Bladed Weapon Assaults and Human Vulnerability

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Abstract. Within the UK, in the year between 1 July 2021 and the 30 June 2022 nearly fifty thousand (n=49,991) knife-enabled crime offences were recorded by police within England and Wales. Furthermore, over 22 percent (n=11,232) of these offences were committed within the Metropolitan Police District (MPD) [1]. Hence, bladed weapon assaults are a significant threat to frontline police officers and staff, particularly those patrolling within London.
Many bladed weapon assaults, and the associated injuries sustained, are survivable with swift medical intervention, however some injuries are so severe that death ensues. Whilst evaluating knife threats and anatomical vulnerability to such assaults, an opportunity arose to review post mortem (PM) reports for deaths caused by bladed weapons which occurred to citizens within the Greater London area. These fatal cases are of great value in understanding where critical and non-critical injuries have occurred and, therefore, are of benefit in evaluating the coverage of body armour, issued to frontline police officers and staff, and to determine where vulnerabilities exist.

This study reviews a large dataset (n=75) of PM reports of deaths due to bladed weapon assaults in 2019, within the MPD. It includes anatomically correct body maps to illustrate the location of the injuries and identifies the principal location of the fatal injury. It also summarises the cause of death. Statistics are presented with regards to the depth of the fatal stab wound, blade type, as well as an overview of the victims, such as age and gender.

In UK policing, Operation Hampshire is a recently introduced means for police officers and staff to report an assault, or having been subjected to hate crime, whilst on duty. This study presents data from Operation Hampshire associated with bladed weapon assaults. Hence, this second dataset outlines blade weapon injuries received during policing, as a useful comparison to the fatal injuries reported within PM reports.

The aim of this study is to analyse both datasets to determine the most probable location(s) of fatal and non-fatal stab wounds during attacks on police officers and staff with bladed weapons. Furthermore, this study also reviews current body armour designs, and proposes enhancements to protection schemes, to be worn by front line police officers and staff, to reduce their vulnerability.

. INTRODUCTION

Within the UK between 1 July 2021 and the 30 June 2022 nearly fifty thousand (n=49,991) knife-enabled crime offences were recorded by police within England and Wales [1]. Hence, a significant threat to frontline police officers and staff are knife assaults. Many bladed weapon assaults, and the associated injuries sustained, are survivable with swift medical intervention, however some injuries are so severe that death ensues. Whilst evaluating knife threats and anatomical vulnerability to such assaults, an opportunity arose to review post mortem (PM) reports for deaths caused by knife assaults which occurred to citizens within the Greater London area. These fatal cases are of great value in understanding how and where critical injuries have occurred and, therefore are of benefit to evaluating the coverage of body armour issued to police officers and staff.

This study reviews a large dataset of fatal weapons attacks (n=75) which occurred to citizens within the Greater London area, in 2019, by examining the post mortem (PM) pathological reports of murder victims. Examining these fatal cases is an invaluable resource when evaluating the coverage of body armour issued to frontline police officers and staff. Hence, this study evaluates the location and depth of injuries, cause of death and, if known, details of the weapon(s) and circumstances, and illustrates these injuries on anatomically correct, body maps.

Furthermore, records of assaults and hate crime on MPS police officers and staff, documented under Operation Hampshire, have been used to accompany the above data, by summarising non-fatal bladed weapon attacks during police operations.

The aim of this study is to appraise the most probable location(s) of fatal and non-fatal stab wounds and to review current body armour designs, worn by front line police officers and staff, to evaluate their vulnerability.

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. EXAMINING FATAL BLADE WEAPONS ASSAULTS ON CITIZENS WITHIN THE MPD

Preparing and applying best practice to handling the data

During the preparation and planning of this study the year chosen, to examine fatal bladed weapon assaults on citizens within the Metropolitan Police District (MPD), was 2019. This year was prior to the coronavirus global pandemic, therefore the dataset would not be influenced by government restrictions, such as national lockdowns of the UK population.

