



LUND UNIVERSITY

A Swedish nationwide forensic study of the manner of death in single stab injuries to the trunk

Berg von Linde, Maria; Acosta, Stefan; Khoshnood, Ardavan M.; Wingren, Carl Johan

Published in:
Forensic Science International

DOI:
[10.1016/j.forsciint.2023.111910](https://doi.org/10.1016/j.forsciint.2023.111910)

2024

Document Version:
Publisher's PDF, also known as Version of record

[Link to publication](#)

Citation for published version (APA):
Berg von Linde, M., Acosta, S., Khoshnood, A. M., & Wingren, C. J. (2024). A Swedish nationwide forensic study of the manner of death in single stab injuries to the trunk. *Forensic Science International*, 354, Article 111910. <https://doi.org/10.1016/j.forsciint.2023.111910>

Total number of authors:
4

Creative Commons License:
CC BY

General rights

Unless other specific re-use rights are stated the following general rights apply:
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Read more about Creative commons licenses: <https://creativecommons.org/licenses/>

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00



A Swedish nationwide forensic study of the manner of death in single stab injuries to the trunk

Maria Berg von Linde, MD^{a,b,*}, Stefan Acosta, MD, PhD^{c,d}, Ardavan M. Khoshnood, MD, PhD^{e,f}, Carl Johan Wingren, MD, PhD^{a,g}

^a Unit for Forensic Medicine, Department of Clinical Sciences Malmö, Faculty of Medicine, Lund University, Lund, Sweden

^b Swedish National Board of Forensic Medicine, Unit for Forensic Medicine, Sölvegatan 25, 223 62 Lund, Sweden

^c Vascular Centre, Department of Cardiothoracic and Vascular Surgery, Skåne University Hospital, Malmö, Sweden

^d Department of Clinical Sciences Malmö, Lund University, Ruth Lundskogsgatan 10, 205 02 Malmö, Sweden

^e Department of Emergency Medicine, Skåne University Hospital Malmö, Malmö, Sweden

^f Department of Clinical Sciences Malmö, Lund University, Clinical Research Centre, CRC 91-12, Box 50332, 202 13 Malmö, Sweden

^g Department of Forensic Medicine, Copenhagen University, Frederik V's Vej 11, 2100 Copenhagen, Denmark

ARTICLE INFO

Keywords:

Forensic pathology
Sharp force
Homicide
Suicide
Single stab

ABSTRACT

Introduction: Forensic pathologists are frequently confronted with questions about whether an injury is likely to have been inflicted by an assault or be self-inflicted. However, little is known of the epidemiological variables that might be applicable to differentiate between homicides and suicides in deaths caused by single stab injuries to the trunk.

Method: Using the Swedish forensic autopsy register, we identified 94 homicides and 45 suicides between 2010 and 2021 in which death followed a single stab injury to the trunk. We extracted characteristics from the cases and performed statistical analyses using the Mann-Whitney U test, Chi-square test and logistic regression model. **Results:** Victims of homicides were younger than suicide victims (median age 33 years vs. 52 years, $p < 0.05$), and males were in the majority in both groups (93% vs. 82%). In numerous homicide victims, stab wounds were placed in the back and in axillar regions, unlike in suicides victims in which the stabs were all placed on the medial part of the anterior trunk. Vertical entrance wounds in the skin combined with a medially running injury channel ($n = 13$) showed a positive predictive value of 100% (95% CI 75.3–100) for homicide, although the sensitivity was low. Homicides were conclusively associated with an outdoor death scene (OR 19.0, 95% CI 7.6–47.1), injury to thoracic bone/cartilage (OR 3.8, 95% CI 1.6–9.0), influence of alcohol (OR 7.1, 95% CI 2.9–17.7) and illicit drugs (OR 4.3, 95% CI 1.5–11.9).

Discussion and conclusion: The observed forensic characteristics of stab injuries could be used as a tool when assessing the manner of death in single stabs. Further research on variables associated with manner of death are needed and we suggest also including characteristics of surviving victims in such analyses.

1. Introduction

Forensic pathologists are often tasked with determining the likelihood that an injury was inflicted by another person, self-inflicted or possibly inflicted in an accident. In the setting of deaths due to sharp force injuries, numerous studies have aimed at identifying characteristics of the victims and findings that can aid in the differentiation between homicides and suicides [1–7]. Homicide victims typically have a

mean age of 35–40 years, with the victim often being inebriated. Stabs to the back, injuries to thoracic bones or cartilage, and characteristic defensive wounds are also indicators of assaults [1,2,4–7]. In contrast, suicide victims are slightly older (mean age 47–56 years) and are more likely to have a psychiatric history. In precordial stabs, a horizontal stab wound is associated with suicides, as well as so called hesitation wounds which can be recognized as superficial incisive wounds typically found on the forearms or around the stab injury indicating repeated

* Correspondence to: Unit for Forensic Medicine, Department of Clinical Sciences, Malmö. Faculty of Medicine, Lund University, Sölvegatan 25, 223 62 Lund, Sweden.

E-mail addresses: maria.berg_von_linde@med.lu.se (M. Berg von Linde), stefan.acosta@med.lu.se (S. Acosta), ardavan.khoshnood@med.lu.se (A.M. Khoshnood), carl.johan.wingren@sund.ku.dk (C.J. Wingren).

