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TECHNICAL NOTE

ANTHROPOLOGY

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Macroscopic and Microscopic Analysis of Knife Stab Wounds on Fleshed and Clothed Ribs

ABSTRACT: Stab wounds upon bone are analyzed to interpret the weapon used and the physical context in which the attack occurred. The literature demonstrates that most research conducted pertaining to wound patterns has been carried out on defleshed and unclothed bone samples, not adequately replicating actual circumstances. For this research, six half pig torsos (*Sus scrofa*), fleshed (including muscle, fat, epidermis, and dermis layers) and clothed, were stabbed using three knife types, applying both straight and downward thrusts. Analysis conducted macroscopically and through a scanning electron microscope with an environmental secondary electron detector revealed a general lack of consistency in wound pattern and associated secondary effects. Consequently, it was not possible to establish wound pattern per knife type as suggested in previous research or relate it to stab motion. Advantage of microscopic analysis was evident in recognizing wound traits and observation of trace evidence not visible macroscopically.

KEYWORDS: forensic science, forensic anthropology, sharp force trauma, stab wounds, knives, wound patterns, stab motion, macroscopic analysis, SEM analysis

Within countries that adopt stringent restrictions upon firearms, an alternative trend of the utilization of sharp weapons has emerged as a means by which to commit violent crimes, including homicides (1); such is the case in the United Kingdom (2,3), where a surge of knife-related crime has occurred in recent years. More specifically, the city of London has been the focus of particular attention, as the rate of knife-related stabbings is the highest in the United Kingdom (4). The reality of this tendency is reflected clearly at the Accident and Emergency Unit, Royal London Hospital, where some of the worst cases are treated and where stabbing incidents currently constitute a total of 25% of the cases treated, including very young teenagers, compared with statistics from 1997 at which time such incidents comprised <10% of total casualties treated (5).

Knife attacks occur within a variety of locations and circumstances (6), with access to such potentially fatal weapons being possible within most homes (1,2,6–10); such weapons may be easily concealed, and no current legal restrictions exist pertaining to the possession of such implements because of their utilitarian nature (as opposed to hunting knives or like weapons that are designed specifically for killing and dismemberment); and such weapons may also be readily disposed of when required (2,4,6). The latter point is of importance within the United Kingdom, as Section 1 of the Prevention of Crime Act 1953 prohibits any individual to bear offensive weapons of any class in public areas without lawful authority or excuse (Archbold, 24.106a) (11).

In homicide cases, the identification of trauma inflicted upon the body and the type of weapon utilized may be assessed through soft tissue or bone analysis; within the latter instance, a knife injury can be identified by a distinct narrow V-shaped incision, with striations perpendicular to the kerf floor, minimal wastage (defined as fragments of bone separated from the main section of bone), and in some instances, hinge fractures (defined as a portion of bone lifted from a fractured area but still attached to its original bone) may occur (12,13). It is here where the role of forensic anthropology can be of assistance during the postmortem examination (14–18).

The aim of this research was to identify potentially useful diagnostic features produced by knife type. Two manners of stab motions were to be used, with the resultant wounds being examined via macroscopic and scanning electron microscope (SEM) analysis. The results were to be compared as per Thompson and Inglis (16).

Materials and Methods

Six halved and recently butchered pig torsos (*Sus scrofa*) were purchased from a reputable butcher and processed for study soon after being obtained. Pig samples were specifically selected, as the species is widely accepted to be comparable to humans with respect to elements such as soft and hard-tissue structure, and general density (6,16,19). The torso was selected as a focal point for this research, as it is normally the most frequently affected anatomical area with reference to stabbing attacks (2,7,20–22).

Three separate tests were conducted using two half torsos in each case. The torsos varied in size, and all possessed sternal–costal cartilage, with the sternum being present in various degrees of completeness; in only one sample was the whole sternum present. The rib number in each case varied between eight and 12 ribs, with a mean of 9.66 ribs per sample.

