DURATION AND EXTENT OF ADIPOCERE FORMATION IN HOT - HUMID AREAS OF PAKISTAN: A RETROSPECTIVE STUDY

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ABSTRACT

Objective: To find out duration of adipocere formation in hot and humid area.
Study Design: Cross sectional study.
Place and Duration of Study: Mohi-Ud-Din Islamic Medical College Mirpur Azad Kashmir and HITEC-IMS Taxila, from Jan 2017 to Jan 2019.
Methodology: Total 25 cases with adipocere formation were included in this study. The cause of death, time since death, death circumstances, surrounding environment from where the body was recovered and demographic profile of the deceased were considered, while cases of septicemic deaths were excluded from the study. The adipocere was confirmed by forensic medicine consultants by its soft, moist and greasy consistency, grayish white appearance and ammoniacal smell.
Results: Most of the cases recovered during months of March to June from open and closed areas, while 3 cases were recovered from water source or river banks. The time duration of recovery from time of death was from 5 days to 15 days 3h. The adipocere formation showed a high odds ratio 2.0-(95%-CI-0.115-3.482) and OR-1.5-(95%-CI-.098-2.306) for bodies recovered from water and open areas respectively. The adipocere formation in hot and rainy season showed OR-3.3-(95%-CI .190-4.199) and OR-2.4-(95%-CI .122-3.642) respectively. The adipocere formation occurred more during days 1-5 with an OR-1.9-(95%-CI .221-1.625).
Conclusion: The adipocere formation can be seen as early as 2 days in a hot humid environmentin closed areas, while the extent of adipocere is larger in bodies recover from water source.

Keywords: Adipocere, Environmental conditions, Hanging, Strangulation, Subtropical climate, Water source.

INTRODUCTION

Adipocere can produce a waxy layer across the body and act as a barrier against the usual process of decomposition, and a modified process of putrefaction providing significant protection over time[1], while breaking down process of organic matter in the body after death is decomposition. Adipocere helps in identification if the victim is unknown or even determining cause of death. The adipocere is grey-white, crumbly soap-like postmortem product that arises from decomposition of adipose tissue consisting of phospholipids, fatty acids, proteins and glycerol, releasing fatty acids and other components. Adipocere is not an end product and degrades when exposed to aerobic conditions. Adipocere may remain within the soft tissues reserving the internal organs and bones that may also form adipocere with time. Adipocere may be consumed by macrofauna (the fly genus, Piophila (Diptera: Piophilidae) and beetle species, Omosita colon (Coleoptera: Nitulidae)[2-4].

The factors influencing adipocere formation include age and sex of the deceased, water, soil, and presence/absence of clothing. The main factors are sufficient adipose tissue, anaerobic environment, moisture either from environment or from the body itself, warm temperatures, a mildly alkaline pH, and anaerobic bacteria such as *Clostridium perfringens* and *Clostridium frigidicanes*[5,6].

Though mechanism of adipocere formation is still not clear, however, according to most investigators, the body fat is hydrolyzed to unsaturated fatty acids (palmitoleic acid, oleic and linoleic acid) by lipases, which are then hydrogenated to saturated fatty acids (palmitic

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acid, stearic acid, and myristic acid) by endogenous bacterial enzymes. The free fatty acids so formed are conjugated with Na+, K+, Ca2+, and Mg2+ to form insoluble soaps. Theoxo- and hydroxo-fatty acids have also been identified as constituents of adipocere[7,8].

The presence of water and fat compensate each other to such a degree that small amount of adipocere is likely to form which later guarantee formation of large quantities of adipocere. Moisture is necessary for commencement of bacterial and enzymatic activities, however, not essential prerequisite for the continuation of adipocere process. As the body loses moisture by process of hydrolysis, the tissues become dehydrated and produce conditions un-favorable to bacterial proliferation[9-10].