<https://doi.org/10.1016/j.forensiint.2023.111910>

Received 22 September 2023; Received in revised form 27 November 2023; Accepted 6 December 2023

Available online 10 December 2023

0379-0738/© 2023 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

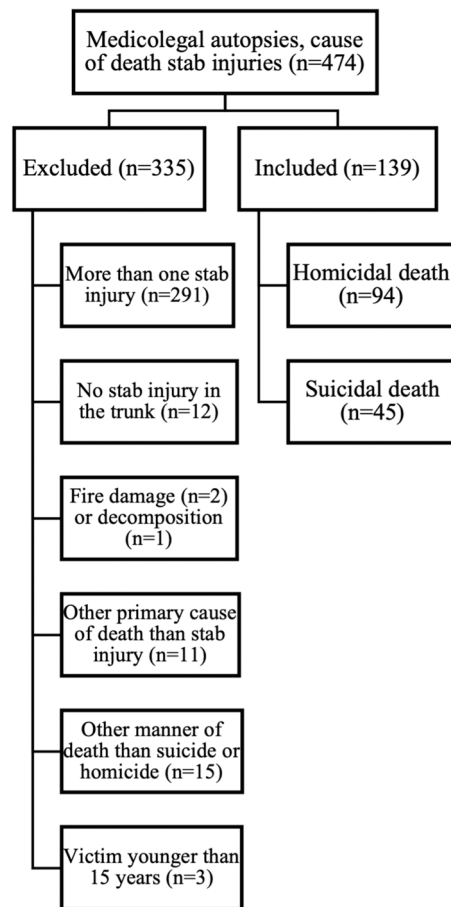


Fig. 1. The selection of cases from all cases with stab injuries as a cause of death as listed in the autopsy register from 2010 to 2021.

self-inflicted cuts [1,3–7].

Findings from the police investigation at the death scene can also contribute to guidance in assessing the manner of death. In homicides, the clothing of the victims is usually penetrated and no weapon is found at the scene or placed elsewhere from the body [1,4,7], while suicide victims are typically found in their homes with exposed skin around the sharp force injury and a suicide note present [1,3,4,7].

Accidental fatal stabs are rare and usually occur in straightforward circumstances such as occupational [8] or alcohol-related accidents [9]. Also, accidental stabs are typically caused by objects other than knives (such as blunt pointed objects and glass surfaces) thus presenting with different wound characteristics [8,9].

Often the fewer the injuries, the more challenging the forensic assessment of manner of death becomes. To guide the assessment in cases of a single fatal stab injury, anatomical distribution and injury characteristics can be identified based solely on that single injury. To the best of our knowledge, there are two prior studies on single stabs using an epidemiological approach in populations of homicides and suicides [10,11] (summarized in [Supplementary Table S1 and S2](#)). These studies presented results that are similar to studies involving sharp force in general. Single stab injuries are mostly located in the chest in victims dominated by males with a lower mean age in the homicide group compared to the suicide group [10,11]. Detection of alcohol was more prevalent in homicide victims than in suicide victims [10]. Stabbing through clothing was described in most of the homicides [10] and the sharp objects in most suicides were found in situ in the body [10]. However, crucial variables like defensive injuries in the homicide cases and hesitation injuries in the suicide cases were mostly absent [11] or not included in the study [10]. The studies are limited to autopsy cases

from an Australian and Swedish forensic institution, respectively. Since deaths caused by single stabs are infrequent, especially in suicides, both studies have rather small sample sizes ($n = 71$ and $n = 79$, respectively).

To strengthen the evidence base for assessing single stab injuries to the trunk, we analyzed all such cases autopsied at the Swedish National Board of Forensic Medicine between 2010 and 2021. We set out to identify characteristics that can guide the forensic assessment of the manner of death – homicide or suicide. Such an epidemiological perspective can be applied in forensic casework when assessing such injuries in a forensic autopsy case.

2. Materials and methods

2.1. Study population

A retrospective observational study was conducted, in which deceased cases with stab injuries to the trunk between 2010 and 2021 were identified from the autopsy register maintained by the Swedish National Board of Forensic Medicine. We applied the coding system of the International Classification of Diseases 9th edition (ICD-9). Codes for sharp force were combined with codes for causes of death involving injuries to the trunk. The applied ICD-9 codes are documented in [Supplementary Table S3](#). In total, 474 autopsy cases were identified and manually reviewed according to the inclusion and exclusion criteria presented in [Fig. 1](#). From the 474 cases, a total of 139 cases (94 homicides and 45 suicides) met the inclusion criteria.

We included cases of homicidal and suicidal deaths in which a single stab injury to the trunk was the primary cause of death. Accidental stab wounds did not qualify as a relevant comparison group because of the differing patterns of injuries and were thus excluded. Besides the stab injury, presence of incisive or blunt injuries was accepted for inclusion in the study, but cases with more than one stab injury, regardless of anatomical location, were excluded. In cases where it was difficult to distinguish a stab injury from a deeper incisive injury, injuries involving muscle tissue on the extremities and injuries penetrating the thoracic or abdominal wall on the trunk were classified as stab injuries. Fatal injuries caused by a combination of incision and stab and/or with more than one direction of the stab wound channel, were still considered a single stab and hence included. Stab injuries located in the groin were not categorized as a location of the trunk and were thereby excluded from the study. Cases of severe fire damage or decomposition were excluded since the extent of the stab injuries could not be reliably determined. Cases younger than 15 years of age and cases with the manner of death classified as accidental death or undetermined were excluded.

2.2. Collection of variables

Data on demographics, psychiatric history, scene of death, and autopsy findings, including toxicological results, were extracted from autopsy, toxicological, and police reports, as well as paramedic, medical, and psychiatric records. Material from the examination of the death scene was also included.

The victim's age in years was included as a continuous variable.

We categorized the location of the scene of death into victims found (i) at home, (ii) at other location indoors or (iii) outdoors. In cases where the victim died during hospital care, the scene of death was defined as the location where the victim was found injured before being brought to the hospital. The garden or courtyard outside the victim's home was defined as an outside location. However, the stairwell outside an apartment was defined as an inside location other than the victim's home.

The presence of a supposed weapon at the death scene was categorized into sharp object found (i) in situ in the body or (ii) elsewhere at the death scene. If no information could be obtained about a sharp weapon at the death scene, the variable was categorized as (iii) absent.

Table 1
Demographics of the study population.