Sample Preparation

Previous research has been conducted pertaining to the identification of sharp force trauma upon bone, by utilizing a variety of sharp instruments; most of such studies were carried out on

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previously macerated bone samples, or under controlled methods (6,10,14,16,18,23), elements not specifically representative of the actual circumstances usually connected to homicide cases. It is documented that soft tissue and clothing worn by potential victims produce a variable upon the degree of penetration by sharp instruments, as the mentioned elements provide factors of resistance against the stabbing force (3,10). Therefore, care was taken to replicate as realistically as possible, a knife attack upon an individual by partially separating the skin with the use of a scalpel to allow the removal of excess subcutaneous fat within the samples utilized. Once this was accomplished, the skin was sewn back into place by using embalming twine (7).

The next step involved covering each sample by sewing light cotton fabric around it, thus recreating the attire of light cotton shirts, as normally worn by young males in the United Kingdom regardless of season. Once each sample was wrapped, a firm sponge was placed against the dorsal side to represent the organs contained within the thoracic cavity.

Equipment

Three types of kitchen knives were utilized: two straight-bladed knives and a serrated-bladed knife, all purchased as a set from a Pound World® store (Wolverhampton, UK) for £1 Sterling. The lengths of the knives were measured from the tip to where the blade met the handle and for width across the widest point. The large straight-bladed knife (with reference to the samples referred to as STBL) measured 199 mm in length and 32.7 mm wide; the short straight-bladed knife (with reference to the samples known as STBS) measured 120 mm long and 17.6 mm wide. The serrated knife (referred to as SEBL) was 203 mm in length and 21.3 mm wide, with its teeth arranged in a scalloped pattern along the left edge of the blade; the tooth dimensions of the latter example were a length of 0.04 mm and a width 0.25 mm, being set 0.03 mm apart from each other.

Stabbings

The author is clearly aware that from a purely bio-mechanical angle, the manipulation of a weapon during a stabbing attack is difficult to replicate, because of the random nature of any given assault. For the purposes of this experiment, the stabbings were conducted upon each half torso, with each being placed securely against a solid round structure in anatomical position at 1.25 m, thereby mimicking an individual of approximately 1.70 m in height, standing upright, and facing the assailant. A healthy man of 1.83 m in stature acted as the assailant; most stabbing cases occurring in public settings involve interactions between men, in the process causing more physical damage than women in such instances (2). The assailant was instructed to inflict 12 stabbings upon each sample, six utilizing a straight forward motion followed by six stabbings in a downward thrust motion. Each stab was completed with the right hand while leaning forward, with the assailant bracing himself on his left foot and standing at a point of contact approximately 53 cm away from each sample.

The penetration force was not measured here as the experiment was conducted based upon the premise of a random attack; penetration forces do vary greatly in magnitude between one instance to another, depending upon resistance variables obtained from soft tissue and clothing, the type of knife, and the stature of the victim and attacker (10) among other factors; however, based on Gilchrist et al. (10), the force utilized here can be considered as moderate, as the blade was expected to penetrate soft tissue, cartilage, and bone tissue.

Recording and Maceration

After each set of stabbings was inflicted, the sample remained *in situ* and each tear visible upon the fabric was marked with a blue-inked circle to represent each of the straight thrusts and with red-inked circles to indicate the downward thrusts. Subsequent data were accurately compiled regarding the position of the stabbings within each sample, followed by the careful removal of the cotton fabric while transferring the marks of the entrance wounds directly onto the skin by the use of colored ink, to accurately facilitate examination of the soft tissue. In this manner, it was possible to more accurately track each wound trajectory through to potential contact with the ribs, thereby enabling a more precise record of wound placement. Additionally, the dorsal side of each sample was carefully examined to note whether any of the stabbings had penetrated straight through, thereby damaging the periosteum and soft tissue.

Each rib was subsequently removed, appropriately marked, and placed in a container and left to simmer between 20 and 30 min within a solution of water and biological detergent to more readily macerate the ribs by hand; this method also aided in the careful treatment of wound sites, thereby avoiding the possibility of accidental markings that might be created if a scalpel was utilized to remove the tissue. Once all of the ribs were macerated and prepared, they were arranged upon a table in anatomical order.

