



Characteristics of fatal penetrating injury; data from a retrospective cohort study in three urban regions in the Netherlands



N.A.G. Hakkenbrak^{a,b,*}, E.R. Bakkum^b, W.P. Zuidema^a, J.A. Halm^a, T. Dorn^c, U.J.L. Reijnders^c, G.F. Giannakopoulos^a

^aTrauma Unit, Department of Surgery, Amsterdam University Medical Centre, the Netherlands

^bTrauma Unit, Department of Surgery, Northwest Clinics, Alkmaar, the Netherlands

^cDepartment of Forensic Medicine, Public Health Service of Amsterdam, the Netherlands

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ABSTRACT

Introduction: Penetrating injury (PI) is a relatively rare mechanism of trauma in the Netherlands. Nevertheless, injuries can be severe with high morbidity and mortality rates. The aim of this study is to assess fatalities due to PI and evaluate the demographic parameters, mechanism of injury and the resulting injury patterns of this group of patients in three Dutch regions.

Methods: Patients suffering fatal PI (stab- and gunshot injuries), in the period between July 1st 2013 and July 1st 2019, in the region of Amsterdam, Utrecht and The Hague were included. Data were collected from the electronic registration system (Formatus) of the regional departments of Forensic Medicine.

Results: During the study period 283 patients died as the result of PI. The mean age was 44 years (SD 16.9), 83% was male and psychiatric history was reported in 22%. Over 60% of the injuries were due to assault and 35% was self-inflicted. Almost half of the incidents took place at home (47%). Injuries were most frequently to the head (24%) and chest (16%). Mortality was due to exsanguination (chest 27%, multiple body region's 17%, neck 9% and extremities 8%) and traumatic brain injury (21%). Up to 40% of the patients received medical treatment, surgical intervention was performed in 25%. The injuries to the extremities suggest a (potentially) preventable death rate of over 8%. Over 70% of the total population died at the scene.

Conclusion: Fatal PI most often involves the relatively young, male, and psychiatric patient. Self-inflicted fatal PI accounted for 35%, addressing the importance of suicide prevention programs. Identification of preventable deaths needs more awareness to reduce the number of fatal PI.

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Introduction

Assault and unintentional injury result in a significant level of morbidity and mortality. Thereby, remaining the leading cause of death in people under the age of 50. Accounting for approximately 530.000 deaths a year in Europe according to the World Health Organisation (WHO) [1]. Annually a further 30.000 fatalities are the result of interpersonal violence [2].

The incidence of penetrating injury (PI), stab and gunshot injuries, varies enormously depending on several factors such as demographic characteristics, violent crime rates and firearm legisla-

tion. The incidence of trauma admissions to the Emergency Department due to PI differs from 0.2% in Switzerland up to 20–45% in the USA and 21–60% in South Africa [3–5].

In the Netherlands, the incidence of PI is low, most often concerning stabbing injuries amongst young males (51.1% stabbing injuries versus 26.3% gunshot injuries) [6]. The regional trauma network covering the provinces North Holland and Flevoland (Netwerk Acute Zorg Noordwest (NAZN) and SpoedZorgNet) reported an increase of PI in 2019 up to 99 (NAZN) and 111 (Spoedzorgnet); 1.9% and 1.3% of all trauma-related injuries [7].

Worldwide, numerous studies have been performed to assess the mechanism of injury (MOI) and treatment of PI to improve outcome [5, 8]. This has led to advanced (pre)hospital care and better outcome of trauma patients during the last decade [8–12]. Hence, PI is of great interest for both clinical and forensic medicine due to the subsequential morbidity and mortality. The aim of this study is

* Corresponding author at: Amsterdam UMC, location VUMC, Department of Trauma Surgery, Room 7F-002, De Boelelaan 1117, 1081 HV, Amsterdam, the Netherlands.

