injuries displayed the following types of wounds:
Table 5: Nature of Injury

<table>
<thead>
<tr>
<th>Nature of Injury</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single fatal penetrating incised wounds:</td>
<td>577</td>
</tr>
<tr>
<td>Single fatal penetrating incised wounds with one other significant injury:</td>
<td>78</td>
</tr>
<tr>
<td>Single fatal rifled firearm injury:</td>
<td>61</td>
</tr>
<tr>
<td>Single fatal rifled firearm injury with one other significant injury:</td>
<td>12</td>
</tr>
<tr>
<td>Single fatal shotgun injury:</td>
<td>9</td>
</tr>
<tr>
<td>Single fatal shotgun injury with one other significant injury:</td>
<td>5</td>
</tr>
<tr>
<td>Bilateral single wounds:</td>
<td>24</td>
</tr>
<tr>
<td>Multiple (&gt;3) fatal injuries of the chest:</td>
<td>75</td>
</tr>
</tbody>
</table>

In summary, 665 of cases were the result of wounds inflicted by sharp objects such as knives. In one case, injury was inflicted with a broken bottle and in another case the injury was caused with a screwdriver. Rifled firearms were used in 73 cases and shotguns were used in 14 cases. In the single fatal rifled firearm group there were 37 (61%) cases of perforating injuries of the chest with both an entrance and an exit gunshot wound present. All the firearm wounds were consistent with low velocity firearm injuries.

Shotgun ammunition used was mainly of the buckshot variety with 5mm diameter pellets found in 9 cases and 7mm diameter pellets found in 4 cases. In one case birdshot pellets with a diameter of 3mm were used. This was a close range injury with an entrance wound diameter of 30mm. Only
three of the buckshot cases were close range with entrance wound diameters of 85mm, 53mm, and 30mm respectively.

Associated significant injuries consisted of 48 cases with single injuries on the same side as the index wound on the chest, 10 cases of a penetrating head injury without underlying visible brain injury, 6 cases with a deep neck injury without vascular injury, and 33 cases with a penetrating abdominal wall injury without underlying injury. None of these injuries were regarded as potentially fatal.

4.4 Intrathoracic injuries

The cases were also grouped according to the nature of the fatal intrathoracic injuries. The multiple and bilateral injury groups were excluded, as it was difficult to establish which of the wounds was the fatal wound.

There were 302 cases with single fatal penetrating vascular injuries and 305 cases with single fatal penetrating cardiac injuries. Single fatal penetrating injuries to the lungs were present in 122 cases.
4.4.1 Fatal Penetrating Vascular Injuries

Single fatal penetrating vascular injuries were present as follows:

Table 6: Fatal penetrating vascular injuries

<table>
<thead>
<tr>
<th>Injury</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascending aorta</td>
<td>54</td>
</tr>
<tr>
<td>Pulmonary trunk</td>
<td>49</td>
</tr>
<tr>
<td>Pulmonary arteries and major branches</td>
<td>32</td>
</tr>
<tr>
<td>Arch of the aorta</td>
<td>24</td>
</tr>
<tr>
<td>Descending aorta</td>
<td>19</td>
</tr>
<tr>
<td>Left subclavian vein</td>
<td>19</td>
</tr>
<tr>
<td>Left subclavian artery</td>
<td>17</td>
</tr>
<tr>
<td>Both left subclavian vessels</td>
<td>17</td>
</tr>
<tr>
<td>Both right subclavian vessels</td>
<td>14</td>
</tr>
<tr>
<td>Superior vena cava</td>
<td>12</td>
</tr>
<tr>
<td>Pulmonary veins and major branches</td>
<td>8</td>
</tr>
<tr>
<td>Right subclavian artery</td>
<td>8</td>
</tr>
<tr>
<td>Internal thoracic vessels</td>
<td>7</td>
</tr>
<tr>
<td>Right common carotid artery</td>
<td>6</td>
</tr>
<tr>
<td>Both pulmonary trunk and ascending aorta</td>
<td>5</td>
</tr>
<tr>
<td>Left innominate vein</td>
<td>4</td>
</tr>
<tr>
<td>Left common carotid artery</td>
<td>1</td>
</tr>
<tr>
<td>Inferior vena cava</td>
<td>1</td>
</tr>
<tr>
<td>Right subclavian vein</td>
<td>1</td>
</tr>
<tr>
<td>Innominate artery</td>
<td>0</td>
</tr>
</tbody>
</table>