Macroscopic Analysis

All of the ribs were examined to accurately assess the distribution of stab type per half torso; wound patterns were duly noted

TABLE 1—*Distribution of stab wounds by knife type, test number, and stabbing motion.*

	SEBL1	SEBL2	STBL1	STBL2	STBS1	STBS2
Straight trust	rib 3,	rib 2	rib 3	rib 4	rib 6	rib 4
	rib 5*	rib 3*	rib 4	rib 6*	rib 8	rib 5
	rib 7†	rib 4	rib 5	rib 7*		rib 6
			rib 6	rib 5		
			rib 8			
Downward trust	rib 1	rib 4	rib 3	rib 3	rib 1	rib 2
	rib 2		rib 4	rib 4*	rib 2*‡	rib 3
	rib 3		rib 5	rib 6	rib 3‡	rib 4
			rib 6	rib5	rib5*	rib 5

*Two wounds.
†Three wounds.
‡STBS1 ribs 2 and 3 sharing a downward thrust.

FIG. 1—*A straight and a downward thrust stab sharing the same point of contact in sample STBS2 rib 4.*

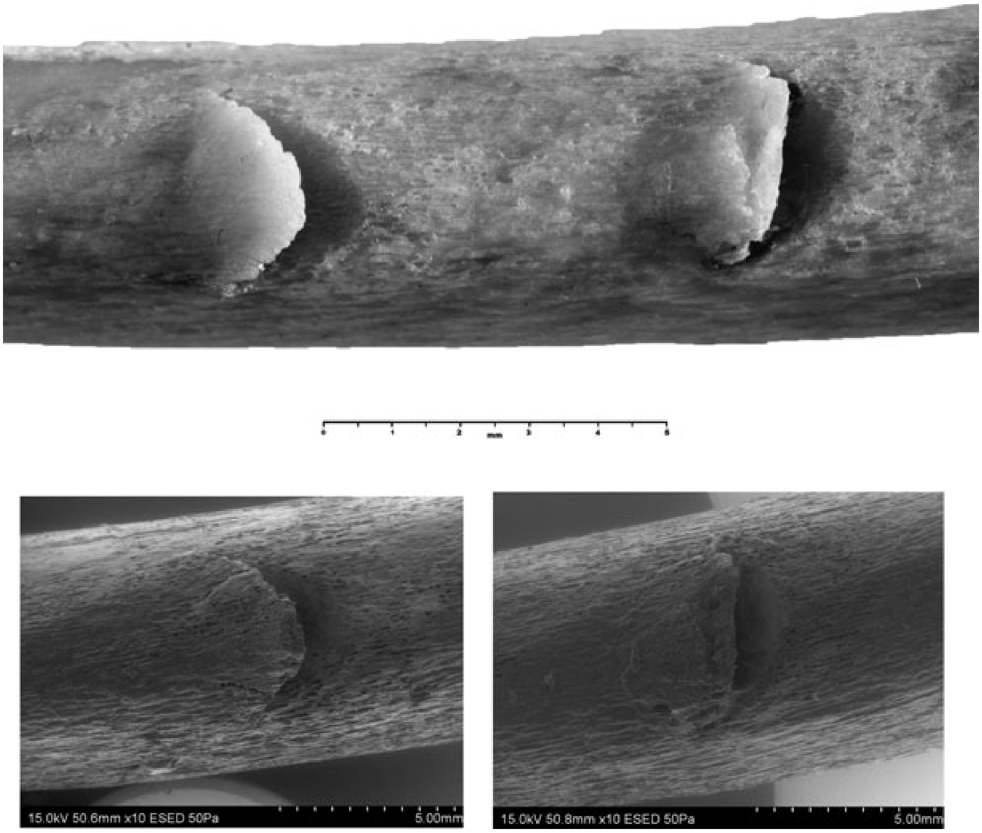

FIG. 2—*STBL2 rib 4 with wedge shape incisions on cranial edge created by downward thrust stabs producing hinge fractures.*

and examination made for possible secondary effects caused by each stabbing, while at all times producing a cross-reference with respect to the observations recorded before maceration.