In 2019 there were 77 fatal stabbings of citizens within the MPD, of which 75 full PM reports were available. Best practice was applied when handling the data used within this study by:

1. the authors notifying the Senior Coroner at Westminster Coroner's Court;
2. applying Caldicott principles to the dataset throughout this study, including anonymization;
3. commissioning a Crown Prosecution Service (CPS) approved company (Evidential Ltd) to plot each bladed weapon assault on an anatomically correct model (similar to the professional avatar images used in court cases);
4. using Criminal Justice Secure eMail (CJSM) addresses to communicate;
5. retaining post mortem reports within the MPS electronic storage.

Illustrating the data

Four anatomically correct avatars, illustrating anterior, posterior, right and left lateral views, were used to create body maps to show the location of knife injuries received by the murder victims. The avatars were created using open source software Make Human, Version 1.2.0 (Mac IOS) [2] nominally for an average UK male [3]. Details of the Make Human avatar are male 100%; age 29; muscle 43.90%; weight 119.40% and height 173.01cm. This was combined with an internal anatomical male model from 3D 4 Medical - Essential Anatomy 5 (V5.0.8).

However the avatar is androgynous and illustrates wounds for the 75 male and female victims in the correct anatomical location. Hence, the body maps, in figures 1 to 4 below, illustrate the distribution of injuries, which include the fatal wound(s), as well as other injuries received during the assault. A caveat being, due to the high frequency, non-fatal defensive wounds to the hands and inconsequential wounds to the feet have not been illustrated.

Victims' background

Gender and age of victims

The gender and age of victims are summarised in table 1.

Table 1 – gender and age of victims of fatal bladed weapon assaults within the MPD in 2019

			Age range				
	Total of fatal stabbings in 2019	Fatal stabbings in dataset	<18	18 - 24	25 - 31	32 - 38	39+
Male	67 (87%)	66 (88%)	6 (8%)	27 (36%)	12 (16%)	11 (15%)	10 (13%)
Female	10 (13%)	9 (12%)	1 (1%)	2 (3%)	3 (4%)	0 (0%)	3 (4%)
Total	77 (100%)	75 (100%)	7 (9%)	29 (39%)	15 (20%)	11 (15%)	13 (17%)

Circumstances

The majority of the PM reports contain a brief description of the circumstances of the assault and often toxicology results are present. Although, we cannot know where details of the assault have not been passed onto the pathologist, the following percentages (in table 2 below) provide an indication of substance use and the events surrounding the fatalities in 2019.

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Figure 1: Anterior body map of injuries from fatal bladed weapon assaults

(Note: non-fatal, defensive wounds to the hands and inconsequential wounds to the feet, have not been illustrated).