E-mail address: n.hakkenbrak@amsterdamumc.nl (N.A.G. Hakkenbrak).

to evaluate the demographic parameters, incidence, injury characteristics and patterns of fatal PI in The Netherlands.

Methods

We performed a retrospective cohort study at the Department of Forensic Medicine of the Public Health Service of Amsterdam, Utrecht, and The Hague. Fatalities as result of PI, stab- and gunshot injuries, reported at the department of Forensic Medicine were collected and analysed. According to the Dutch funeral law, the physician is to perform a physical examination to pronounce death. In case of unnatural death such as PI, it is mandatory to consult a forensic physician. Hereafter, all physical examinations performed by the forensic physician are reported in the department's electronic registration system (Formatus). The participating Departments of Forensic Medicine include the catchment area of the Public Health Service of Amsterdam (including the regions Amsterdam-Amstelland and Zaanstreek-Waterland), Utrecht (Utrecht West, Zuidoost, Stad, Eemland and Lekstroom) and The Hague (Delft, The Hague, Leidschendam-Voorburg, Midden-Delfland, Pijnacker-Nootdorp, Rijswijk, Wassenaar, Westland and Zoetermeer), together accounting for approximately 3.7 million inhabitants (ca. 22% of the Dutch population) [13–15].

Study design

Patients who died due to PI between July 1st 2013 and July 1st 2019, reported by the Department of Forensic Medicine of Amsterdam, Utrecht and The Hague were screened for eligibility. Patients of all ages who deceased due to or as the result of stabbing- or gunshot injuries were included. Data were retrieved from the electronic database of the Departments of Forensic Medicine. The results were reported according to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines (STROBE) [16].

Outcome measures

Outcome measurements included the MOI, patient characteristics (age, gender, medical- and psychiatric history), injury characteristics (type- and anatomical location of injury, cause of injury, and intoxication), treatment by (helicopter) emergency medical services ((H)EMS) and mortality characteristics (location, cause of death and complications).

HEMS are available in the Netherlands since the late 1990's to provide high level of care at the scene, performing surgical procedures such as thoracocentesis and resuscitative thoracotomy to improve outcome and reduce mortality of the severely injured patient [17]. Survival benefits have been reported in several Dutch studies [17–19].

MOI was divided into stab- and gunshot injuries. The injuries were assessed and scored as accidental, self-inflicted or assault as described by the forensic physician. Medical treatment was categorized; blood transfusion and intubation were reported as non-invasive treatment, surgical procedures such as chest tube insertion and thoracocentesis or procedures restricted to the operating theatre (or due to the emergency setting performed at the scene, Emergency Department, or Intensive Care) such as resuscitative thoracotomy or laparotomy were reported as surgical treatment. The anatomical locations of injury were divided into six body regions: 1.) Brain, neck, and cervical spine (head); 2.) Face; 3.) Chest; 4.) Abdomen; 5.) Extremities including pelvis and hip; 6.) Multiple injuries [20].

Time until death was reported in days. Psychiatric disorders were categorised into four groups: cognitive impairment, personal-

Table 1
Patient characteristics.

	N = 283	Stabbing N = 145 (51.2%)	Gunshot N = 138 (48.8%)
Forensic region			
Amsterdam	169 (59.7%)	83 (49.1%)	86 (50.9%)
The Hague	60 (21.2%)	33 (55.0%)	27 (45.0%)
Utrecht	54 (19.1%)	29 (53.7%)	25 (46.3%)
Age, yr. (SD)	44.0 (16.9)	48.6 (17.8)	39.5 (14.7)
Gender			
Male (%)	234 (82.7%)	110 (75.9%)	124 (89.9%)
Female (%)	49 (17.3%)	35 (24.1%)	14 (10.1%)
Psychiatric history			
history	34 (12.0%)	25 (17.2%)	9 (6.5%)
Mood disorders (%)	15 (5.3%)	14 (9.7%)	1 (0.7%)
Personality disorders (%)	2 (0.7%)	1 (0.7%)	1 (0.7%)
Cognitive impairment (%)	11 (3.9%)	11 (8.0%)	-
Other (%)	38 (13.4%)	18 (12.4%)	20 (14.5%)
None (%)			

ity disorders, mood disorders and other disorders or a combination of disorders.