Microscopic Analysis

The use of SEM was extremely useful for assessing diagnostic features produced by each individual weapon (14) as the process provides excellent imaging, and a range of magnifications (24) can be utilized for effective wound pattern detection; an Hitachi S-3400N SEM (Hitachi, Ltd., Tokyo, Japan) with an environmental secondary electron detector (ESED) was employed, permitting the examination of samples without the use of any kind of coating, thereby preserving the optimum integrity of the samples examined (25).

Each contact site was observed to assess wound pattern with reference to the kerf characteristics and any diagnostic features that were not evident at the macroscopic level. Here too, a cross-reference was produced with observations recorded before maceration. The results were compared as per Thompson and Inglis (16).

Results

Owing to the small sample size, the prevalence is presented here. Seventy-two stabs were inflicted, of which 26 (36.11%) failed to strike a rib. Of the total 36 straight thrust stabbings, 25 were successful in impacting bone tissue (69.44%), 24 (96%) were discovered between ribs 3 and 8, and 14 (58.33%) were concentrated on the midsection between ribs 5 and 7 of the samples. The only exception to the aforementioned patterns was SEBL2 rib 2 with

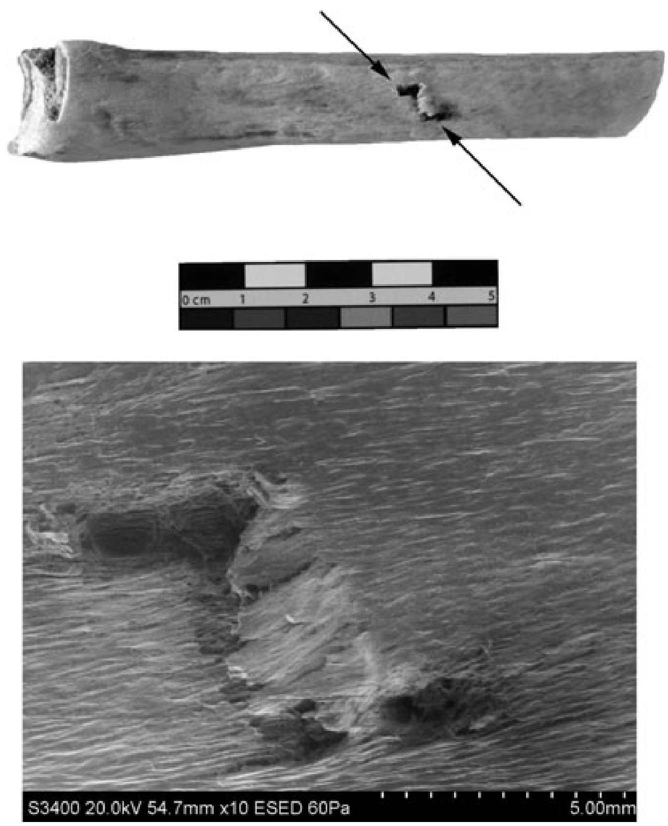

FIG. 3—*SEBL2 rib 3 with two straight thrust wounds. Hinge fracture associated with upper wound.*

one straight thrust lesion. In none of the samples were ribs 1, 9, 10, 11, and 12 (the latter four where present) affected by this kind of stab motion (Table 1).

In the case of the downward thrust stabbings, 21 (58.33%) of the 36 performed were successful in striking a rib. However, unlike the straight thrust stabbings, these were distributed upon the upper half of each of the torsos between ribs 1 and 6, with the majority concentrated between ribs 2 and 5, representing 80.95% of the total stabs produced (Table 1). Only one sample was observed, STBS2 rib 4, which displayed a straight and downward thrust at the same point of contact (Fig. 1). The distribution of stab wounds presented earlier is partly dictated by the relationship of the respective heights of the assailant and the victim.