Figure 2: Left lateral body map of injuries from fatal bladed weapon assaults

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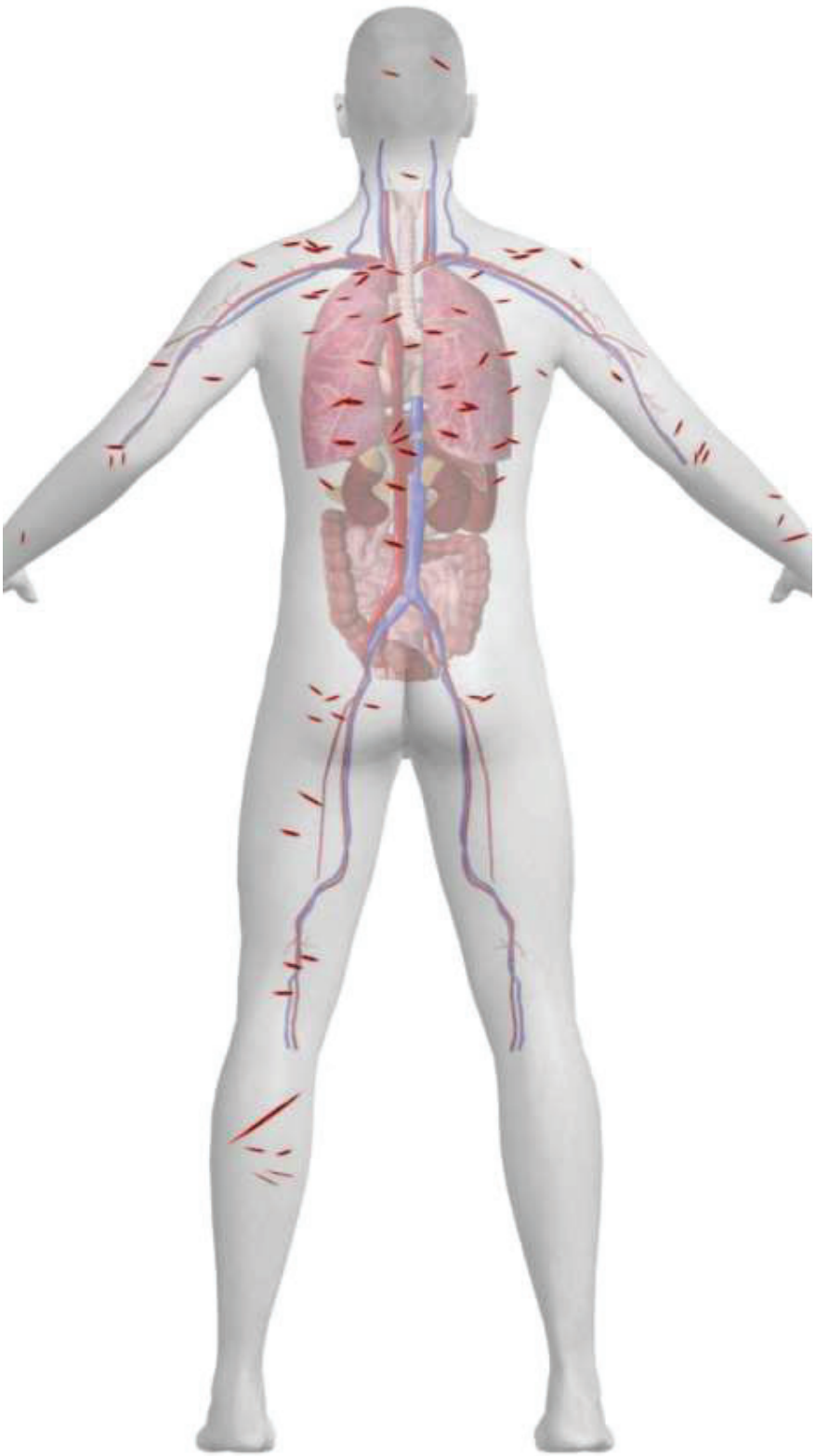

Figure 3: Posterior body map of injuries from fatal bladed weapon assaults

(Note: non-fatal, defensive wounds to the hands and inconsequential wounds to the feet, have not been illustrated).

Figure 4: Right lateral body map of injuries from fatal bladed weapon assaults

Table 2 – circumstances of victims of fatal bladed weapon assaults within the MPD in 2019 (Note: if a victim has taken non-prescription drugs and was part of a gang they would be recorded in both categories)

		Circumstances				
Total of fatal stabbings in 2019	Fatal stabbings in dataset	Presence of non-prescription drugs	Presence of significant quantity of alcohol only	Multiple assailants or gangs	Domestic dispute	Terrorism
77	75	43 (includes 7 with alcohol)	5	29	8 (3 male; 5 female)	2

Principal anatomic locations of fatal stab wounds

Figure 5 illustrates a high level overview of the principal anatomical locations of fatal stab wound victims in 2019.

Two thirds of fatal stab wounds are located within the torso and nearly a quarter of fatal stab wounds are to the neck.

Within the dataset many victims received several bladed weapon injuries, clustered within a similar location, eg within their torso, which would include the fatal wound. However there are three victims, represented in figure 5, as having multiple sites of fatal stab wounds. The combined fatal wound locations are i) head and neck, ii) neck, chest and arm (brachial artery) and iii) torso and lower extremities (femoral artery and vein).