Injuries to the ascending aorta were present in 54 (18%) cases. In total, injuries to the entire thoracic aorta accounted for 97 (34%) cases. Injuries to the subclavian vessels as a group were present in 76 (25%) cases. There were 40 (13%) cases with injury to the pulmonary vessels and
its major branches outside the pericardium. A further 13 cases of injury to the internal thoracic vessels were present, but were excluded as result of underlying cardiac injury.

4.4.2 Fatal Penetrating Cardiac Injuries

There were 305 cases of fatal penetrating cardiac injuries:

Table 7: Injuries to the chambers of the heart

<table>
<thead>
<tr>
<th>Injury to right ventricle</th>
<th>151</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury to left ventricle</td>
<td>115</td>
</tr>
<tr>
<td>Injury to right atrium</td>
<td>11</td>
</tr>
<tr>
<td>Injury to left atrium</td>
<td>8</td>
</tr>
<tr>
<td>Injury to both ventricles</td>
<td>15</td>
</tr>
</tbody>
</table>

In 5 cases, four of which were the result of firearm injuries, the pathologist performing the autopsy did not specify the extent of the injury to the heart. In 12 cases there was a ventricular septal injury underlying an anterior injury to the ventricular wall. A valvular injury was present in 4 cases and in 7 cases there was an associated injury to the root of the great vessels.
In 267 of the 305 cases blood was present in the pericardial sac:

**Table 8: Volume of pericardial tamponade**

<table>
<thead>
<tr>
<th>Volume Range</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 100ml</td>
<td>53</td>
</tr>
<tr>
<td>101 - 200ml</td>
<td>68</td>
</tr>
<tr>
<td>201 - 300ml</td>
<td>76</td>
</tr>
<tr>
<td>301 - 400ml</td>
<td>50</td>
</tr>
<tr>
<td>401 - 500ml</td>
<td>16</td>
</tr>
<tr>
<td>501 - 600ml</td>
<td>4</td>
</tr>
</tbody>
</table>

No blood was present in the pericardial sac in 38 cases, of which 17 cases were the result of rifled firearm or shotgun injury. Of these cases, 4 cases had no evidence of blood recorded in the chest cavity. All 4 cases were the result of penetrating incised wounds; 2 of which injured the right ventricle and 2 of which injured the left ventricle. The 34 remaining cases with no blood in the pericardial sac all had large associated haemothoraces.

In cases of fatal penetrating cardiac injuries, unilateral haemothorax was present in 199 cases on the left and in 22 cases on the right. Bilateral haemothoraces were present in 32 cases of which 19 were the result of rifled firearm or shotgun injuries.
Table 9: Volume of Unilateral Haemothoraces

<table>
<thead>
<tr>
<th>Volume(ml)</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 250</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>251 - 500</td>
<td>29</td>
<td>2</td>
</tr>
<tr>
<td>501 - 750</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>751 - 1000</td>
<td>36</td>
<td>3</td>
</tr>
<tr>
<td>1001 - 1250</td>
<td>37</td>
<td>5</td>
</tr>
<tr>
<td>1251 - 1500</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>1501 - 1750</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>1751 - 2000</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>2001 - 2250</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>&gt;2250</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

Mean volume: 1057ml SD 595ml 1109ml SD 648ml

The average combined volume of the bilateral haemothoraces was 1404ml with a Standard Deviation of 797ml. Fatal penetrating cardiac injuries were the result of a penetrating incised wound in 270 (89%) cases, rifled firearm injury in 26 (9%) cases and a shotgun injury in 7 (2%) cases.

In 7 cases injury to a coronary vessel was recorded with the right coronary artery injured in 1 case and the left anterior descending coronary artery injured in 6 cases. In 14 (4.6%) cases the wound track injuring the heart also injured the liver. Seven of these cases were the result of penetrating incised wounds.
4.4.3 Fatal Penetrating Lung Injury

A single fatal penetrating lung injury was present in 122 (14.5%) cases with 59 cases involving the left lung and 63 cases involving the right lung. All the cases were associated with large unilateral haemothoraces with an average volume of 940ml on the left and 1002ml on the right.