	Homicides (n = 94)	Suicides (n = 45)	Difference (p- value)
Males, n (%)	87 (92.6)	37 (82.2)	p = 0.08
Females, n (%)	7 (7.4)	8 (17.8)	
Age, median of years (range)	33.0(15–84)	52.0(15–90)	p < 0.001
Psychiatric diagnosis*, n (%)	12/16 (75.0)	21/28 (75.0)	p = 1.0
No psychiatric diagnosis*, n (%)	4/16 (25.0)	7/28 (25.0)	

Variables involving gender and psychiatric diagnosis were presented in numbers and percentages and the differences between homicide and suicide were estimated using Fisher's exact test. Age was presented as median age (years) and range and difference between homicide and suicide was estimated using Mann-Whitney U test.

*Missing values: psychiatric diagnosis n = 95 (68.3%)

The anatomical locations of the entrance wound of the stab injuries were partitioned into (i) anterior, (ii) right axillar, (iii) left axillar and (iv) posterior side of the trunk. The anterior trunk was also divided into (i) right side, (ii) left side and (iii) midline (including injuries placed in line with or in proximity to the midline, including all injuries penetrating the sternum). The more precise positions of the injuries were orientated according to midline, midclavicular and axillary lines, skeletal structures and umbilicus.

We also documented whether the entrance wound (i) involved the skeleton or cartilage of the ribcage, such as ribs(s)/sternum/scapula, (ii) penetrated the intercostal space or (iii) the abdomen.

The orientation of the stab injury's entrance wound in the skin was categorized into (i) horizontal, (ii) vertical, (iii) diagonal down right or (iv) diagonal down left.

The length (cm) of the stab wound channel was included as a continuous variable.

The orientation of the stab wound channel was categorized into (i) cranial (ii), caudal or (iii) straight horizontal in the sagittal plane, in combination with (i) medial (ii), lateral or (iii) straight sagittal in the horizontal plane. If the stab wound channel had more than one direction, the direction which was considered to have caused the fatal internal injury was the one taken into account.

Sharp injuries, besides the stab injury, were classified as defensive or hesitation injuries if specifically stated as such injuries in the autopsy report or if there were sharp injuries with typical appearance/description and location of defensive or hesitation injuries. Sharp injuries with initial signs of a healing process, indicating that they were older than the events leading to the death, were excluded.

We extracted any findings of ethanol and narcotic substances in blood and/or urine, excluding drugs considered part of emergency medical treatment. The results were categorized into: (i) positive or (ii) negative alcohol results and also (i) positive illicit narcotic drugs, (ii) positive licit narcotic drugs or (iii) negative narcotic results. Narcotics considered illicit were tetrahydrocannabinol, amphetamine, cocaine and heroin.

2.3. Statistics

Categorical variables were presented in numbers and percentages. Differences in manner of death (homicide/suicide) were analyzed using the Chi-Square test and Fisher's exact test. Continuous variables were presented in mean or median, range and comparison between homicides and suicides were tested using Mann-Whitney U test. We also applied univariate logistic regression models to analyze associations between variables and the manner of death. Odds ratios (OR) were expressed with a 95% confidence interval (CI). The data analyses were performed

Table 2
Location and circumstances at the scene of death.

	Homicides (n = 94)	Suicides (n = 45)	Difference (p- value)
Body found at home*, n (%)	16 (17.0)	35/44 (79.5)	p < 0.001
Body found elsewhere indoors*, n (%)	27 (28.7)	3/44 (6.8)	
Body found outdoors*, n (%)	51 (54.3)	6/44 (13.6)	
Object found in situ in the body, n (%)	3 (3.2)	12 (26.7)	p < 0.001
Object found elsewhere, n (%)	26 (27.7)	31 (68.9)	
Object not found, n (%)	65 (69.1)	2 (4.4)	
Stab through clothing*, n (%)	15/20 (75.0)	8/25 (32.0)	p < 0.001
Intact clothing*, n (%)	1/20 (5.0)	8/25 (32.0)	
No clothing*, n (%)	4/20 (20.0)	9/25 (36.0)	
Suicide note, n (%)	0 (0)	11 (24.4)	p < 0.001
No suicide note, n (%)	94 (100)	34 (75.6)	

Variables involving scene of death, finding of sharp object, examination of clothing and suicide note were presented in numbers and percentages. The differences between homicide and suicide regarding scene of death, finding of sharp object and examination of clothing were estimated using Chi-Square test. The difference between homicide and suicide regarding presence of suicide note was estimated using Fisher's exact test.

*Missing values: scene of death n = 1 (0.7%), examination of clothes n = 94 (67.6).

using IBM SPSS Statistics Premium 28.

The diagnostic performance of combination of injury pattern in relation to manner of death was evaluated by sensitivity, specificity, positive predictive value, negative predictive value and accuracy with 95% CI (MedCalc Software Ltd. Diagnostic test evaluation calculator. https://www.medcalc.org/calc/diagnostic_test.php, [Version 22.009; accessed September 7, 2023]).

3. Ethical approval

The study was approved by the Swedish Ethical Review Authority (Dnr 2022–04847–01).

4. Results

4.1. Study population

The study population consisted of 139 cases, 94 homicides and 45 suicides (Table 1). Males were in the majority in both categories. The median age was significantly younger for homicide cases compared to suicide cases (median age 33 vs. 52 years, p < 0.001).