Wound Pattern, Placement, and Damage

Within both methods of stabbings, the macroscopic analysis illustrated a general lack of consistency in wound patterns including

FIG. 4—*STBL1 rib 6 with a straight thrust stab causing a complete breakage at the sternal end.*

FIG. 6—*A downward thrust stab striking the caudal edge of STBS1 rib 2 with the upper edge of the knife and puncturing STBS1 rib 3 on the cranial edge.*

FIG. 5—*SEBL2 rib 2 knife tip penetrated the body of the rib with dorsal perforation during a straight thrust stab.*

puncture wounds, nicks, wedged, and crescent-shaped incisions and fractures. Some of the wounds presented the expected V-shape associated with sharp force trauma; those that did not were light incisions (nicks), or unusual wound patterns. Likewise, placement within each rib and the degree of damage among the three knife types varied widely as well.

Additionally, some of the wounds displayed secondary effects that were observed on the bone tissue. Hinge fractures are clearly visible on wedge and crescent shape wounds on the cranial edge (Fig. 2) and body of the rib (Fig. 3), complete fractures (Fig. 4), dorsal damage (the tip of the knife going through) (Fig. 5), markings by upper dull edge of the knife (Fig. 6), and wastage (Fig. 7). Of the 46 ribs injured through both types of stabbings, 18 (39.13%) exhibited secondary effects, and 22 of the 34 secondary effects observed were created by downward thrust stabs (64.70%) (Table 2). Although all knife types were represented, the short straight-bladed knife produced a higher extent of damage to the bone tissue.

Wound pattern variation at the microscopic level was also evident, with particular reference to nicks, where the V-shape that is characteristic of knife wounds could be fully appreciated (Fig. 8); additionally, damage to the kerf floor varied throughout the samples, from simple superficial alterations to fractures presenting a zig-zag effect as the blade cut through the cortical bone (Fig. 9; also visible on Fig. 5). It should be noted that this zig-zag pattern was readily noticeable in straight thrusts striking the body of the rib as the knife blade slid over it. In some downward thrust stabs, the blade also slid after the initial point of contact.

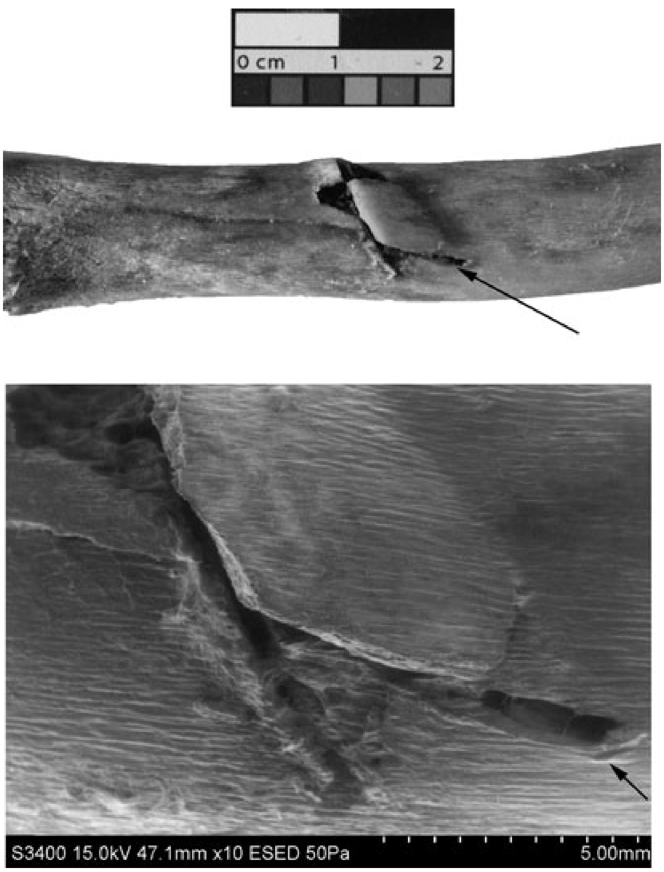

FIG. 7—*STBS1 rib 5 exhibiting wastage due to a downward thrust stab, note the associated hinge fracture. Arrow indicates a separate downward thrust stab wound.*

One characteristic associated exclusively with downward thrust stabs is the cone shape associated with the initial point of contact of the knife upon the bone (13), representing 71.42% of the total wounds inflicted in this manner (Fig. 10).