The timing of adipocere formation is highly variable and based on environmental temperature, humidity, nature of soil and method of burial. In a temperate climate (21-45°C - optimal temperature for bacterial growth and enzymatic release), adipocere formation starts within days, becomes apparent in 3 months, and extensive in 5-6 months[11]. In extremely warm water adipocere formation occurs within days or weeks while in cold water (4°C) it takes about 12-18 months. However, once adipocere is formed, it can persist for hundreds of years, and preserve the body. Fresh Adipocere is rancid, soft, whitish and translucent in appearance and contain high levels of unsaturated fatty acids, while old adipocere is yellowish, dry, hard, cracked and brittle in nature[9,10].

Azad Jammu Kashmir, has predominantly subtropical climate with seasonal changes in temperature compared to temperate climate, with a range of above 40°C (104°F) in the summer and below 0°C (30°F) in the winter. No study has been done in this subtropical region of Kashmir and Taxilla to know the environmental effects on adipocere formation.

METHODOLOGY

This cross sectional retrospective study was done at Department of Forensic Medicine, MIMC Mirpur Kashmir and HITEC-IMS Taxila in collaboration with DHQ hospitals Mirpur and Taxila after taking approval from institutional ethical committee (No. 1-3/17 MIMC/IEC-6 dated 10.01. 2017). The postmortem records were analyzed of the last 2 years from 2017 to 2019. The adipocere formation to any extent with known time of death were included, while those with apparent infection were excluded from the study, as the bacteria helps in adipocere formation. Details of each case categorized into cause of death, death circumstances, extent of adipocere formation and surroundings environment from where the body was recovered were noted. Thecondition of the body was taken into account along with demographic profile and the body characteristics including age, sex, presence of clothing, and presence of insects were noted in a predesigned proforma. Adipocere formation of the body tissue was diagnosed by the authors themselves on gross examination with its characteristics ammoniacal smell, soft, moist and greasy consistency, andgrayish white appearance. The technique was convenient sampling. A minimum sample size was used and calculated using formula as described by Ralph B13 for the study.

Data were entered into a Microsoft Excel 2003 spreadsheet and analyzed, using the SPSS 18.0.1. The demographics and outcome variables were summarized using descriptive summary measures, expressed as percentage for categorical variables. Chi-square test was used to compare the variables between male and female deceased. Multivariate logistic regression analysis used to identify the independent predictor variables. Adjusted matched odds ratio with its corresponding 95% confidence interval was used and significance was taken at p-value ≤0.05.

RESULTS

Twenty nine cases with adipocere formation were examined during the two years study period. Out of which 25 cases (86.2%) (20 male (68.9%) and five (17.2%) female) were included in the study, and four cases (13.8%) were excluded as their time and cause of death was not

established. All the cases were from 2017 to 2019 during the month of March to February. During April to July weather is hot (27-39°C) and humid (20%-90%), August to October is rainy while it is cold during December to February (0-6°C). All the cases were brought directly for postmortem examination without any preservation, recovered from surrounding areas of Mirpur and Taxila, and died due to unnatural cause. The cases were recovered from closed rooms at home without air conditioning (10 cases), open grounds (12 cases), and from water sources or riverbank (three case). All the cases were partially or fully clothed at the time of death. Female bodies were recovered mostly from home; only one female was recovered from a water source.

Table-I shows season of recovery, time duration between death and postmortem examination of the deceased and their place of recovery. Regarding season of recovery out of selected 25 cases, 15 (60%); were recovered during the month of March to June (summer) out of which 12 (48%) were males and 3 (12%) females; 6 (24%) males and 2 (8%) females recovered during rainy season July to October, while only two (8%) cases (one (4%) males and 01 (4%) females) during winter season - December to

Table-I: Season of recovery, Time duration between death and postpartum examination and place of recovery of deceased.