4.5 Blood Alcohol Concentration

The blood alcohol concentration (BAC) was measured in 839 of the 841 cases by gas chromatography performed by the Forensic Chemical Laboratory in Cape Town. The highest single blood alcohol concentration measured was 0.45g/100ml.

Of the 839 cases with BAC estimation, 46 cases who underwent resuscitation in hospital prior to demise and autopsy, had a positive BAC. This represents 7.67% of the cases who underwent hospital treatment. Table 10 shows the number of cases with positive BAC with and without this group included:
Table 10. Blood Alcohol Concentration (BAC)

<table>
<thead>
<tr>
<th>BAC (g/100ml)</th>
<th>n=839</th>
<th>n=793</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>167(20%)</td>
<td>148(19%)</td>
</tr>
<tr>
<td>0.01 - 0.09</td>
<td>61(7%)</td>
<td>51(6.5%)</td>
</tr>
<tr>
<td>0.10 - 0.19</td>
<td>244(29%)</td>
<td>233(29%)</td>
</tr>
<tr>
<td>0.20 - 0.29</td>
<td>281(33.5%)</td>
<td>276(35%)</td>
</tr>
<tr>
<td>0.30 - 0.39</td>
<td>82(10%)</td>
<td>81(10%)</td>
</tr>
<tr>
<td>0.4+</td>
<td>4(0.5%)</td>
<td>4(0.5%)</td>
</tr>
</tbody>
</table>

The BAC average excluding the treated group was 0.17 g/100ml. The average BAC in cases with penetrating incised wounds was 0.18 g/100ml, in rifled firearm injuries was 0.07g/100ml, and in shotgun injuries was 0.07g/100ml.

4.6 Hospital Treatment

A total of 60 (7.1%) cases underwent hospital treatment before death which included resuscitation, tube thoracostomy, emergency room thoracotomy, thoracotomy in theatre, or combinations thereof. One patient had a lobectomy. In 7 cases (11.7%) the injuries were firearm related and in 53 cases (88.3%) the injuries were due to sharp instruments.

All of the above the patients received emergency resuscitation on arrival at hospital and 18.3% of cases underwent tube thoracostomy. Twenty-two patients (36.7%) underwent a thoracotomy and
one patient had a sternotomy. In 6 cases the heart was sutured and in 1 case the lung was sutured. Two patients required bilateral tube thoracostomies.

5. DISCUSSION

5.1 Study population

The high incidence of homicide (49% of all non-natural deaths in 1990) highlights the violent nature of our society. Fatal penetrating injuries of the chest included in this study constituted 22.6% of the non-natural cases admitted to the Salt River Medicolegal Laboratory. This is consistent with figures from Johannesburg which showed an incidence of 21.2%.47

In 1986, homicide victims constituted 22.3% of all admissions to the Salt River police mortuary and in 1990 the figure was 39%. This is in keeping with the rise in the homicide rate to 65/100000 population recorded in 1994 (personal communication, Dr L B Lerer). In contrast, the homicide rate for New York is 14.5/100 000 per annum.63
5.2 Demographic Data

The demographic data in this study is similar to other studies, but shows a higher preponderance of male victims (94%). Many theories exist as to why males constitute the majority of victims and aggressors in violence. The subject is complex, but there are two main schools of thought in the criminological, sociological and psychological fields of study.

The first school of thought ascribes the phenomenon of a male preponderance to mainly biological causes, such as higher levels of androgens which may lead to a higher innate aggressiveness in males. The second school of thought requires the victim/aggressor to be seen in the environment of a male dominated or patriarchal system, which may include certain specific cultural effects. An example of this would be a belief amongst traditional black South African males that a man is less of a man if he does not carry a weapon. Group violence, such as gangsterism experienced amongst young coloured males in the Western Cape, is also explained under this behaviourist or socialization theory.