4.2. Circumstances at the scene of death

In most homicide cases, bodies were found outdoors (54.3%), as detailed in Table 2. In contrast, most of the suicide cases were found in the victims' own homes (79.5%). Also, in most homicide cases, no murder weapon was found at the scene (69.1%), which significantly differed from suicide cases where the sharp object was present at the scene in almost all cases, either still in situ in the body (26.7%) or elsewhere at the scene (68.9%). Stab through the victim's clothing was seen in 75.0% of the homicide cases. In suicides the number of victims being stabbed through clothing, victims with intact clothing and without clothing at the trunk were evenly distributed (32.0%, 32.0%, and 36.0% respectively). The difference was statistically significant between the groups (p < 0.001). Some kind of suicide message was identified at the

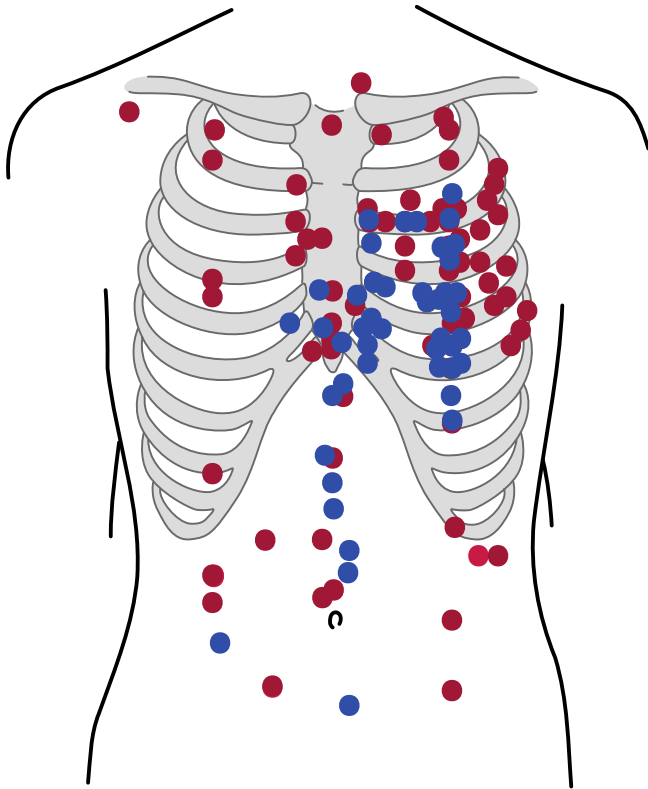


Fig. 2. Location of homicidal and suicidal stabs in the anterior trunk. The red spots represent the placement of homicidal stab wounds and the blue spots represent suicidal stab wounds.

scene in 24.4% of the suicide cases.

4.3. Autopsy findings

Most stabs in homicides (77.7%) and all stabs in suicides were located in the anterior trunk (Fig. 2). Stabs were placed in the area from the third to the sixth rib at the left side of the anterior thorax in 36.2% of the homicide cases and 60.0% of the suicide cases. Otherwise, homicidal stabs showed an overall scattered distribution of their placement, while all suicidal stabs were placed lower than the second ribs and in line with or medially from the midclavicular lines. Only two suicidal stabs were

placed on the right side of the trunk. In suicidal stabs located in the anterior abdomen, 7 of the 9 stabs (77.8%) were placed above the umbilicus in line with or attached to the midline. In homicides, 5 of 13 stabs (38.5%) in the anterior abdomen were placed in the same region. In suicides, no stabs were observed on the back or in the axillar region, in contrast to homicidal stabs which were observed in these locations in 22.3% of the cases (Fig. 3). These stabs were predominantly located in the thorax.

Most stabs due to homicide involved the skeleton of the ribcage (66.7%) (Table 3). In suicides, there was an even distribution between injuries involving the skeleton of the ribcage (40.0%) and the intercostal space (40.0%). The homicidal stabs had a greater distribution of stab injuries with vertical entrance wounds in the skin compared to suicides (26.7% vs. 9.1%) and less distribution of horizontal entrance wounds (24.4% vs. 45.5%). The length of the injury channel did not significantly differ between homicidal and suicidal stabs (mean length 12.4 vs. 10.9 cm). The maximum length of the injury channel in homicidal stabs was 22.5 cm, in contrast to 17 cm in suicidal stabs. In the sagittal plane, injury channels with caudal orientation dominated among homicidal (70.6%) and suicidal stabs (51.9%). In the horizontal plane, stab wound channels with medial orientation were overrepresented among homicide cases (79.7%) and significantly differed ($p = 0.02$) from suicidal stab wound channels with medial orientation (50.0%). Among homicide victims, 10.6% had characteristic defensive injuries to the forearms and 28.9% of the suicide victims exhibited hesitation injuries to the forearms or attached to the stab wound in the trunk.

4.4. Toxicological results

Most homicides (58.1%) had positive alcohol results which was significantly ($p < 0.001$) higher than for suicides (16.3%) (Table 4). Positive results for illicit narcotic drugs were also significantly ($p = 0.008$) more common in homicide compared to suicide (35.5% vs. 11.4%). Positive licit narcotics were more common in suicides (18.2% vs. 8.6%). Positive alcohol combined with positive narcotic results also showed significantly higher ($p < 0.001$) distribution among homicide victims compared to suicides (28.0% vs. 2.3%).

4.5. Factors associated with either homicide or suicide

Bodies found at a death scene that was not the victim's home were conclusively associated with homicide (OR 19.0, 95% CI 7.6–47.1) (Fig. 4). A weapon removed from the stab wound was associated with homicide (OR 11.0, 95% CI 2.9–41.6). Stabbing through clothes was