Variables	Male n=19 (76%)	Female n=6 (24%)	Total n=25	Like hood ratio	*p*-value
Season of Recovery					
Summer (March –June)	12 (63.1%)	3 (50%)	15 (60%)		
Rainy (July-October)	6 (31.6%)	2 (33.3%)	8 (32%)		0.645
Winter (December-February)	1 (5.3%)	1 (16.6%)	02 (4%)		
Time in days between death and postpartum					
Day 5	4 (21%)	-	4 (16%)		
6	1 (5.3%)	1 (16.6%)	2 (8%)		
7	1 (5.3%)	1 (16.6%)	2 (8%)		
8	2 (10.5%)	-	2 (8%)		
9	2 (10.5%)	1 (16.6%)	3 (12%)		
10	1 (5.3%)	1 (16.6%)	2 (4%)		0.888
11	3 (15.7%)	0 (0%)	3 (12%)		
12	1 (5.3%)	1 (16.6%)	2 (8%)		
13	2 (10.5%)	-	2 (8%)		
14	1 (5.3%)	-	1 (4%)		
15	1 (5.3%)	1 (16.6%)	2 (8%)		
Place of Recovery					
Closed	7 (36.8%)	3 (50%)	10 (40%)		
Open place	10 (52.7%)	2 (33.3%)	12 (48%)		0.171
Water source	2 (10.5%)	1 (16.6%)	03 (12%)		

Table-II: Multivariate Logistic Regression for the predictors associated with adipocere formation.

Variable	St. Error	Odds Ratio	95% CI	*p*-value
Closed				
Open	1.39	1.5	0.098 – 2.306	0.571
Water	0.45	2.0	0.115 – 3.482	0.771
Winter				
Hot	1.55	3.3	0.190 – 4.199	0.377
Rainy	0.63	2.4	0.122 – 3.642	0.501
Days				
10-15				
5-10	1.37	1.1	0.671- 1.490	0.571
1-5	1.16	1.9	0.221- 1.625	0.099

February. The comparison between male and female was found to be non-significant (p<0.05) when season of recovery were compared. The time between death and postmortem varies from

Table-III: Demographic data, Extent of adipocere formation, Time and Cause of death and Site of recovery of the diseased.

Age (years)	Gender	Date of recovery	Site of recovery	Presence of Insets	Clothing	Time since death	Cause of death	Extent of Adipocere formation
24	M	13 Mar	Closed	Nil	Present	4 day 10 hrs	Cut throat	Over the abdomen and right thigh
37	M	27 Mar	Open	Nil	Present	4 day 20 hrs	Hanging	Over the abdomen, left shoulder and patchy area on left arm
39	M	12 Apr	Closed	Nil	Present	4 day 09 hrs	Undeter-mined	Over abdomen, and part of left buttock
41	M	22 Apr	Open	Nil	Present	4 day 18 hrs	Strangula-tion	Patchy area over face, abdomen, part of left upper
37	F	29 Apr	Closed	Nil	Present	5 days 5 hrs	Undeter-mined	Over the front & back of trunk, buttock and right thigh
30	M	1 May	Open	Nil	Present	5 days 12 hrs	Head injury	Over abdomen, patchy left upper limb and right thigh
23	M	4 May	Open	Nil	Present	6 days 9 hrs	Incised wounds	Over abdomen, left upper limb except hand, buttocks
34	F	12 May	Closed	Nil	Present	6 days 18 hrs	Burn	Over breast, abdomen, left upper limb and left thigh except hands and feet
4	M	19 May	Open	Nil	Present	7 days 2 hrs	Cut throat	Over abdomen, both shoulders and small areas over left thigh
29	M	30 May	Open	Nil	Present	7 days 5 hrs	Gunshot	Face, patchy areas over trunk, both upper and lower limbs except hands and feet
45	F	3 Jun	Closed	Nil	Present	8 days 7 hrs	Undeter-mined	Over front of the trunk and both the upper limbs, right thigh except hands
33	M	9 Jun	Open	Nil	Present	8 days 9 hrs	Alcohol	Over the face, front of trunk, and both upper limbs except hands
29	M	15 Jun	Closed	Nil	Present	8 days 12 hrs	Gunshot injury	Abdomen, right upper limb except hand, and front of the right thigh
21	F	20 Jun	Water	Nil	Present	9 days 2 hrs	Drowning	Face, over the front and back of trunk, right arm and thighs except hands and feet
30	M	23 Jun	Closed	Nil	Present	9 days 9 hrs	Gunshot	Over the abdomen, buttock, left thigh
56	M	12 Jul	Open	Nil	Present	10 days 12 hrs	Undeter-mined	Over abdomen, thighs, left shoulder
45	M	17 Jul	Closed	Nil	Present	10 days 2 hrs	Hanging	Over the right thigh, right upper limb, left shoulder except hands
52	M	19 Aug	Water	Nil	Present	10 days 3 hrs	Drowning	Overthe right leg except foot, left arm, and abdomen
34	F	21 Aug	Open	Nil	Present	11 days 2 hrs	Strangula-tion	Over the front & back of trunk, both the arms and right thigh
29	M	2 Sep	Closed	Nil	Present	11 days 8 hrs	Alcohol	Over abdomen, right upper left arm, left thigh
32	M	25 Oct	Closed	Nil	Present	12 days 3 hrs	Hanging	Over both upper limbs except hands, buttock and right thigh
36	M	28 Oct	Water	Nil	Present	12 days 2 hrs	Drowning	Over the front and back of the trunk and part of right thigh
31	M	30 Oct	Open	Nil	Present	13 days 7 hrs	Head injury	Over abdomen, right upper limb except hand, and right thigh
30	F	16 Dec	Open	Nil	Present	14 days 2 hrs	Burn	Over the body except lower legs and feet
28	M	2 Feb	Open	Nil	Present	14 days 3 hrs	Hanging	Over abdomen and upper limbs except hands