Although this research was not directed at analyzing trace evidence, through microscopic examination it became evident that textile strands were present within some of the wounds (Fig. 11).

Discussion

When the wounds were observed both macroscopically and microscopically, the patterns and secondary effects varied across the three knife types used. Because of such inconsistencies regarding potential patterns, it was not possible to conclude upon individual sets of diagnostic features pertaining to each knife type. Furthermore, the striations expected from sharp force trauma caused by a knife on bone were not observed under SEM for any knife type, although the V-shape was observed in most cases. Wastage is normally considered to be at a minimum in connection with knife stabbings (12); however, within this research results were obtained that clearly illustrated evidence of considerable wastage on some points of contact.

Conversely, in relation to the stab motions applied, some characteristics were noted. With the downward thrust stabs, regardless of knife type, a cone shape was observed in some of the samples, created by the point of the knife upon initial impact upon the hard tissue; in some cases, the blade proceeded to slide over the bone after impact, but because this occurrence was not observed in all of the downward thrust stabs, it cannot be stated to be a diagnostic feature aiding in the identification of a stab of this nature in all cases. Furthermore, the straight thrust wounds found in areas other than the edges of the ribs, regardless of knife type,

TABLE 2—*Secondary results from straight thrust (ST) and downward thrust (DT) stabbings distributed by knife type, test number, and respective rib number.*

	Hinge Fracture	Fracture	Dorsal Damage	Marking by Upper Dull Edge of Knife	Wastage
SEBL1 rib 2					DT
SEBL1 rib 3	DT				
SEBL2 rib 2			ST		
SEBL2 rib 3	ST*				ST*
SEBL2 rib 4	ST				DT
STBL1 rib 6	DT*	ST Complete			DT*
STBL1 rib 8	ST				
STBL2 rib 3				DT DT	
STBL2 rib 4	DT* DT				DT*
STBL2 rib 5				ST* DT	ST*
STBL2 rib 7	ST ST				
STBS1 rib 1	DT*				DT*
STBS1 rib 2	DT†	DT Incomplete			DT†
STBS1 rib 5	DT*				DT*
STBS1 rib 6					ST
STBS1 rib 8					ST
STBS2 rib 4	DT*				DT*
STBS2 rib 5	DT*				DT*

*Associated from same stab wound.
†From different stab wounds.

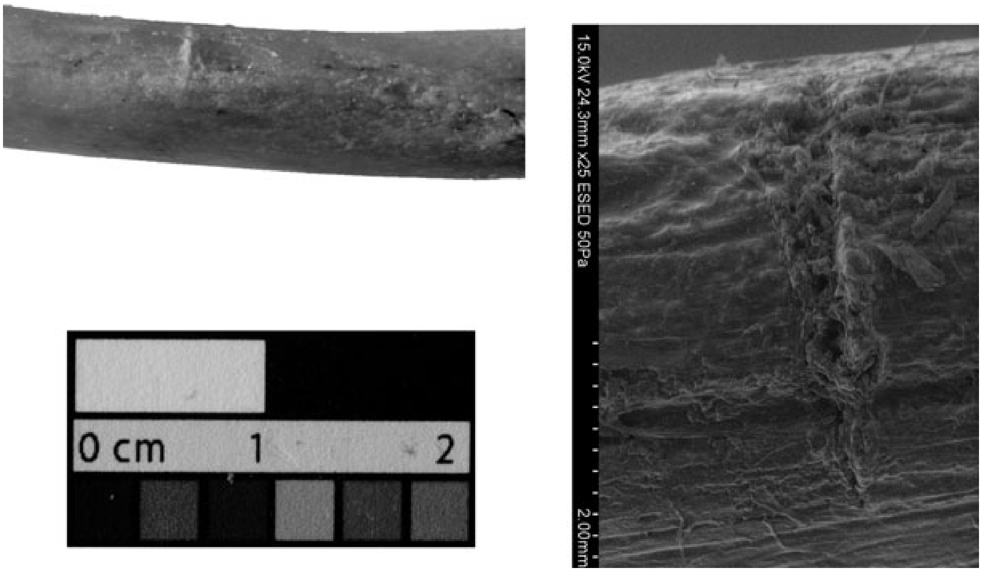

FIG. 8—*STBL1 rib 4, a straight thrust stab leaving a V-shaped incision seen microscopically.*