The majority of trauma-related (potentially) preventable death in penetrating injury regard injuries to the extremities and chest (excluding vascular and airway injury) [21, 22]. With regard to this study, based on external physical post-mortem examination, injuries to the extremities will be reported on regarding preventable death, as autopsy reports are not provided.

Statistical analysis

The results are presented descriptively. Analysis was performed on patient characteristics to assess for differences between the stab- and gunshot cohort. Mean and standard deviation (SD) were reported for descriptive analysis of continuous data. Numbers and frequencies were reported for categorical data.

Results

A total of 283 fatalities due to PI were reported by the participating Departments of Forensic Medicine between July 1st 2013 and July 1st 2019: Amsterdam 169 (59.7%), The Hague 60 (21.2%) and Utrecht 54 (19.1%) (Table 1). Age differed between the two cohorts with a mean age of 48.6 years (SD 17.8) in the stabbing cohort and 39.5 years (SD 14.7) in the gunshot cohort. Overall, there was a difference in gender (82.7% male).

Stabbing injuries

Patient characteristics

Approximately half of all fatal injuries were the result of stabbing injuries (51.2%, $n = 145$). Over 75% of the patients were male and 35.2% had psychiatric history (Table 1). Mood disorders such as bipolar disorder and depression were most common with respectively 17.2%, followed by substance abuse (alcohol, drugs, or medication) (12.4%) and personality disorders, e.g., schizophrenia, borderline and anxiety (9.7%). Intoxication (alcohol, drugs, and medication) was reported in approximately 11.7% of the fatalities.

Injury characteristics

Over half of the stabbing injuries were sustained at home (61.4%) and due to assault (51.0%) (Table 2). An additional 42.8% was self-inflicted. The majority of the injuries regarded isolated injury (54.5%), most often to the chest (22.8%), extremities (14.5%)

Table 2
Injury characteristics.

	N = 283	Stabbing N = 145	Gunshot N = 138
Location (%)			
Home	134 (47.3%)	89 (61.4%)	45 (32.6%)
Public area	118 (41.7%)	39 (26.9%)	79 (57.2%)
Work	6 (2.1%)	3 (2.1%)	3 (2.2%)
Other	3 (1.1%)	13 (9.0%)	9 (6.5%)
Intention (%)			
Assault		74 (51.0%)	97 (70.3%)
Self-inflicted	99 (35.0%)	62 (42.8%)	37 (26.8%)
Accidental	1 (0.4%)	1 (0.7%)	
Unknown	3 (1.1%)	1 (0.7%)	2 (1.4%)
Number of injured body regions			
N = 1	140 (49.5%)	79 (54.5%)	61 (44.2%)
N = 2	76 (26.9%)	41 (28.3%)	35 (25.4%)
N ≥ 3	67 (23.6%)	25 (17.2%)	42 (30.4%)
Treatment (%)			
Non-invasive	55 (19.4%)	19 (13.1%)	36 (26.1%)
Surgery	56 (19.8%)	36 (24.8%)	20 (14.5%)

Table 3
Injuries, by body region.

	N = 283	Stabbing N = 145	Gunshot N = 138
Head (brain/neck)	69 (24.4%)	20 (13.8%)	49 (35.5%)
Chest	45 (15.9%)	33 (22.8%)	12 (8.7%)
Abdomen	5 (1.8%)	5 (3.4%)	0
Extremities	21 (7.4%)	21 (14.5%)	0
Multiple injuries	143 (50.5%)	66 (45.5%)	77 (55.8%)

and head (13.8%) (Table 3). Stabbing injuries to the neck were self-inflicted in 12 patients (60%).

