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The impact of trauma and blood loss on human decomposition

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1. Introduction

Human decomposition is governed by a set of biological processes that reduces, desiccates and liquefies soft tissue after death. As the post mortem environment and conditions vary, so too do the states and rates of decomposition [1–3]. The environmental, contextual or intrinsic variables may be used to predict the progression and rate of decomposition [4–11]. Temperature [9] and humidity (or moisture) [12] play a central role in the colliquation of human tissue after death. There is however, continued debate over the role of some of the other variables such as; exposure to freezing temperatures [13–15], sunlight, [5–6] [16], extent of clothing [6] [4], and body size [17–19].

It has been proposed that trauma may impact decomposition by increasing access for insects thus speeding the degradation of tissue [20] [5] [21]. Tissue trauma, to the extent it causes death, generally involves blood loss to some extent. The impact of blood loss on the biological process of decomposition is not a variable that has so far been investigated.

The volume of blood in the circulatory system depends on body size, but generally the total volume is between 5 and 6 l [22]. Exsanguination is medically defined as an extensive loss of blood due to internal or external hemorrhage. A blood loss of > 40%, without surgical intervention, will cause death by exsanguination. Lee et al. 1986 [23] developed methods to accurately estimate the volumes of blood lost at a scene when the body is absent to predict the survivability of that blood loss. The estimates were based on weights of dried blood, or weights of items or surfaces saturated in blood [24] [22]. These methods were found to be extremely time consuming and unpractical [24]. Fractal analysis of digital photos of bloodstains has been successfully used for larger volumes of blood as a more objective mathematical method to estimate blood volumes [25]. Currently, blood volumes are estimated based on the dimensions of the blood pool and experimentation with a similar substrate with a known volume of blood [24] [26–28]. These estimates are generally conducted for court purposes where there is a lack of body and an opinion requested as to the survivability of that volume of blood loss.

There are several reasons why blood loss may impact the progression of decomposition. As blood is mainly a liquid (55%), the loss of fluid from the body may impact the humidity levels of the tissue. The bio-chemical composition of blood may have a greater impact on moisture levels in tissue than previously considered. Blood contains proteins, amino acids, nitrogenous waste (toxic end-products), nutrients (fats, amino acids, phospholipids, vitamins & minerals and glucose), gasses (oxygen, carbon-dioxide and nitrogen) as well as electrolytes [29]. Some of the components of blood which may impact the moisture levels in a body are proteins and electrolyes. Plasma proteins governs the balance of water between blood and tissue by producing ‘colloid osmotic pressure’. A reduction in albumin, the most abundant plasma protein can result in a loss of fluid from the blood and gain in the interstitial spaces. The electrolyes in the plasma contain sodium ions which directly impacts the osmolarity (measure of solute concentration) of blood. Blood therefore does play in important role in tissue hydration, and the absence of blood within the body may promote mummification of tissues and delay colliquation.

The aim of this study was to assess the visible volume of blood lost from a deceased using scene photographs and autopsy reports to determine whether the volume of blood loss by itself, or in combination with any other variable, had a positive or negative impact on the progression of decomposition.

1.1. Materials & methodology

This study is a small component of a larger study undertaken to examine the variables which affect decomposition in burials, water, indoors and outdoors in Canada [30]. A total of 7328 cases were reviewed using the Canadian Violent Crime Linkage Analysis System (ViCLAS) from all Provinces and Territories across the country. A total of 341 cases mainly from British Columbia and Ontario (80%) were selected based on the completeness of information and access to photographs from the scene and autopsy. In all cases, the time since death and circumstances of death were known. The stage of decomposition was scored on a scale of 0 for no visible signs of decomposition, 1–2 for autolysis, 3–5 putrefaction and 6–8 for skeletonization. The validity of scoring the stage of decomposition based on photographs has recently been validated by by a number of researchers [31]. These researchers evaluated the accuracy of scoring the level of decomposition in the field with in situ subjects compared to evaluations using photographs of those same subjects. They determined that with experience,

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classifications can be made based on photographs rather than on site assessments with no loss in accuracy.