5 days to 15 days. The bodies recovered on day 5 were 4 (16%), on each day[6-13], and 15 were 2 (8%), while on each days 9 and 11 the bodies recovered were 3 (12%). The chi square did not show any significant difference within the days (p>0.05). A total 10 (40%) cases recovered from closed 12 (48%) from open and 3 (12%) from water source. The difference between male and female regarding place of recovery was also statistically non-significant (p-0.171).

Table-II shows demographic data, time and cause of death, site of recovery of the diseased and extent of adipocere formation. Majority of the cases involved were males. Most bodies exhibited subcutaneous formation of adipocere while only one showed adipocere transformation in both subcutaneous and some internal organs. Majority of cases found in open areaswere of hanging, cut throat, strangulation or undetermined. The bodies recovered from water were drowned. In some cases death was due to gunshot injuries, sharp or blunt force trauma.

Age of the deceased was varying from 4 to 56 years. Most deceased (24 cases, 96%) had unnatural deaths; in four cases the cause of death remained undetermined at the time of autopsy and toxicology reportswere awaiting; however, they may had suffered sudden unexpected deaths and the probable cause was natural; one involving cardiopulmonary system. All the deceased were partially or fully clothed with one to two layers of clothing, however, textile of the clothing was not described in the reports. Clothes on the body of the cases recovered from lands were dry, while in cases recovered from water sources were wet at the time of recovery.

There was no air conditioning in the closed room from where the bodies were recovered and no case was found lying in the open under the rain during the rainy month. The extent of adipocere formation was ranging from part to large area of the body (except hands and feet) and was only slight different among the age groups, correlating with sex of the deceased, site and durationof exposure. The bodies recovered from the water sources showed more extensive adipocere involvement compared to cases recovered from open and closed areas with same duration of exposure. The extent of adipocere formation in female was over a larger body area than of males with the same circumstances of death and of same time duration.