Treatment

Non-invasive treatment, such as blood transfusion and thoracotomies, was performed in 19 patients (13.1%) and surgical treatment in 36 patients (24.8%). Surgical treatment was specified in 32 patients: in 22 patients a resuscitative thoracotomy was performed, damage control laparotomy was performed in five patients, in one patient both thoracotomy and laparotomy were performed, two neck injuries were operated upon, one femoral artery injury and one patient was connected to the extracorporeal membrane oxygenation (ECMO) machine in the operating theatre.

Seventeen of the patients that were operated upon received additional HEMS care at the scene. This included resuscitation or thoracocentesis. In twelve patients a resuscitative thoracotomy was performed by the HEMS at the scene. Overall, patients who were operated upon were relatively younger, with a mean age of 36.8 years (SD 16.6) and suffered stabbing injuries (64.3%).

Extremity injury

Furthermore, in 124 cases patients suffered from injury to the extremities. In 70 patients these injuries were the result of stabbing (48.3%). Overall, 25 patients in the stabbing cohort deceased due to isolated extremity injuries and 23 of them to subsequent exsanguination. Of these, 21 patients died at the scene, four in the hospital (one in the Emergency Department). In two cases the use of a tourniquet was reported, in 21 cases this information was missing. Two patients were operated upon their injury. With regard to (potentially) preventable death, extremity injury accounted for 8% of the injuries.

Mortality

Over 70% of the patients died at the scene, this was similar for both groups (71.0% for the stabbing cohort). Less than one percent

of the patients passed away during transport (0.7%). Overall, 24.4% of the patients died in the hospital; 25.5% in the stabbing cohort (8.3% emergency department, 4.1% operating theatre). Time until death was reported in 17 cases with a median of 0 days (range 0 – 8 days). In the majority of the fatalities the cause of death was due to injury to the chest (31.7%), head (17.2%) and extremities (17.2%). The injuries led to exsanguination in 91% of the patients. One patient died due to perforating cardiac injury, one to blast injury, three as result of other injury and six to complications during hospitalization (Table 4).

Almost half of the fatal stabbing injuries (n = 62) were self-inflicted: 16 patients suffered fatal self-inflicted injury to the neck (25.8%), 21 to the extremities (33.9%), eight to the chest, four to the abdomen and 12 deceased as the result of injuries to multiple body regions.

A medico-legal autopsy was advised by the forensic physician in 79 fatalities (54.5%).

Gunshot injuries

Patient characteristics

In 48.8% the fatalities were caused by gunshot injuries (n = 138). Up to 90% of the patients were male, and 8.0% had a previously known psychiatric history (Table 1). Mood disorders were most common (6.5%). Intoxication was reported in 6.5% of the fatalities.

Injury characteristics

In comparison to the stabbing cohort, patients suffered relatively more often injuries to multiple body regions (≥3 body regions, 17.2% vs 30.4%). The type of firearm was reported in 17 cases; in eight cases a semi-automatic firearm (handgun) was used, in seven cases a non-automatic firearm (revolver, rifle) and in two cases an automatic firearm. In total, 57% of the gunshot injuries were suffered in public area and up to 70% of the injuries were intended by others. Isolated injury (44.2%) most often regarded the head (35.5%), of which 69.4% was self-inflicted (Table 3). In more than half of the cases multiple body regions (≥2 body regions) were injured.

Treatment

Non-invasive treatment was performed in 36 patients (26.1%) compared to surgical treatment in 20 patients (14.5%). Surgical treatment was specified in 19 patients: in 13 patients a resuscitative thoracotomy was performed, in two a damage control laparotomy (including external fixation of both humeral bones in one patient), in three patients both thoracotomy and laparotomy were performed, and one patient received an intracranial pressure monitoring device. Twelve of the patients that were operated upon received additional HEMS care at the scene. In ten patients the thoracotomy was performed by the HEMS.