A large proportion of the cases in this study represented the earlier rather than later stages of decomposition. For the indoor cases, 75% ($n = 144$) were classified at stage 0 and 1 (early onset autolysis) with an average PMI of 7 days for stage 1. For the outdoor data set 79% of the cases were classified at stage 0 and 1 (average PMI of 4 days). A maximum time range of one year PMI was selected for this set of cases, as it was found that after one year, most bodies stabilized and remained at the stage of decomposition they were at, regardless of the progression of time.

Many of the cases did not exhibit signs of blood loss. Due to dilution or absorption of the blood, the extent of blood loss could not be evaluated for deceased in burial or water contexts, or for scenes with large post mortem intervals. If there was visible sign of blood loss at the scene in the photographs, or a lack of information from the autopsy referring to blood loss the variable was scored as a zero. The majority (52.5%) of deceased in all the scene types exhibited no visible sign of tissue damage or blood loss.

The extent of blood loss was assessed by the first author, a qualified and experienced Bloodstain Pattern Analyst (BPA) with many years of experience within the Royal Canadian Mounted Police (RCMP). The level of blood loss was evaluated in general rather than specific terms: (1) minimal (a few fluid ounces); (2) moderate (between minimal and < 50% of the individuals determined total volume); (3) extreme (> 50%) and (4) exsanguination. The diagnosis of total exsanguination was taken from the pathologists report as well as photographs from the scene. Of the 47.5% of the cases with blood loss ($n = 176$), 17.9% of the cases had minimal blood loss, 20.5% moderate, 5.9% extreme and 3.2% total.

The level of blood loss was compared to the type of trauma (ballistic, sharp, blunt) to determine whether there was a correlation between the volume of blood lost and type of trauma. Due to the high numbers of homicides in the database, the most common type of trauma was blunt force (21.4%) followed by ballistic (15.4%) and then by sharp trauma (14.3%). The set of cases with 'other' or 'no trauma' include those individuals who have died of natural causes such as heart attack. For the evaluation that age had on the progression of decomposition, the dataset was divided into age groups of 10 years from 0 to 100.

A total of 46 variables were scored for each case of the 341 cases in the study (Table 1). For a full description of the methodology refer to Cockle and Bell 2017 [2]. Most of the variables were quantified using an interval scale, however others were scored using a nominal scale. All variables were examined using general and multivariate step-wise regression analysis. Blood loss was one of the variables examined to determine whether the extent of blood loss was significant as an independent variable, or dependant variable in combination with other variables. Any variables with a significance score of less than a *P*-value of 0.15 were removed (alpha to remove or enter in the step-wise process). The model identified those variables with the highest R-value regardless of their *P*-values. The only two variables with multicollinearity: Post Mortem Interval (PMI days) and the accumulated daily temperature (ADD acc temp) were not used in the general regression analysis together [2].

2. Results

The data suggest that there is a correlation between the volume of blood loss and type of trauma. In Canada, blunt and sharp trauma are generally more common than ballistic, however for the cases in this study blunt (21.4%) and ballistic trauma (15.4%) was more common than sharp force (14.3%), as mechanisms of death. The examination of the volume of blood lost by trauma type demonstrates a difference between blunt and sharp trauma (Fig. 1). Blunt force trauma generally resulted in a minimal to moderate (< 50%) blood loss compared to sharp trauma which will resulted in more extreme (> 50% or exsanguination) blood loss. Ballistic trauma resulted in blood loss generally < 50% of the total. For some of the other cases involving trauma such as drowning or 'other', there was associated trauma and blood loss which was not the main type of trauma causing death.

A comparison between the manner of death and age illustrated a higher incidence of homicides in individuals under the age of 30 years compared to any other manner of death. For individuals between the ages of 30 to 60, the leading manner of death was suicide. Accidental death appeared to be more between 20 and 40 years of age (Fig. 2).