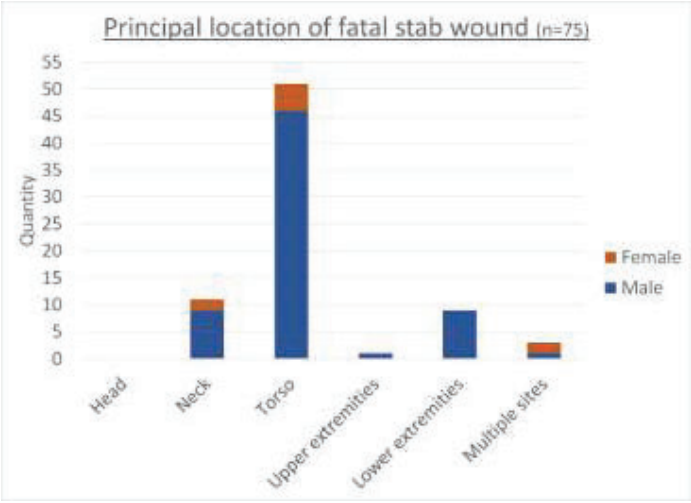

Figure 5 – Principal location of fatal bladed weapon injury

In over 90% of victims studied, in this review of bladed weapon assaults, their cause of death was ascribed to **loss of blood**.

Fatal damage within the torso

Looking further at the sites of fatal damage within the torso, the heart, lungs, aorta, inferior vena cava (IVC) and a combination of these, account for 74% of the sites within the torso.

Fatal damage to an organ(s) accounts for 60% of deaths, compared with fatal damage to a great vessel(s) accounting to 22%, in 6% of cases damage to both organ(s) and great vessel(s) are cited as the cause of death. Furthermore, in 12% of cases the wounds are complex, leading to extensive damage within the victim's torso.

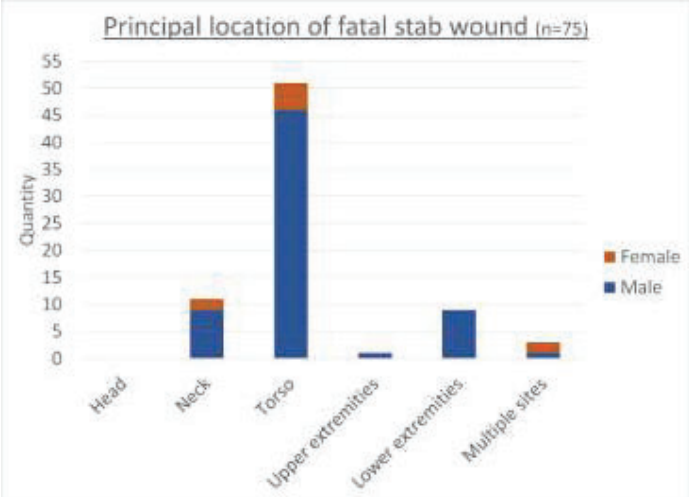

Figure 6 – Frequency of fatal damage to organs and great vessels within the torso

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Fatal damage to the neck

There were 11 bladed weapon assaults to the neck which resulted in death, mainly due to critical damage to arteries and vessels of the victim. Eight of the victims had damage to their carotid artery and their internal or external jugular vein. In fifty percent of the above 8 victims their trachea was also damaged.

Two victims received fatal damage to their subclavian artery, which is near to the clavicle, however the point of entry of the knife was in the neck. One victim had fatal damage to their axillary vein.

Fatal damage within the upper and lower extremities

There was only one victim with an individual, fatal stab wound to the upper extremities which occurred to the victim's upper arm, cutting the brachial artery and damaging the brachial vein. Severing of the brachial artery also contributed to the death of another victim.

Nine of the victims of fatal stab assaults within the dataset were located in their lower extremities. Of these, six fatal wounds were attributed to severing the femoral artery and/or vein. Furthermore, two assaults were caused by fatal injury to the popliteal fossa (behind the knee where structures pass between the thigh and leg) and one death occurred due to a severed varicose vein.

Depth of fatal stab wound

Over 95% of fatal stab wounds were 50mm or greater in depth, as illustrated in figure 7. This is valuable knowledge for the design of protection schemes when combined with the depth of the critical organs, as reproduced from Breeze et al [4] in table 3.