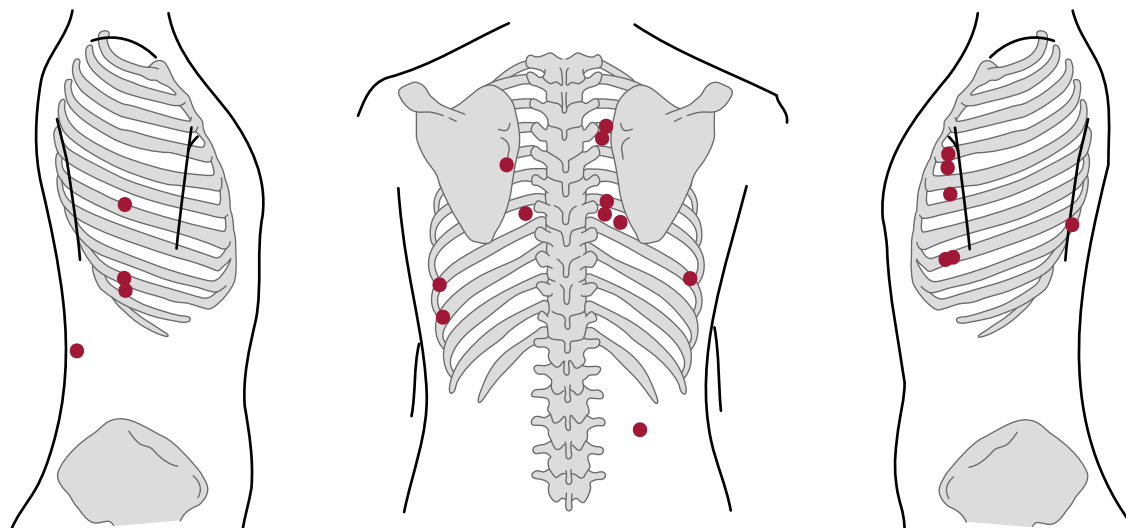


Fig. 3. Location of homicidal stabs in the axillar and posterior trunk. The red spots represent the placement of homicidal stab wounds.

Table 3
Findings from the forensic autopsy.

	Homicides (n = 94)	Suicides (n = 45)	Difference (p- value)
Injury to sternum/ribs/ scapula* , n (%)	62/93 (66.7)	18 (40.0)	p = 0.004
Injury through the intercostal space* , n (%)	15/93 (16.1)	18 (40.0)	
Injury to the abdomen, n (%)	16/93 (17.2)	9 (20.0)	
Horizontal direction of the entrance wound* , n (%)	21/86 (24.4)	20/44 (45.5)	p = 0.02
Vertical direction of the entrance wound* , n (%)	23/86 (26.7)	4/44 (9.1)	
Diagonally down right direction of the entrance wound* , n (%)	28/86 (32.6)	10/44 (22.7)	
Diagonally down left direction of the entrance wound* , n (%)	14/86 (16.3)	10/44 (22.7)	
Length of the injury channel* , mean (range) (cm)	12.4 (5–22.5) (n = 11)	10.9(6–17) (n = 53)	p = 0.4
Cranial direction of the injury channel* , n (%)	18/68 (26.5)	11/27 (40.7)	p = 0.3
Caudal direction of the injury channel* , n (%)	48/68 (70.6)	14/27 (51.9)	
Straight horizontal direction of the injury channel* , n (%)	4/68 (5.9)	2/27 (7.4)	
Medial direction of the injury channel* , n (%)	55/69 (79.7)	11/22 (50.0)	p = 0.02
Lateral direction of the injury channel* , n (%)	11/69 (15.9)	9/22 (40.9)	
Straight sagittal direction of the injury channel* , n (%)	3/69 (4.3)	2/22 (9.1)	
Defensive injuries, n (%)	10 (10.6)	1 (2.2)	p = 0.1
No defensive injuries, n (%)	84 (89.4)	44 (97.8)	
Hesitation injuries, n (%)	0 (0)	13 (28.9)	p < 0.001
No hesitation injuries, n (%)	94 (100)	32 (71.1)	

Variables involving injury to the ribcage/abdomen, orientation of the entrance wound, orientation of the injury channel in the sagittal and horizontal plane, presence of defensive and hesitation injuries were presented in numbers and percentages. The differences between homicide and suicide regarding injury to the ribcage/abdomen, orientation of the entrance wound and orientation of the injury channel in the sagittal and horizontal plane were estimated using Chi-Square test. The differences between homicide and suicide regarding presence of defensive and hesitation injuries were estimated using Fisher's exact test. Length of the injury channel was presented as mean length (cm) and range and difference between homicide and suicide was estimated using Mann-Whitney U test.

*Missing values: injury to the ribcage n = 1 (0.7%), direction of the entrance wound n = 9 (6.5%), length of the injury channel n = 75 (54.0%), direction of the injury channel, sagittal plane n = 42 (30.2%) and horizontal plane, n = 48 (34.5%).

conclusively associated with homicides, using intact clothing and no clothing on the upper body as a reference (OR 6.4, 95% CI 1.7–23.8).

Injuries to the ribcage were to a larger extent associated with homicidal stabs (OR 3.8, 95% CI 1.6–9.0) (Fig. 4). The observation of a vertical entrance wound in the plane of the skin was associated with homicide, using horizontal entrance wounds as reference (OR 5.5, 95% CI 1.6–18.7). Stab wound channels with a medial orientation were associated with homicide (OR 4.1, 95% CI 1.4–12.2), using wound channels with a lateral orientation in the horizontal plane as reference. The association remained significant when excluding stabs located in the axillar trunk and stabs placed in the midline (OR 4.4, 95% CI 1.2–16.5). Vertical entrance wounds combined with a medial oriented injury channel (n = 13) showed a sensitivity of 16.0% (95% CI 0.09–0.26), specificity of 100% (95% CI 91.4–100), positive predictive

Table 4
Results from the toxicological analyses.

	Homicides n = 94	Suicides n = 45	Difference (p- value)
Positive alcohol* , n (%)	54/93 (58.1)	7/43 (16.3)	p < 0.001
Negative alcohol* , n (%)	39/93 (41.9)	36/43 (83.7)	
Positive narcotics: Illicit drugs* , n (%)	33/93 (35.5)	5/44 (11.4)	p = 0.008
Positive narcotics: Licit drugs* , n (%)	8/93 (8.6)	8/44 (18.2)	
Negative narcotics* , n (%)	52/93 (55.9)	31/44 (70.5)	
Positive alcohol and positive narcotics* , n (%)	26/93 (28.0)	1/43 (2.3)	p < 0.001
Positive alcohol and negative narcotics* , n (%)	28/93 (30.1)	6/43 (14.0)	
Negative alcohol and positive narcotics* , n (%)	15/93 (16.1)	12/43 (27.9)	
Negative alcohol and negative narcotics* , n (%)	24/93 (25.8)	24/43 (53.8)	

Variables of alcohol, illicit and licit narcotics and also interaction of alcohol and narcotics (illicit and licit substances together) combined were presented in numbers and percentages. The difference between homicide and suicide regarding detection of alcohol was estimated using Fisher's exact test. The differences between homicide and suicide regarding detection of narcotics and interaction of alcohol and narcotics were estimated using Chi-Square test.