The impact of blood loss to the progression of decomposition was examined using regression and stepwise regression. A stepwise regression analysis was conducted with the two largest subsets of data for the outdoor ($n = 96$) and indoor ($n = 191$) scene types. For the indoor cases, temperature (ADD acc temp), Insect involvement and blood loss were examined as dependant variables for the progression of decomposition (Table 2.a.). Blood loss was determined to be a significant variable in the decomposition score with a *P*-value of 0.009. The relationship of blood loss to the progression of decomposition is negative,

Table 1
The variables examined with the potential to impact the progression of human decomposition in Canada.

Environmental	Immediate context	Intrinsic variables
Total precipitation	Shelter (structure)	Sex (M/F)
Temperature (max)	Urban (10 types)	Age
Temperature (min)	Rural Context (water/land)	Facial appearance (pop group)
Average Temperature	Type of water (salt/fresh/sewer)	Height
Average temperature for first month missing	Fresh water (stagnant/flowing)	Weight
ADD acc temp	***Level of submersion***	**Build (thin to obese)**
Average Humidity	Depth of burial	Illness or Disease
Month missing	Type of surface (9 types)	Manner of Death
Month Located	Slope of terrain	Type of Trauma
PMI in days	Reflective quality of surface (3 types)	Number of blows
Ecozone	Level of shade	Area of Trauma
Ecodistrict	Debris on body	***Extent of Blood loss***
Geographical Location	Type of debris on body	Drugs (taken before death)
	Position of body	Drugs (type)
	Extent of clothing	***Alcohol***
	Shroud (covering/wrapping)	
	Impact of Scavenging	
	Impact of Insect activity	

Note: These are the 46 variables examined during the original larger study [30]. The variables in bold are those which demonstrated a statistically significant correlation between the progression of decomposition and presence or extent of that variable. Those variables in bold and italics demonstrated a negative relationship with the progression of decomposition.

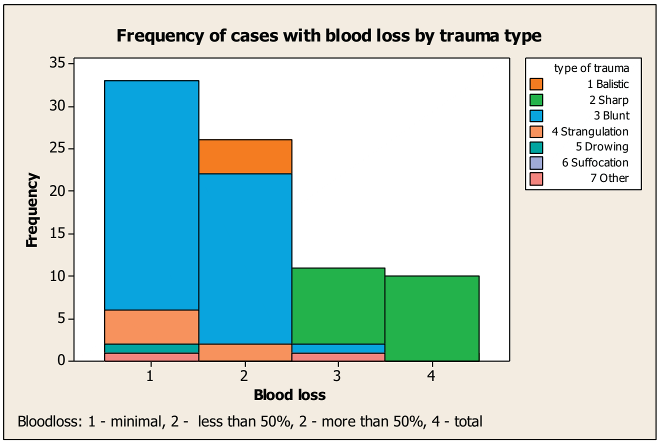

Fig. 1. The frequency of cases with blood loss per trauma type. There is an obvious relationship between the type of trauma and the amount of blood loss associated to it. The smaller and moderate amount of blood loss is associated to blunt force trauma where as higher levels of blood loss are associated to sharp trauma. The greater blood loss associated with sharp trauma is likely due to the potential of severed arteries and veins. Blood loss in relation to drowning or strangulation is due to the combination of other trauma types (such as blunt or sharp) with the primary manner or death. Ballistic trauma generally results in a moderate amount of blood loss. $N = 341$.