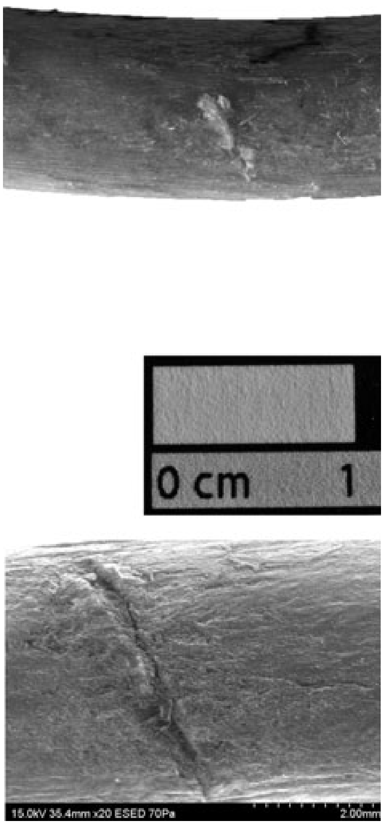

FIG. 9—*STBL1 rib 5 showing a zig-zag pattern left on the kerf floor as knife slid on cortical bone during a straight thrust tab.*

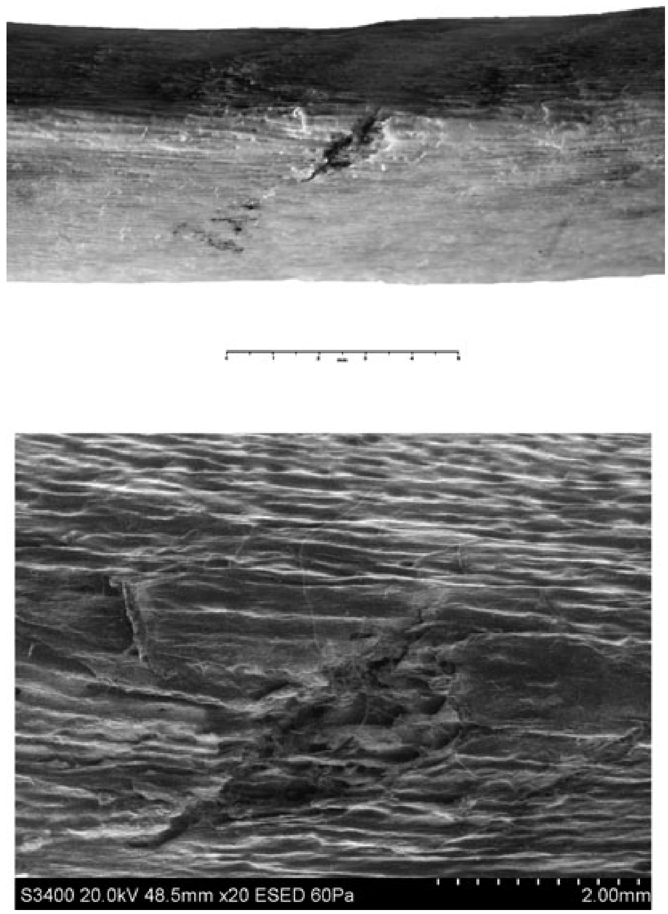

FIG. 10—*SEBL2 rib 4 cone shaped puncture created by knife tip during a downward thrust stab.*

demonstrated that when the knife penetrated the body, the hard tissue resisted the impact, resulting in more damage (Figs 3–5); once more, out of the three knives used during this research, the short straight-bladed knife caused the most prominent damage using either stab movement, regardless of point of contact (Fig. 7); again, these results could not be used as actual diagnostic features.