*Missing values: alcohol n = 3 (2.2%), narcotics n = 2 (1.4%), alcohol and/or narcotics n = 3 (2.2%).

value of 100% (95% CI 75.3–100), negative predictive value of 37.6% (95% CI 35.4–39.9) and accuracy of 44.3% (95% CI 35.3–53.5) to homicide.

Influence of alcohol at the time of death was associated with homicides (OR 7.1, 95% CI 2.9–17.7), which remained significant after adjusting for age and gender (OR 6.9, 95% CI 2.7–17.9) (Fig. 4). We also observed that a positive result for illicit drugs was conclusively associated with homicide (OR 4.3, 95% CI 1.5–11.9).

5. Discussion

Our findings regarding the age and sex of the victims are in accordance with previous studies, suggesting that our population seems relevant for the question at hand [1,2,10–16]. Furthermore, overrepresentation of ethanol [1,2,11,12,16] and illicit narcotics [1,10] in homicide victims was in agreement with previous studies.

Previous studies state that a large proportion of male homicide victims, especially due to a single stab, were killed by a friend or acquaintance in an alcohol-related context [2,12–14]. In contrast, victims killed in a domestic setting by a partner, relative or other person with a close relationship to the victim more commonly had multiple stab wounds [2,13,14,17]. This could explain why homicide victims in our study population were most frequently found outdoors, which is in contrast to previous studies on Scandinavian populations with numerous sharp injuries that reported that homicide victims were more often found indoors [13], or more specifically in their own homes [11,12]. However, the observed shift from indoor to outdoor locations for homicides could as well indicate changing dynamics in violent crimes, potentially influenced by the rise in gang-related activities and the significant increase in firearm-related violence as a result [18]. Other studies set in Lisbon (Portugal) [1] and New York (USA) [7] showed that homicides were mostly found outdoors [1,7], in line with our study results.

We observed that the single stab injuries were predominately located on the left side in the anterior thorax, which is in accordance with previous research on single stabs [2,10,13]. Also, no suicidal stabs were located in the axillar region or in the back of the trunk, strengthening

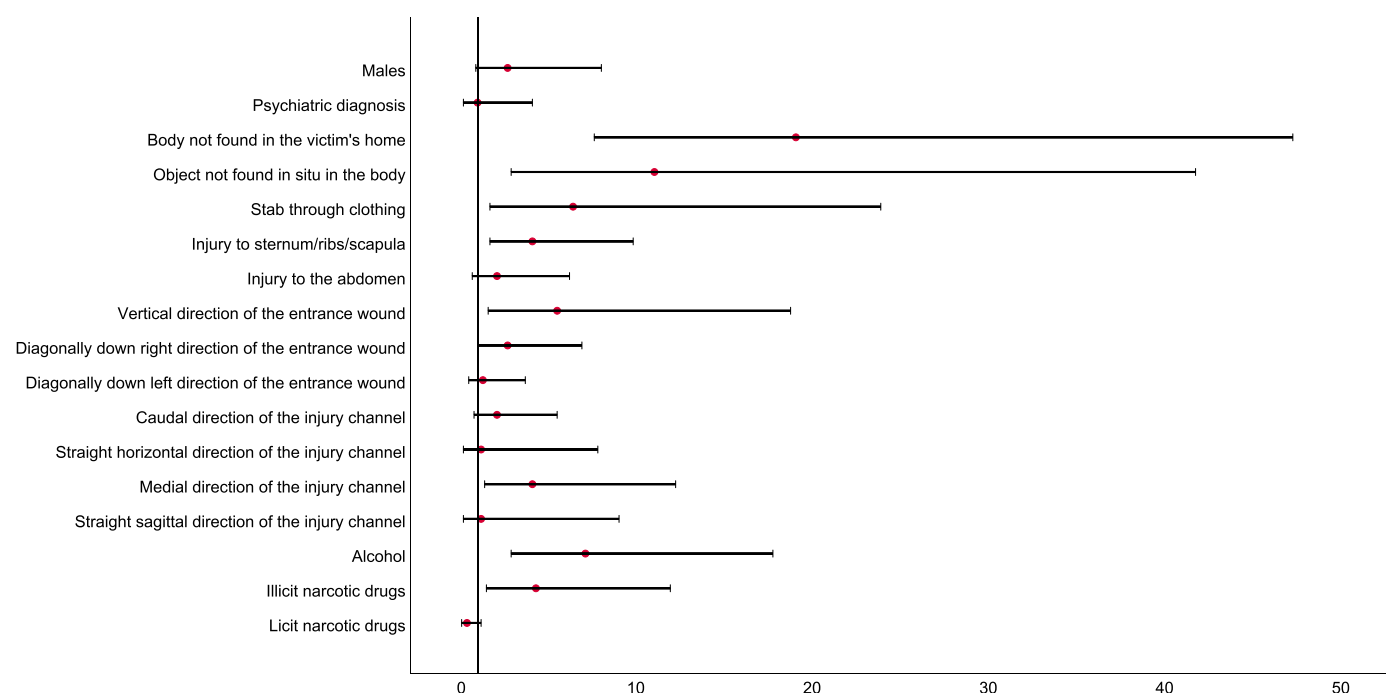


Fig. 4. Associations between characteristics and manner of death (homicide/suicide) Forest plot with univariate logistic regression models presenting associations between variables and homicide using suicide cases as reference. The vertical running line represents OR = 1, the red dots represent the OR for each variable and the error bars a 95% CI. The variables presented are males (reference = females), psychiatric diagnosis (reference = no psychiatric diagnosis), body not found in the victim's home (reference = body found in the victim's home), object not found in situ in the body (reference = object found in situ in the body), stab through clothing (reference = no stab through clothing, that is intact clothing or no clothing), injury to sternum/ribs/scapula and injury to the abdomen (reference = injury through the intercostal space), vertical, diagonally down right and diagonally down left direction of the entrance wound (reference = horizontal direction of the entrance wound), caudal and straight horizontal direction of the injury channel (reference = cranial direction of the injury channel), medial and straight sagittal direction of the injury channel (reference = lateral direction of the injury channel), alcohol (reference = no alcohol), illicit and licit narcotic drugs (reference = no narcotics).