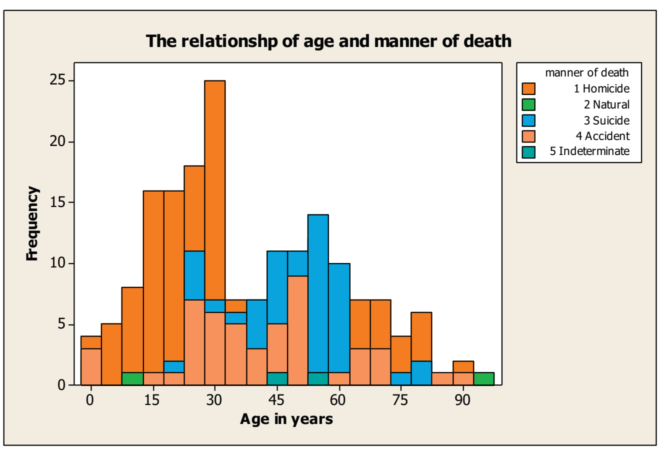

Fig. 2. The frequency of manner of death is shown by age group. All cases 1 year PMI or less $N = 341$. There is a much higher frequency of homicides in the 10 to 30 age range compared to the adult group. Conversely the adult group (40 to 60) has a much higher incidence of suicide.

therefore, the results suggest that increased blood loss may retard the progression of decomposition. These three variables were responsible for 49% [R^2 (adj)] of the variability in the progression of decomposition indoors.

For the outdoor data set, a total of seven variables were identified as contributing variables in the predictive model. Collectively: total precipitation, PMI days, body size, scavenging, Insects, alcohol and blood loss accounted for 84% of the variability in the progression of decomposition (Table 2.b.). The PMI in days was used for this analysis instead of the ADD acc temp as it was demonstrated to have more predictive value in the outdoor scene context. Table 2.b. demonstrates the negative relationship of blood loss to the progression of decomposition with a moderate correlation (P value of 0.2).

The impact of blood loss was examined for all cases in the study (Table 2.c). The four variables of PMI in days, alcohol, blood loss and insects were identified the most significant variables in the model, explaining 60% of the variability in the stage of decomposition. Blood loss was identified as a significant variable within the model with a P-value of 0.019. For the indoors and combined indoors and outdoors models, blood loss was identified as a significant variable shown to have a negative relationship with the progression of decomposition.

Table 2
Stepwise Regression of variables impacting the rate of decomposition indoors, outdoors and in all scene types.

Variables	P-value	t-value	
1.a. Indoors n = 191 (1 year PMI or less)			
ADD Acc temp	0	6.82	
Insects	0	6.36	
Blood-loss	0.009	−2.64	$R^2 = 49.92\%$
1.b. Outdoors $n = 96$			
total precipitation	0.215	1.2737	
PMI days	0.002	3.1844	
body size	0.006	2.819	
scavenging	0	7.8081	
insects	0	11.6484	
alcohol	0.027	−2.2554	
Blood-loss	0.219	−1.2392	$R^2 = 84.2\%$
1.c. All scene types n = 341			
PMI Days	0	16.6601	
Alcohol	0.001	−3.3796	
Insects	0	12.9481	
Blood-loss	0.019	−2.3639	$R^2 = 60.04\%$

Note: A low p-value (< 0.05) is a meaningful addition to the model. The R-squared is the explained variation in response data (the progression of decomposition). The higher the R-squared, the better the model fits the data. t-tests assess one regression coefficient at a time. The T-value measures the size of the difference relative to the variation in the sample data. All scene types include the indoors and outdoor scenes.

3. Discussion

There is a range of differing opinions in the literature regarding the role that tissue trauma plays in the progression of decomposition. It has been reported that insects are attracted to trauma sites and the increase in insect activity relates to an increased rate of decomposition [5]. However, Galloway [4] commented on a study by Burger [32] that blow flies were less attracted to post-mortem incisions and trauma sites, than to the natural body orifices. Fisher [18] suggested that since blood is an excellent medium for bacterial growth, trauma would accelerate decomposition at a specific injury site. It is unknown whether Fisher was suggesting a florescence of bacteria associated to the presence of blood inside or outside the body.