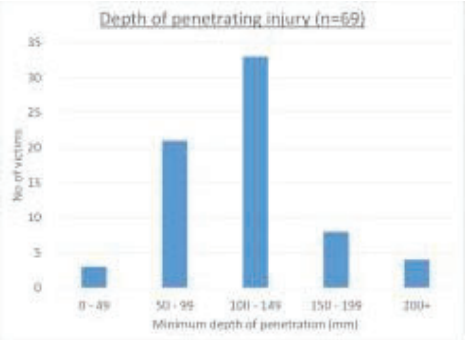

Figure 7 – depth of penetrating injury described within PM reports

Table 3 – Depth of organs reproduced from reference 4

Percentile	Entry point 1		Entry point 2		Entry point 3
	Skin to lung	Skin to heart	Skin to lung	Skin to heart	Skin to liver
1%	18	18	19	19	17
5%	19	20	23	23	19
25%	23	24	29	39	23
50%	25	27	33	49	28
75%	30	32	40	57	30
95%	37	40	51	65	37
99%	44	46	60	71	42
Mean	27	28	35	47	27

Type of bladed weapon

Within the 75 PM documents there are 42 reports which describe wounds solely from knives with a single cutting edge. Only six reports describe wounds solely from knives with a double cutting edge, and in one report both single and double bladed weapons are referred to.

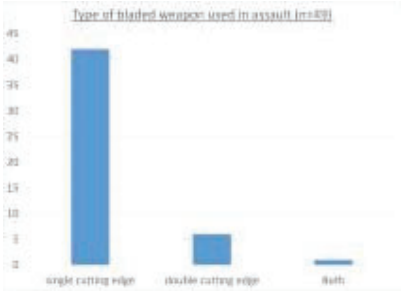

Figure 8 – type of bladed weapon described with PM reports

EXAMINING OPERATION HAMPSHIRE BLADED WEAPON ASSAULTS

Background to Operation Hampshire

Operation Hampshire was introduced into UK policing in 2016 as a means for police officers and staff to report an assault, or having been subjected to hate crime, whilst on duty. The principal data set is based on assaults within the Metropolitan Police Service (MPS) recorded from the beginning of January

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2018 to the end of March 2022 [5]. Furthermore, detailed analysis of the location of injuries from a single year (2021) are presented [6].

Assaults recorded

Between January 2018 and March 2022 there were 30,763 Operation Hampshire victims reported, which averages at 603 per month. From this data set 467 victims, on average of 9 per month, were identified as victims of knife crime during the 51 months [5].

Severity of injury

In the full MPS data set (January 2018 to March 2022, inclusive) for Operation Hampshire 44% of MPS victims (n=13,548) sustained an injury. Of these victims 39% sustained minor injuries, 4% received moderate injuries, 1% was serious and one assault was fatal. This indicates that, in general, police officers and staff are more likely to endure minor injuries, rather than moderate, serious or fatal ones.

Table 4 – All MPS assaults reported to Operation Hampshire between January 2018 to March 2022 (inclusive) reproduced from reference 5

OP HAMPSHIRE	2018	2019	2020	2021	2022	Grand Total
Threats Only						
Offences	114	130	213	186	45	688
%	2%	2%	4%	3%	1%	2%
No Injury						
Offences	3107	3529	4458	4525	1118	16527
%	52%	55%	74%	75%	19%	54%
Minor						
Offences	2432	2745	3088	2823	694	11858
%	40%	46%	51%	47%	12%	39%
Moderate						
Offences	285	289	333	300	81	1294
%	5%	5%	6%	5%	1%	4%
Serious						
Offences	81	82	107	100	25	395
%	1%	1%	2%	2%	0%	1%
Fatal						
Offences	0	0	1	0	0	1
%	0%	0%	0%	0%	0%	0%
Grand Total	6019	6379	8178	8024	1963	30763

Table 5 – MPS knife crime victims reported to Operation Hampshire – January 2018 to March 2022 (inclusive) reproduced from reference 5