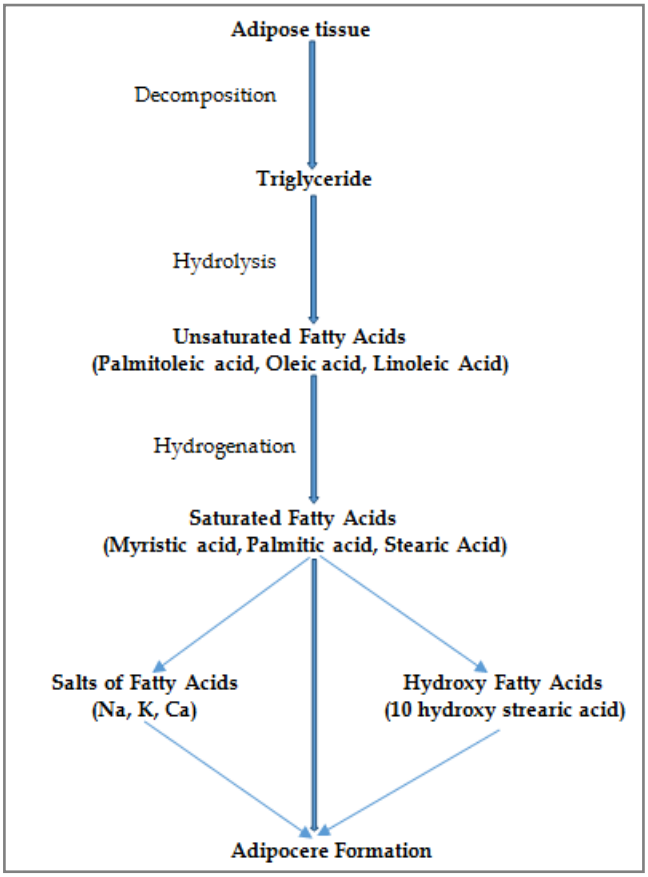

Figure-1: Process of adipocere formation.

Duration of exposure till postmortem examination was varying from 5 to 22 days as by the autopsy surgeon in the autopsy report. The extent of Adipocere formation varied from the front of the trunk to all over the body (except hands and feet). Among the excluded five cases, four were male and one was female. All the bodies were recovered from a non-air-conditioned house during the months of May to September, died due to unnatural causes and time since death was not known.

Table-III shows the multivariate Logistic regression for the predictors associated with

adipocere formation. The adipocere formation showed a high odds ratio 2.0 (95% CI 0.115-3.482, *p*=0.771) and OR 1.5 (95% CI .098-2.306, *p*=0.571) for bodies recovered from water and open areas respectively. The adipocere formation also showed a raised OR 3.3 (95% CI 0.190-4.199, *p*=0.377) and OR-2.4; (95% CI .122-3.642; *p*=0.501) for hot and rainy season respectively. The adipocere formation occurred more during days 1-5

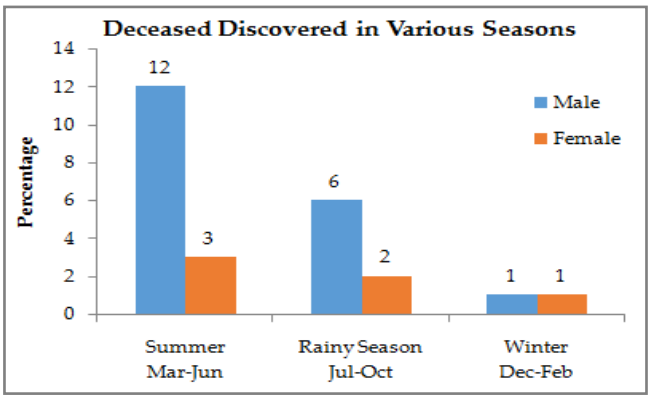

Figure-2(a): Deceased discovered in variour seasons.

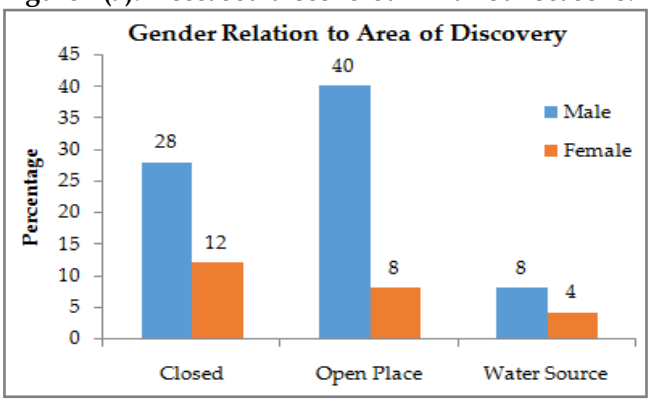

Figure-2(b): Gender relation to area of discovery.

with an OR of 1.9 (95% CI .221-1.625; *p*=0.099).

Figure-1 shows flow chart for process of adipocere formation.

Figure-2(a) shows comparison of the deceased discovered in various seasons. A good number of bodies recovered from open areas in summer season, compared to bodies recovered from water area in all seasons, however, the numbers were much less in rainy season.