Mortality

In 73% the patients died at the scene, less than one percent passed away during transport and 23.2% died in-hospital (4.3% at the emergency department and 2.2% in the operating theatre). In the majority of the fatalities cause of death was due to injury to the head (44.2%), chest (23.9%) and extremities (28.2%) (Table 4). Time until death was reported in 17 cases with a median of 0 days (range 0 – 10 days).

A quarter of the fatal injuries (n = 37) were self-inflicted: 35 patients suffered fatal self-inflicted injury to the head and two to the chest. In case of assault, multiple body regions were injured in 39.2%, followed by injury to the chest (30.9%) and head (24.7%).

In 101 fatalities (73.2%) a medico-legal autopsy was advised by the forensic physician.

Table 4
Cause of death, injury.

	Exsanguination	Tissue disruption (incl. perforation and blast injuries)	Combination/other	Complication
Head (brain/neck) N = 86 (Stabbing N = 25) (Gunshot N = 61)	24 (Stabbing N = 22) (Gunshot N = 2)	59 (Stabbing N = 1) (Gunshot N = 58)	3 (Stabbing N = 2) (Gunshot N = 1)	
Chest N = 79 (Stabbing N = 46) (Gunshot N = 33)	75 (Stabbing N = 43) (Gunshot N = 32)	1 (Gunshot) 1 (Stabbing)		2 (Stabbing)
Abdomen N = 15 (Stabbing N = 10) (Gunshot N = 5)	13 (Stabbing N = 8) (Gunshot N = 5)			2 (Stabbing)
Extremities N = 25 (Stabbing)	23 (Stabbing)		1 (Stabbing)	1 (Stabbing)
Multiple injuries N = 76 (Stabbing N = 37) (Gunshot N = 39)	49 (Stabbing N = 36) (Gunshot N = 13)	22 (Gunshot)	3 (Gunshot)	2 (Stabbing N = 1) (Gunshot N = 1)

Discussion

This retrospective cohort study investigated the patient- and injury characteristics of fatal PI in the Netherlands, assessing the fatalities in the forensic region of three large urban areas.

In the Netherlands, the incidence of PI is relatively low, accounting for approximately 3% of all traumatic hospital admissions; *n* = 2.323 in 2018 [23]. The corresponding in-hospital mortality rate for trauma patients in the Netherlands is 2% [23]. During the study period, annually 47 people died due to PI, based on a population of approximately 3.7 million inhabitants. The resulting mortality rate for fatal PI in relation to the overall death rate in the participating regions is 0.15% (1: 672 death) [24]. In addition, according to the Trauma Registry, PI accounts for approximately 184 trauma admissions a year in the forensic region of Amsterdam [7]. Meanwhile, fatal PI accounted for 28 fatalities a year, during the study period.

Previous studies regarding PI report in-hospital mortality rates of 0.5–21% in the UK, 3.6% in the Netherlands and up to 6.8–41% in Germany [8, 25, 26]. This study solely described fatal penetrating injuries, similar to these studies, most victims regard young male victims. However, almost half of the fatal injuries were due to stabbing injuries. This percentage is high compared to previous literature, describing mainly gunshot injuries [8, 26]. This difference might be explained by the Dutch firearm legislation and relatively high percentage of self-inflicted injuries in our study population.

In addition, several Dutch studies reported stabbing injuries as most common MOI for trauma admissions following PI (5.1% vs 26.3%, 73% vs 21%) [6, 12]. However, in this study, based on forensic records, the number of fatal stabbing- and gunshot injuries did not differ (51.2% vs. 48.8%). There are several explanations for these findings. First, gunshot injuries are more often instantly fatal due to the high impact of trauma, therefore, these patients are less represented in the previously published studies regarding PI admitted to the Emergency Department. Secondly, as depicted in Table 4, in line with the number of self-inflicted injuries, self-inflicted gunshot injuries are most often to the head, hence, fatal compared to self-inflicted stabbing injury to the extremity, chest or abdomen.