OP HAMPSHIRE and KNIFE CRIME	2018	2019	2020	2021	2022	Grand Total
Threats Only						
Offences	0	5	5	1	0	11
%	0%	4%	4%	1%	0%	2%
No Injury						
Offences	18	30	33	20	9	110
%	18%	26%	28%	17%	47%	24%
Minor						
Offences	56	69	61	64	9	259
%	60%	60%	51%	53%	47%	55%
Moderate						
Offences	14	9	11	27	1	61
%	15%	7%	9%	22%	5%	13%
Serious						
Offences	5	3	9	9	0	26
%	5%	3%	8%	7%	0%	6%
Fatal						
Offences	0	0	0	0	0	0
%	0%	0%	0%	0%	0%	0%
Grand Total	93	116	119	121	19	467

However, when comparing the above percentages, based on the full dataset, with injuries specifically sustained by knife crime victims a different distribution of injury severity emerges. Injuries were recorded in 74% of knife crime victims (n=346), with 55% of victims reporting minor injury, 13% with moderate injury, 6% with serious injury and no fatalities [5].

Location of injuries from knife assaults in 2021

In 2021 there were 121 knife crime assaults in which nine caused serious injury to the victims. Figure 9 is a Vitruvian map which illustrates the locations in which victims received serious injuries. Hence, victims received injuries to hands, wrists, arms, chest, abdomen, back, neck, jaw and forehead.

Furthermore, in one knife crime assault the police body armour was impacted, and in another knife assault struck the officers radio. Hence the location of both of these attacks were also to the torso [6].

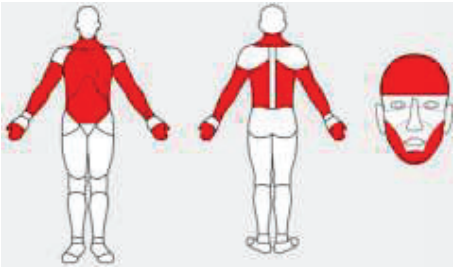

Figure 9 – Vitruvian map indicates the location of injuries recorded during 2021, reproduced from reference 6

DISCUSSION

The general distribution of wounds, described in the 75 post mortem reports from victims murdered in 2019, shown that there are approximately twice the quantity of stab wounds to the anterior body map, compared with the posterior. When analyzing the left and right lateral body maps, there are twice the number of stab wound on the left lateral body map, compared with the right, which is often attributed to more assailants being right-handed and thereby stabbing the victim on the left during a frontal attack [7].

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Furthermore, when studying the positions of the wounds there is there is no cause to believe that certain anatomical locations have been targeted by the assailant.

When analysing the location of the fatal stab wound two thirds of fatal stab wounds are located within the torso and nearly a quarter of fatal stab wounds are to the neck. When determining the cause of death loss of blood was cited in over 90% of the victims.

Further scrutiny of the injuries to the torso revealed acute damage to one or multiple organs, great vessels or both. Victims with critical damage to their neck had injuries to their carotid artery, internal or external jugular vein, subclavian artery or axillary vein, typically the trachea was also damaged. Fatal damage to the upper and lower extremities was attributed to severing arteries and veins.

Data reported from Operation Hampshire between January 2018 and March 2022 (inclusive) shows that when police officers are subjected to knife assaults they are more likely to be injured and their injuries are more severe, compared with other assaults. Focusing specifically on assaults and injuries that occurred during 2021, the nine victims received serious injuries to hands, wrists, arms, chest, abdomen, back, neck, jaw and forehead (see figure 9). Although this is only a small sample of the data, these injuries are in similar locations when comparison with the body maps in figures 1 to 4 for murder victims. Even though police officers wear body armour for routine patrol duties, in 2021 two police officers received impacts to the torso (one to the body armour and one to the radio (worn around the shoulder region of the body armour)). In these assaults the assailant did not successfully target an unprotected location, however in both instances the impacts were close to the edge of the HO accredited armour panel.