Figure-2(b) shows male and female deceased recovered from different areas during study period. The male bodies recovered from open, closed and water areas were more than the number of female deceased in these areas.

DISCUSSION

Our study showed that most of the cases recovered in the month of April to July had adipocere formation in short time when the weather was hot and humid, the average room temperature ranged between 27-39°C with humidity between 20-90%. Our results are in consistent with Sikary *et al*[9] who showed adipocere formation in hot humid climatein short period and declared that in hot and humid climate external water or moisture is not needed and the water present in the decomposing tissue is sufficient for adipocere formation[11,12]. Same results were seen by Stuart *et al*[7] who showed more than half of the bodies in each vault had extensive adipocere formation in very hot humid climate within days and agreed that only internal body water is sufficient for adipocere formation and even moisture was not necessary. These results are not in agreement with Kasuda *et al*[12] who declared marked decomposition in the bodies in hot humid climate with earth burials, or wood shavings; however, sufficient adipocere was also noticed in bodies with airtight coffins. Same results are shown by Ueland *et al*[5] who declared major decompositionis probably by bacterial activity in a hot andhumid climate in dry room on concrete surfacewith only suspected adipocere of the deceased.

Four cases in our study were recovered from water source while the rest were from the closed (house) or open areas, showing that if climate is favorable external water source or moisture is not needed for adipocere formation. Adipocere is favored by moisture, warm, anaerobic environment and personal characteristics, while inhibited in cold, and aerobic environment. It is more frequently seen in obese, females and well-nourished newborn infants[9,11]. Adipocere helps in determining injury pattern, identification, cause of death and time since death[2-3].

Our results showed adipocere formation over a larger area of the body in cases which were

recovered from water sources than the bodies recovered from closed spots. These results are in consistent with Marcella *et al*[14] who showed extensive adipocere formation in bodies recovered from water sources. DeDono *et al*[6] declared extensive adipocere formation in drowned persons within 3 days in the month of October. Sikary *et al*[9] reported a case of adipocere formation all over the body in 22 days in the month of August recovered from sea beach and was submerged in water for some time. Stuart *et al*[7] reported a case of adipocere formation in a non-buried partially submersed body in a domestic setup in 9 days.

The typical conditions of adipocere formation like water immersion, wet graves and damp vaults; are 10 times slower than adipocere formation in atypical dry conditions. The good quantity of adipose tissue, moisture, anaerobic conditions, bacterial presence, moisture, mildly alkaline pH, warm temperatures, high humidity, and complete submersion of the body in water contributed to the early formation of adipocere in any environment while, partial submersion, water type, clothing, insect, and bacteria inhibit adipocere formation[15,16].

In our study, the age-group ranged from 4 to 56 years did not show any correlation with the extent of adipocere formation, however, certain studies showed some correlation between age and formation of adipocere[3,17]. Adipocere, generally is more common in higher fat composition[5].

In our results, the female bodies showed more extent of adipocere formation than males in same circumstances with same duration of exposure. These results are in agreement with a number of studies[6-9] which showed extensive adipocere in females bodies compared to male of same age, same environment with same duration of exposure. The decomposition process and formation of adipocere vary between different bodies and even within different areas of the same body. Stuart *et al*[7] declared submerged male was skeletonised while the woman's had adipocere due to its higher fat content.

In our results, adipocere formed in most of the cases within 5 days, were recovered from open or closed area, while only four cases were recovered from water sources. Cases recovered within 5 days showed adipocere formation mainly over the abdomen and in few cases adipocere involved adjacent proximalupper or lower limb. Cases recovered after 7 days showed more extensive involvement- involving abdomen, upper and lower limbs, and buttock. The time for adipocere formation is highly variable and depends upon environmental and body factors, while persistence is based on absence of oxygen[16-18].

LIMITATION OF STUDY

In this retrospective study duration and extent of adipocere formation were determined on gross examination on small number of cases. A study on large scale is needed to confirm the findings.

CONCLUSION

Adipocere formation is faster in a subtropical climate (hot and humid weather). External water is not a prerequisite for adipocere formation, however, it does enhance the rate and extent of adipocere formation.

CONFLICT OF INTEREST

This study has no conflict of interest to be declared by any author.

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