It is of note that the male volunteer reported that using the straight short blade gave him more control of the force and precision with regard to the placement of the knife where he truly wanted it to be during the stabbing process, regardless of stab

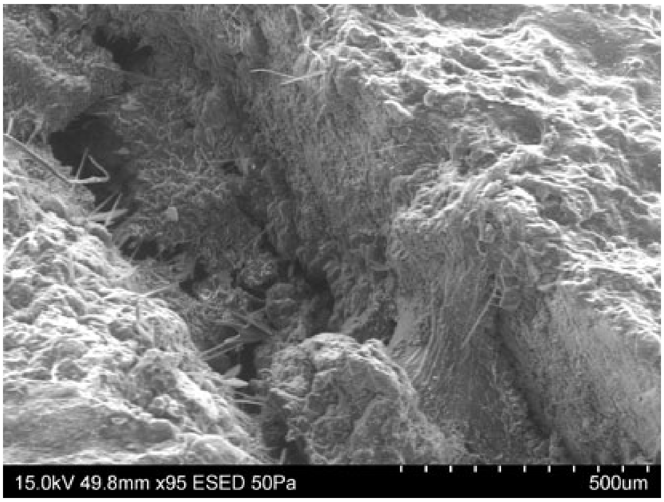

FIG. 11—*Textile fiber found within the wound in sample SEBL1 rib 2.*

motion, leaving the impression that it was a potentially more powerful weapon. Furthermore, the volunteer indicated that this particular knife did not "wobble" during the stabbing process.

As per Thompson and Inglis (16), a consistency in wound pattern was reported per knife type after stab wounds were inflicted in a controlled manner on defleshed bone, using a serrated and straight-bladed knife. Because of the consistency in patterns, the wounds were measured by length and width. On this last point, an attempt was made to do likewise; however, because of the broad range of patterns obtained, the results could not be quantified in a cohesive manner. The differences between the two studies are believed to be the result of multifactorial variables and randomness addressed during the experiment, which reflect more real circumstances.

Not all of the 72 stabs inflicted were successful in striking a rib and causing injury; some struck cartilage or passed between the intercostal spaces (20). The straight thrust stabs clustered on the midsection of the torso, and ribs 1 and 2 were not affected in either of the samples except for SEBL2. This pattern is because of the position of the volunteer in front of the sample, as if facing a victim, and to strike the first two ribs, the volunteer would have had to raise his arm more than would normally be required for this stab motion. The exception in SEBL2 rib 2 (Fig. 5) was possibly due to the fact that this half torso was the largest sample used, allowing this particular rib more surface exposure, and to be placed at a somewhat lower position in comparison with the other samples. On the other hand, the downward thrust stabs were clustered instead in the upper portion of the samples, caused by the volunteer raising his arm to inflict this kind of wound. The wound placement on the ribs discussed here is related in part to the association of the respective heights of the victim and assailant.

The trace evidence present on some of the ribs in the form of textile fibers constitutes a potential and significant evidentiary element in the resolution of homicide cases (25); new technologies have recently been developed which further assist in detection and recovery in such instances (1,26). It is recommended here that if such information is sought as part of an investigation, due care must be taken before any process of maceration is conducted, so as not to degrade or destroy potential evidence. Additionally, it is clear that the utilization of SEM with ESED is advantageous, as knowledge of such evidence cannot always be assessed at the macroscopic level.

Summary and Conclusions

The varied wound patterns and lack of consistent diagnostic features evident in the wounds produced during this research, demonstrated that caution must be taken when analyzing knife wounds upon bone with reference to knife type; the results obtained stand in contrast to those presented by Thompson and Inglis (16). Additionally, the straight thrust stabs were clustered on the midsection of each torso, while the downward thrust stabs were more evident upon the upper portions, in accordance with the relationship between the victim's height and that of the assailant.

The application of macroscopic analysis of stab wounds on bone will provide information pertaining to wound patterns; however, microscopic analysis can further aid in identifying V-shaped wounds and zig-zag patterns in the kerf floor that may not be otherwise noted. Additionally, SEM can also be of assistance in the detection of trace evidence, for example, textile fibers originating from clothing worn at the time of the attack.

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