Furthermore, even though the incidence of PI is low in the Netherlands, the regional Trauma Network reported an increase of PI [7]. Remarkably, in this study the number of fatal PI remained stable with an average of 47.2 fatalities a year. This may be explained by the increase of PI due to stabbing injuries as they are most often not fatal, whilst the number of gunshot injuries remained stable [27]. Additional benefit of improved prehospital

care, e.g., the implement of the ‘Stop the Bleeding Campaign’ in 2015 may be suggested, especially in stabbing injuries to the extremities, but could not be supported by this study due to missing data reporting on the use of tourniquets [28].

In the Netherlands the incidence of suicide is approximately 11 per 100.000 inhabitants per year, mainly males between 40 and 70 years of age [29, 30]. Therefore, the government aimed to reduce the number of suicides by implementation of a national suicide prevention program (Landelijke Agenda Suïcidepreventie 2021–2025) and Helpline ‘113’ [31]. The results of this study support the necessity of implementation of suicide prevention programs as self-inflicted injury accounted for 35% of all fatal PI. The majority of the patients suffering self-inflicted fatal PI died at the scene. Prevention of suicide is the only possible intervention to reduce the number of self-inflicted fatal PI.

Trauma-related potentially preventable and preventable death (TRPPD) is used to assess the quality of trauma care [32]. TRPPD regard fatalities with severe but survivable injuries if appropriate steps in trauma care had been taken, however, deviations from standard of care led directly or indirectly to the patient’s death [21]. Previous studies have reported injury to the extremities and chest (excluding injuries to the major vessels and airway) to be (potentially) preventable [21, 22]. In this study 23 patients died as result of exsanguination from extremity injury (8.1%), 75 patients died due to thoracic injury (26.5%); in 52% of the patients a thoracotomy was performed. From the 32 patients in the stabbing cohort on whom a thoracotomy was performed, 19 died after arrival at the hospital (59%). These findings suggest a TRPPD of over 8%. To properly assess TRPPD additional prehospital information is required.

Limitations

Some limitations of this study should be noted, due to the retrospective character of the study. In the first years of the study period patient data were collected on paper at the Department of Forensic Medicine. Unfortunately, it was not possible to collect these pre-electronic data of 2013–2014 from the Department of Forensic Medicine of The Hague. Clinical data and hospital information were restricted to the information reported by the forensic physician. Autopsy reports were not accessible due to the Dutch legislation. From 2014 onwards data were collected in the same electronic registration system for all three regions adding strength to this study by reducing information errors and missing values. Due to the Dutch legislation and obligation to consult a forensic

physician in case of unnatural death, e.g., fatal PI, all fatal PI were collected adding to the strength of this study.

Even though medical and psychiatric history were reported in the forensic records, data might be missing due to limited information on medical history at the scene. Therefore, it might be suggested that the actual percentage of psychiatric history is even higher than the reported 22%. The risk of information bias due to missing data regarding medical treatment should be taken into consideration. However, this accounts for both the stabbing and gunshot cohort equally.

This study is the first retrospective cohort study in the Netherlands assessing fatal PI. Even though, PI is relatively rare, this study supports the importance of recognizing PI as a socioeconomic and public healthcare problem, as patients are relatively young, and injuries are often self-inflicted or the result of interpersonal violence.

Conclusion

Fatal penetrating injury is a relatively rare mechanism of trauma. The majority of the population regards young and male patients. Self-inflicted injuries were more often reported in the stabbing group and amongst females. Accounting for 35% of all fatalities, the implementation of suicide prevention programs and helplines remains of great importance. Despite the increasing number of PI, the number of fatal PI remained stable. The preventable death rate of at least 8% supports the necessity for timely implementation of medical care at the scene to adequately treat survivable (extremity) injuries.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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Ethical approval

Not applicable.

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