Mant [33] conducted 150 World War II exhumations and observed that traumatized bodies would skeletonise faster than more intact ones, given the same environmental conditions. He noted that wounding would make cadavers more susceptible to invasion by extracorporeal organisms than bodies that were buried with their skin intact [34]. There have been two studies in Canada [35] and in Britain [36] that have examined the impact of trauma on decomposition. The study by Calce and Rogers [35] examined blunt force trauma, but more in relation to the confusion between trauma and other natural taphonomic changes which impact the body as opposed to the rate of decomposition.

The results of the experimental studies using animal proxies [32] [36] [35] have found that insects do not seem to be attracted to trauma sites, nor is decomposition accelerated in these areas. The impact of trauma on the overall acceleration of decomposition found by Mant [33] may not be the result of tissue damage.

The results from this study identified a correlation between the type of trauma and extent of blood loss. Moderate amounts of blood loss have been attributed to blunt force and ballistic trauma. Extreme blood loss was almost exclusively associated with sharp trauma. Blunt force trauma is the most common type of trauma in the dataset (21%), followed by ballistic (15%) and then sharp (14%) trauma (Fig. 1). Sharp trauma was associated to suicides or homicides, whereas blunt force trauma was generally associated with homicides (except for the few cases of suicide by jumping from a height). It has been speculated that the lack of blood negatively impacts the ability of the bacteria to disperse throughout the body as suggested by Bell et al., [37] and Bell [38–39]. It is also likely that blood loss contributes to a desiccation (removal of H^2O) of the tissues through chemical or physical means.

To determine what impact age has on the progresses within decomposition, an analysis was conducted for the progression of autolysis and then putrefaction for the age groups. For the initial stages of decomposition (stages 0 to 2), the two youngest age groups demonstrated a faster rate of decomposition in PMI days compared to the adult age groups [30]. What was unexpected was the anomalous result for the 20 to 30 age group. The results displayed a very high mean PMI in days which represented a slow pace of decomposition for this age set. It was suspected that this dramatic deceleration in autolysis for the 20 to 30 age group could not be attributed to age alone.

An examination of the manner of death for each age group provided a possible explanation for this anomalous result. There was a noticeable concentration of traumatic death for this age group compared to any other (Fig. 2). The incidence of homicide and violent death was much higher for the 10 to 30 age groups. The manner of death and subsequent extent of blood loss could have been a significant contributing factor in the deceleration of autolysis in this age group. Blunt and sharp trauma was the most common method of homicide in the Canadian dataset which resulted in moderate to high levels of blood loss (Fig. 1). It is proposed that the degree of blood loss contributed to the deceleration of autolysis in the 20 to 30 age set.

The result of this investigation into the impact of blood loss on the progression of decomposition in Canada has been surprising. Blood loss was found to be a significant contributing variable both indoors and outdoors. Apart from time (PMI in days), blood loss was the most frequently identified variable for almost all scene types in the Canadian dataset. The relationship of blood loss to the progression of decomposition in all cases is a negative one. The data suggests an increase in blood loss results in a decrease in the progression of decomposition.

4. Conclusion

The results from this study underscore the importance of considering the impact of blood loss on human decomposition. Clearly tissue trauma *peri* mortem is important, but factoring in blood loss has been a less obvious variable, certainly one not explicitly factored into mapping decomposition trajectories. All scene types considered in this Canadian dataset revealed an important relationship to blood loss. This information may assist death investigators with the knowledge that extreme blood loss may contribute to the deceleration of decomposition and possibly an increase period of tissue preservation. From a taphonomic standpoint, significant blood loss represents a clear inhibitor of bacterial transmigration from the gut into the post mortem blood supply and may help explain the confusing variance reported for intra-environmental contexts for terrestrial exposure, and usefully for indoor decomposition too. The significance beyond actual scene types concerns modelling human decomposition for taphonomic investigations, where the integrity of the post mortem blood supply (or not) is clearly a biasing factor and needs to be considered.

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