previous observations [3,10,11]. As stabs in homicides tended to have more lateral placements on the trunk than suicide stabs, it could explain why stab wound channels due to homicides more often had a medial orientation in the horizontal plane compared to suicides. Moreover, in the present study, stabs with entrance wounds penetrating the skin with a vertical orientation combined with a medial oriented injury channel had a very high positive predictive value for homicide, strongly suggesting homicide when this injury pattern is present. In the sagittal plane, injury channels with a caudal orientation dominated in homicidal stabs, which agrees with previous research [13]. We also identified that vertical entrance wounds and injuries involving bone/cartilage of the ribcage were associated with homicides, in agreement with prior studies [1,3,6,11,19]. We speculate that the observed association could depend on assaults implicating erratic stabs, unlike suicidal stabs in which the victim could be contemplating the stab to a larger extent.

Furthermore, we observed that defensive injuries were present in a small proportion of homicide cases (10.6%), which is marginally less than observed in previous studies of homicidal single stabs (15–40%) [11,13,20]. Homicide victims due to multiple stab injuries generally had more defensive injuries (31–61%) [1,5,7,11,13,20–22]. Numerous sharp force injuries suggest a prolonged duration of the assault that in turn could explain a greater propensity of defensive actions from the victim. Defensive wounds could also be argued to indicate that the victim was aware and able during at least some part of the assault and not sedated by alcohol or drugs, as indicated by the observation that more defense wounds were seen in homicide victims without or with low concentrations of alcohol in their blood in comparison to victims with high alcohol levels [21]. We observed a similar pattern in suicide victims with proportionally fewer hesitation injuries (28.9%), an observation also seen previously in single stabs (20%) [11], in comparison to previous studies involving suicides with numerous sharp force injuries (35–80%) [1,3,5,7,11,21,23]. However, suicides in single stab injuries without any

hesitation wounds were more often not inebriated with alcohol [21].

5.1. Strengths and limitations

Our study analyzed data from a nationwide population, including six forensic institutions covering all forensic autopsies in Sweden between 2010 and 2021. However, although our study includes all cases of single stab injuries subjected to a forensic autopsy in Sweden during the time period, it resulted in a population of just 139 cases, resulting in low statistical power in some of the analyses. The study results seem to be generalizable to cases that died from single stabs to the trunk, as several variables were reproduced from previous studies. However, the injury pattern of deep and severe stab injuries with a fatal outcome cannot directly be transferred to survived stab injuries. Hence, comparative research between survivors and fatal cases is warranted.

Another strength is the broad spectrum of epidemiological variables framing relevant characteristics of the victims, the scene of death and the postmortem examination. To our knowledge, we have presented the largest panorama of variables among studies performed on cases with single stab injuries. However, the study is retrospective and limited to obtainable data from the autopsy registry. Records from psychiatric care were not available in most of the cases, hence information about psychiatric diagnosis was sparse. We also identified a large extent of missing information regarding the status of clothing worn on the trunk and whether the sharp object was found in situ in the trunk. Moreover, the length and direction of the stab wound channel were not documented in several autopsy reports. In a few cases, the hospitalization after the injury event lasted several days, which made the postmortem analysis of alcohol and narcotics from the occasion of the injury impossible. Further, for future research it would be appropriate to collect variables such as handedness of the suicide victim and the perpetrator, which could be correlated to anatomical location and orientation of the stab

injury.

We also draw attention to the fact that the manner of death used for categorizing the variables of this study was determined by the forensic pathologists. Their statements are in turn based on autopsy findings and circumstances at the crime scene, which may introduce some aspects of circular reasoning. Forensic pathologists are experts in determining the manner of death and their assessments are based on the current state of knowledge. Also, each assessment is made by at least two physicians, of which at least one is a certified forensic pathologist. However, there are documented cases in which the circumstances at the death scene seem to have been manipulated to cover up the true manner of death. As an example, a suicide victim changed clothes and hid the weapon after having stabbed herself [24]. These cases raise the question of whether findings from the police investigation should even contribute to the forensic assessment. Nevertheless, it strengthens the importance of autopsy findings as valuable evidence. To reduce potential circular reasoning, additional evidential material should be extracted from case files and verdicts to verify the forensic assessment.

6. Conclusion

In this nationwide study, victims of homicides with single stab injuries to the trunk were associated with young age, outdoor death scene, inebriation, stabbing in the back, axillar regions or lateral from the midclavicular lines at the anterior trunk, vertical wound in the skin, injury involving bone/cartilage of the ribcage and defensive injuries. As the variables were categorized using the manner of death determined by the forensic pathologist, there might be some aspects of circular reasoning in our results, nonetheless as such it has face validity for assessing homicides.

CRediT authorship contribution statement

Khoshnood Ardavan M.: Conceptualization, Visualization, Writing – review & editing. **Wingren Carl Johan:** Conceptualization, Formal analysis, Methodology, Project administration, Resources, Supervision, Writing – review & editing. **Berg von Linde Maria:** Conceptualization, Formal analysis, Investigation, Project administration, Writing – original draft. **Acosta Stefan:** Conceptualization, Formal analysis, Writing – review & editing.