In the UK police body armour for routine patrolling duties is a dual purpose armour, providing handgun and knife protection principally to the torso. (This armour scheme can be worn covertly or overtly, however the majority of the time it is worn in an overt cover). From the data in this study, the torso is the most vulnerable area and therefore the most important area to protect. However, due the inflexibility of materials used to construct armour schemes, "difficult to protect areas" such as around the arm, flank, lower abdomen, shoulders and around the neck are often left without protection as this can severely restrict the wearer's ability to range of motion and thermal comfort. Potential solutions for this issue could be achieved by i) a step change in the flexibility of armour materials or ii) seeking innovation in armour designs by engineering extra knife resistance in difficult to protect areas. The latter is the approach investigated and this concept is now known as Supplementary Knife Resistance (SKR).

Figure 10 – anterior view of body map overlaid with HO accredited armour (blue panel) with SRK illustrated in red

Figure 11 – left lateral view of body map overlaid with HO accredited armour (blue panel) with SRK illustrated in red

Figure 12 - posterior view of body map overlaid with HO accredited armour (blue panel) with SRK illustrated in red

Figure 13 - right lateral view of body map overlaid with HO accredited armour (blue panel) with SRK illustrated in red

(Note: non-fatal, defensive wounds to the hands and the lower legs have not been illustrated).

This is a pragmatic approach to reducing vulnerability by increasing the area of knife resistance, using flexible materials, to augment the area of existing armour panels. In figures 10 to 13 above the

Home Office (HO) accredited armour panels are illustrated in blue, and the SKR is illustrated in red. Both HO armour panels and the SKR have been laid over the body maps (figures 1 to 4). By the addition of SKR there is nominally an increase of 10 to 15 percent in area of knife resistance.

It is imperative that SKR provides the appropriate balance between protection and enabling the officer to move. If the level of knife resistance is unable to achieve HO accreditation then ideally it should be suitable for high frequency knife threats. Furthermore, consideration of the depth of penetration of a knife through an armour scheme, with respect to depth of critical structures, must be considered.

Anatomically, the neck is recognized as a vulnerable and difficult area to protect area, particularly as the arteries and veins are close to the surface of the skin. Protection around the neck area would be advantageous from knife attacks, however there has been concern from the user with regards to a collar hindering movement. This requirements conflict is complex and a delicate balance is needed before the development of knife protection for the neck can be successfully introduced into future generations of routine patrol armour schemes.

There are other vulnerable areas such as the upper and lower extremities, containing the brachial or femoral artery, which are also not protected by police body armour. However police officers are provided with tourniquets and trained in their use in the event of injuries to the upper or lower extremities.

Finally protection schemes, such as body armour, are the final tier within the hierarchy of control, hence it is used in conjunction with police Public and Personal Safety Training (PPST) and equipment.

. CONCLUSIONS

This paper has presented the wounding patterns for 75 victims of bladed weapon assault in the MPD in 2019 in which:

- Two thirds of fatal stab wounds are located within the torso and nearly a quarter of fatal stab wounds are to the neck. In over 90% of victims the principal cause of death is loss of blood.
- Fatal stab wounds to the torso produced catastrophic damage to an organ or a great vessel or both. Fatal damage to the neck and the upper and lower extremities were due to severing an artery and/or vein.
- Over 95% of fatal stab wounds were 50mm or greater in depth;

Assaults to police officers and staff reported to Operation Hampshire showed that:

- police victims subjected to knife assaults are more likely to be injured, and their injuries are more severe, compared with other reported assaults. Hence the importance of PPST and body armour;
- nine victims in 2021 received serious injuries to hands, wrists, arms, chest, abdomen, back, neck, jaw and forehead;
- two police victims received impacts to the torso (one to their body armour and one to their radio (on the shoulder region of the body armour)). In these assaults the assailant did not successfully target an unprotected location, however in both instances the impacts were close to the edge of the HO accredited armour panel.

Finally, innovative solutions to reduce vulnerability, by engineering additional areas of knife resistance, can be achieved by enhancing armour designs in “difficult to protect areas”. This is known as Supplementary Knife Resistance (SKR). In the future, the development of knife protection for the neck is an outstanding area of innovation for overtly worn, routine patrol police body armour.

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