The cases in this study are similar to those in the series by Naughton et al. The majority consists of Black or Coloured male blue collar workers with an average age of 28 years. The high
incidence of scholars is alarming, but may include youths involved in politically related violence prior to the change of government in South Africa. Before the watershed elections of 1994, black youths in South Africa were actively involved in the struggle against Apartheid. This had its roots in the Soweto riots commenced by black youths in 1975.

The demographic features of interpersonal violence are further explained by Butchart and Brown in a political and historical context. They are of the opinion that the pattern of interpersonal violence in South Africa is related, apart from the general factors such as poverty and those mentioned above, to a "specific" factor which is present in colonial and postcolonial societies. This "specific" factor exists where the vertical violence between the colonisers and the colonised is transformed into horizontal violence amongst the colonised due to a lack of economic and political empowerment. This then causes the colonisers' claim that the colonised "are a bad lot, a rowdy lot" to also become the perception of the colonised.

5.3 Site of injury

The majority of injuries were situated on the left anterior chest with the highest number of cases sustaining wounds to the area left of the midline between the second left rib space and the fifth left
intercostal space. This could be a reflection of the fact that most assailants are right handed and attacking from the front. However, assaults are not static events and a large number of variables enter the equation including the relative size of the victim and the assailant, their relative positions, and the types of weapon used. Care should therefore be taken in assessing the handedness of the assailant from the site of the wound. One can only comment on the likelihood of the assailant being right or left handed in any one given situation.

5.4 Nature of injury

Sharp instruments were used in 88.2% of cases, which is a much higher incidence than recorded in the literature published on patients admitted to hospital.\textsuperscript{10,23-26} The incidence of firearm related cases (11.8%) is also lower than expected from the proportion of firearm related homicide cases admitted to the Salt River Medicolegal laboratory during 1990 (22%). This is in keeping with the findings by Harries that the use of knives and sharp instruments tends to increase with a decrease in socioeconomic status.\textsuperscript{50}
5.5 Intrathoracic Injuries

5.5.1 Fatal Penetrating Vascular Injuries

These injuries constituted 36% of cases in the study and consisted largely of injuries to the aorta in general (34%) and the ascending aorta specifically (18%). Injury to the subclavian vessels, as a group, was present in 25% of cases. This is a high incidence and may be related to the fact that both vein and artery were involved in 41% of cases with subclavian vessel injury, compared to the hospital based study on survivors where only 17% of cases showed both arterial and venous injury. This is in keeping with the expectation that patients with both arterial and venous injury would be more likely to exsanguinate before reaching hospital. These figures are also higher than those from Johannesburg, and may point to a regional predilection for supraclavicular stab wounds.

Innominate artery injury was not recorded in this study and reflects the low incidence as reported. This confirms that the true incidence of innominate artery injury is low.
Noting the high incidence of injuries to the ascending aorta and pulmonary artery, it is felt that the triangular anatomical structure of the manubrium sterni may well be playing a double role in directing penetrating incised wounds towards the aorta and pulmonary vessels, while also protecting the innominate artery.

5.5.2 Fatal Penetrating Cardiac Injuries

The number of cases with fatal cardiac injury was similar to the number of cases with vascular injury. The right ventricle (50%) was injured more commonly than the left ventricle (37%), and this is similar to the figures in the literature.\textsuperscript{51} Interventricular septal injuries underlying anterior ventricular wall penetrating incised wounds were present in 4% of cases. Such injuries are a cause of increased morbidity and reoperation in survivors.\textsuperscript{54}

Blood was present in the pericardial sac in 87% of cases and 82% of cases showed the presence of a haemothorax. It must be stressed that the volume of pericardial tamponade and haemorrhages at autopsy may not reflect the volume at the time of death, as the patient may bleed outwards through the defect in the chest wall, and as blood may be lost from the pericardial sac into the chest cavity and the environment during post mortem handling of the body.
Fatal penetrating cardiac injuries were mainly the result of penetrating incised wounds (89%) rather than rifled firearm (9%) or shotgun (2%) injuries, as was similarly recorded in the total number of cases.

Attar et al. indicate that firearm injuries of the heart have a worse prognosis than penetrating incised wounds of the heart. This is because firearm injuries and incised wounds differ in the manner by which they cause cavitation. Sharp instruments create a permanent wound cavity by mechanical disruption of tissue which can be observed as a wound tract.