Declaration of Competing Interest

None.

Acknowledgements

The body sketches in Figs. 2 and 3 were illustrated by Frida Nilsson, Lund University. Language editing was provided by a language editing company. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the

online version at doi:10.1016/j.forsciint.2023.111910.

References

- [1] N. Lupi Manso, I.P. Ribeiro, A.R. Inácio, Sharp force fatalities: differentiating homicide from suicide through a retrospective review (2012–2019) of autopsy findings in Lisbon (Portugal), *Forensic Sci. Int.* 327 (2021), 110959.
- [2] K. Ormstad, T. Karlsson, L. Enkler, B. Law, J. Rajs, Patterns in sharp force fatalities—a comprehensive forensic medical study, *J. Forensic Sci.* 31 (2) (1986) 529–542.
- [3] T. Karlsson, K. Ormstad, J. Rajs, Patterns in sharp force fatalities—a comprehensive forensic medical study: Part 2. Suicidal sharp force injury in the Stockholm area 1972–1984, *J. Forensic Sci.* 33 (2) (1988) 448–461.
- [4] T. Karlsson, Multivariate analysis ('forensiometrics')—a new tool in forensic medicine. Differentiation between sharp force homicide and suicide, *Forensic Sci. Int.* 94 (3) (1998) 183–200.
- [5] C.J. Kemal, T. Patterson, D.K. Molina, Deaths due to sharp force injuries in Bexar County, Texas, with respect to manner of death, *Am. J. Forensic Med. Pathol.* 34 (3) (2013) 253–259.
- [6] C. Brunel, C. Fermanian, M. Durigon, G.L. de la Grandmaison, Homicidal and suicidal sharp force fatalities: autopsy parameters in relation to the manner of death, *Forensic Sci. Int.* 198 (1–3) (2010) 150–154.
- [7] J.R. Gill, C. Catanese, Sharp injury fatalities in New York City, *J. Forensic Sci.* 47 (3) (2002) 554–557.
- [8] G.N. El-Sarnagawy, M.A. Shama, N.E. Helal, Characteristics and outcomes of homicidal and accidental stab wounds in emergency hospitals: A medicolegal comparative study, *Leg. Med.* 58 (2022), 102075.
- [9] B. Karger, M.A. Rothschild, H. Pfeiffer, Accidental sharp force fatalities—beware of architectural glass, not knives, *Forensic Sci. Int.* 123 (2–3) (2001) 135–139.
- [10] M.P. Burke, Y. Baber, Z. Cheung, M. Fitzgerald, Single stab injuries, *Forensic Sci. Med. Pathol.* 14 (3) (2018) 295–300.
- [11] T. Karlsson, Homicidal and suicidal sharp force fatalities in Stockholm, Sweden. Orientation of entrance wounds in stabs gives information in the classification, *Forensic Sci. Int.* 93 (1) (1998) 21–32.
- [12] S. Rogde, H.P. Hougen, K. Poulsen, Homicide by sharp force in two Scandinavian capitals, *Forensic Sci. Int.* 109 (2) (2000) 135–145.
- [13] A.H. Thomsen, H.P. Hougen, P. Villesen, O. Brink, P.M. Leth, Sharp Force Homicide in Denmark 1992–2016, *J. Forensic Sci.* 65 (3) (2020) 833–839.
- [14] T. Karlsson, Sharp force homicides in the Stockholm area, 1983–1992, *Forensic Sci. Int.* 94 (1–2) (1998) 129–139.
- [15] C. Terranova, L. Doro, S. Zancanar, T. Zampini, C. Mazzarolo, B. Bonvicini, et al., Criminological and medico-legal aspects in homicidal and suicidal sharp force fatalities, *J. Forensic Sci.* 65 (4) (2020) 1184–1190.
- [16] M. Vassalini, A. Verzeletti, F. De Ferrari, Sharp force injury fatalities: a retrospective study (1982–2012) in Brescia (Italy), *J. Forensic Sci.* 59 (6) (2014) 1568–1574.
- [17] H. Inoue, N. Ikeda, T. Ito, A. Tsuji, K. Kudo, Homicidal sharp force injuries inflicted by family members or relatives, *Med. Sci. Law* 46 (2) (2006) 135–140.
- [18] A. Khoshnood, Firearm-related violence in Sweden – A systematic review, *Aggress. Violent Behav.* 42 (2018) 43–51.
- [19] V. Scolan, N. Telmon, A. Blanc, J.P. Allery, D. Charlet, D. Rouge, Homicide-suicide by stabbing study over 10 years in the toulouse region, *Am. J. Forensic Med. Pathol.* 25 (1) (2004) 33–36.
- [20] A.C. Hunt, R.J. Cowling, Murder by stabbing, *Forensic Sci. Int.* 52 (1) (1991) 107–112.
- [21] S. Racette, C. Kremer, A. Desjarlais, A. Sauvageau, Suicidal and homicidal sharp force injury: a 5-year retrospective comparative study of hesitation marks and defense wounds, *Forensic Sci. Med. Pathol.* 4 (4) (2008) 221–227.
- [22] J. Herbst, B. Hoppe, H.T. Haffner, Kriterien der Fremd- oder Selbstbeibringung bei Todesfällen durch scharfe Gewalt, *Rechtsmedizin* 10 (1) (1999) 14–20.
- [23] S. Fukube, T. Hayashi, Y. Ishida, H. Kamon, M. Kawaguchi, A. Kimura, et al., Retrospective study on suicidal cases by sharp force injuries, *J. Forensic Leg. Med.* 15 (3) (2008) 163–167.
- [24] G. Pelletti, S. Visentin, C. Rago, G. Cecchetto, M. Montisci, Alteration of the death scene after self-stabbing: a case of sharp force suicide disguised by the victim as a homicide? *J. Forensic Sci.* 62 (5) (2017) 1395–1398.