Firearms create both a temporary cavity and a permanent cavity. The size and extent of the temporary cavity, which exists only for milliseconds, depends on the nature and particularly the elastic tissue content of the tissue, and the amount of energy transferred from the missile to the tissue. Thus the more elastic tissue in an organ, (e.g. lung) the greater the potential expansion of the organ, and the less the damage. In muscle, with low elastic content, the expansion results in destruction.

The energy contained in the missile is dependent on the mass of the missile and the square of its velocity. High velocity missiles therefore have more energy than similar-sized low velocity
missiles and will create a larger temporary cavity. Muscle tissue has less elasticity than lung tissue and therefore damage due to temporary cavity formation is less in lung tissue than in muscle tissue. Because of this temporary cavity formation, there is subsequent injury distant to the permanent cavity, which explains the increased damage to heart muscle seen in firearm injuries. This also explains the phenomenon of vascular injuries distant from the permanent cavity seen in cases of high velocity firearm injuries, which create a larger temporary cavity.

5.5.3 Fatal Penetrating Lung Injuries

Single fatal penetrating lung injuries were present in 14.5% of cases. All the cases were associated with large unilateral haemothoraces. This haemorrhage may explain the surprising finding of a high mortality in such cases by Lerer and Knottenbelt.9

No obvious vascular sources of haemorrhage were documented, but injury to the intercostal vessels remains the most likely source. These injuries may be missed since they are inconspicuous at autopsy. This is supported by the findings of Moar who documented a 27% incidence of intercostal vessel injury.47
Identifying vascular injuries in the collapsed lung can be difficult macroscopically, and this may also explain why these cases had large haemothoraces in the absence of obvious vascular injury.

5.6 Blood alcohol concentration

Alcohol was absent in the blood in 20% of cases. This is in contrast to the figures of Duflou et al\(^2\) who 5 years previously noted a zero blood alcohol concentration in 37.1% of cases. Four cases had a blood level in excess of 0.4 g/100ml. The role of alcohol as contributory factor to death is unclear, but the vasodilatory effect of alcohol may be a contributing factor in exsanguination of patients.

5.7 Hospital Treatment

Only 7.1% of the cases underwent hospital treatment prior to admission to the Salt River Medicolegal Laboratory, emphasising the fact that hospitals only tend to receive patients with a good chance of survival. The fact that only a small proportion of patients underwent formal procedures, such as tube thoracostomy and thoracotomy, after resuscitation, indicates that these patients were agonal on arrival, and therefore did not require definitive intervention. This is in
keeping with the practice of reserving emergency room thoracotomy, as opposed to thoracotomy in a room designed as a theater, as a resuscitative measure for control of haemorrhage, relief of pericardial tamponade, or aortic cross clamping in the severely hypotensive patient.56

These findings are also reflected by Moar47 in Johannesburg, who showed that only 5.8% of patients reach hospital alive. In Cape Town too, the small number of cases reaching hospital alive is a reflection, not only of the nature and severity of the injuries, but also the absence of readily available medical treatment at the time of injury.

6. CONCLUSION

This study confirms the high proportion of fatal penetrating chest injuries amongst homicide victims, and the high incidence of these injuries mainly in the lower socio-economic population group. Until South Africa is completely free from its recent and more distant colonial past, and until the grave socio-economic problems of poverty and unemployment are addressed, continuing violence will ensure that this type of lethal injury will remain.

The findings that penetrating vascular and cardiac injuries are the main contributors to the high mortality carried by penetrating chest injuries as a group, and that the site of these injuries is
mainly on the left central aspect of the chest, may have a bearing on the design of body armour for police and security personnel.

The finding of a high mortality due to otherwise seemingly innocuous single penetrating injuries of the lungs, in the absence of obvious vascular pathology, needs to be studied specifically to determine the exact mechanism of death.

Finally, it is apparent from this study that penetrating injuries of the chest carry a higher mortality than suggested from hospital based studies alone. Although hospital based studies show a high survival rate, partly as a result of aggressive treatment, it is clear that recognition of the serious nature of penetrating chest injuries, combined with rapid transport to hospital and effective treatment, hold the key to reducing the high mortality of penetrating injuries of the chest.
7. Bibliography


