

Impact of Winter Season and Other Contributory Variables on Estimation of Time Since Death using Livor and Rigor Mortis in Varanasi Region

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ABSTRACT

BACKGROUND: A significant question in forensic casework is the estimation of time since death (TSD) in the early post-mortem phase. Muscles undergo a condition of rigor mortis following death, accompanied by post-mortem consumption of adenosine triphosphate. Lividity is a dark purple coloration of the skin induced by blood accumulating in the affected area. Environmental factors play a crucial part in the determination of TSD using different parameters through various methods.

AIMS: The purpose of this study is assessment of TSD and effect of contributory variables on existence of rigor mortis and fixation of lividity in cadavers kept at room temperature during winter season in Varanasi region.

SETTINGS AND DESIGN: This is a prospective and observational study.

MATERIAL AND METHODS: 102 cadavers escorted for medicolegal autopsy at the mortuary of the Department of Forensic Medicine, Banaras Hindu University, Varanasi for the duration of consecutive two years in winter season from December 2019 - February 2020 and November 2020 - February 2021.

RESULT: All the cases were studied for rigor mortis and found an average post-mortem interval of 18.67 ± 9.43 hrs. Post-mortem lividity was found to be not fixed in 21 (20.59%) cases before 10 hrs, while 76 (74.51%) cases of lividity had already been fixed after 10 hrs and 5 (4.9%) cases of lividity were found to be not observable.

CONCLUSION: Livor and rigor mortis have minimal predictive potential due to the effect of different contributory variables on the development of rigor and fixation of lividity.

Keywords: Time since death; Post-mortem Changes; Post-mortem interval; Livor mortis; Rigor mortis.

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INTRODUCTION

A significant question in forensic casework is the estimation of the time after death in the early post-mortem phase. It depends on commonly used approaches of using different methods based on temperature and non-temperature.¹ "The

duration of time that has elapsed since death of the deceased” is marked as post mortem interval (PMI). The primary objective of estimating the time after death at a crime scene is to obtain a preparatory understanding of the timeframe of the assault and to limit the perpetrators’ area.²

After primary flaccidity, rigor mortis is the condition of post-mortem rigidity and certain shortening of the body’s muscles: both involuntary and voluntary. In involuntary muscles, rigor mortis first arises, and then in the voluntary muscles. Rigor mortis arrives between 1-2 hrs following the death and takes about 10-12 hrs to achieve complete development and stays unchanged during the next 12 hrs, and then goes away within the next 12 hrs.³ Muscles undergo a condition of rigor mortis following death, accompanied by post-mortem consumption of adenosine-5'-triphosphate (ATP). Rigor mortis is brought upon by the mechanism in myofibrils in which the slipping-in of actin filament between myosin filament takes place utilizing the intake of reduced ATP levels that correspond to myofibrils shortening and toughening. Further storage elongates and tenderizes the rigor muscles certainly by sliding out of actin filaments among the myosin filaments. This phenomenon is referred to as “rigor mortis resolution”.⁴

Rigor mortis occurs first in the cardiac muscles and spreads from proximal to distal. It is seen in the eyelids followed by the neck, lower jaw, chest, upper limbs, abdomen, lower limbs, and ultimately in the fingers and toes. When putrefaction begins, rigor mortis vanishes, and then secondary flaccidity takes place.⁵ The onset rate and time for the complete development of rigor mortis are highly variable and are primarily dependent on the ambient temperature, as with all post-mortem changes. The onset and intensity of rigor mortis are accelerated by high ambient temperatures, even though intense colds have also been recorded as the rapid arrival of rigor mortis. Furthermore, the development of rigor mortis is influenced by both intrinsic and extrinsic variables.⁶

Accumulation of blood in the lower part of the body is livor mortis or lividity, which results in dark purple skin discoloration. After death, the heart ceases to agitate the blood, so the red blood cells sink due to influence of gravity. Discoloration does not take place in areas of the body that are in contact with the surface due to compression of

the capillaries. Lividity emerges in all bodies under the influence of gravitational pull because blood stays liquid rather than coagulating in the vascular system. The process starts just after the circulation ceases.⁷ Dull-red spots with a diameter of 1 to 2 cm develop within 20 to 30 min to 2 hrs. These spots then become larger, intensified, and converged in 1 to 4 hrs and eventually combine and slip down to the dependent parts of the body. Within four hrs, lividity is typically well formed and achieves a maximum of around 6 to 12 hrs and continues until putrefaction sets in.⁸ The regression of lividity on thumb pressure and resettlement upon shifting decreases and gradually vanish as the post-mortem period increases. This effect is accompanied by a rise in intravascular erythrocyte haemoconcentration in response to plasma transcapillary extravasation.⁹

Generally, India has three major seasons, i.e., winter, summer, and rainy season. In diverse locations at different times, there are several fluctuations in climatic conditions. Environmental factors play a crucial part in the determination of TSD using different parameters through various methods. Our study is about the assessment of TSD and the effect of contributory variables on the existence of rigor mortis and fixation of lividity in cadavers kept at room temperature during the winter season in the Varanasi region of Uttar Pradesh, India.

MATERIAL AND METHODS

A prospective and observational study was performed on 102 cadavers escorted for medicolegal autopsy at the mortuary of the Department of Forensic Medicine, Institute of Medical Sciences, Banaras Hindu University, Varanasi (India) for the duration of consecutive two years in the winter season from December 2019 - February 2020 and November 2020 - February 2021. During this period, a total of 102 cadavers were randomly selected for examination of rigor mortis and livor mortis to estimate the TSD.

This study includes only those cadavers that were kept at prevailing room temperature, were of known identity and had an exact time of death. We excluded those bodies that were, having severe diseases like AIDS, Hepatitis B, Cancer, having Covid-19, having mutilated body parts and kept in cold storage. We also excluded neonates in this

study. For the evaluation of rigor mortis, we also excluded those cadavers who had crushed bone, bone dislocation, and joint inflammation. We excluded bodies that had dark coloured skin for the examination of livor mortis. The existence of rigor mortis was checked and confirmed by lifting the eyelids, movement of the lower jaw, and flexibility of different joints. The flexibility of the shoulder joint, elbow joint, wrist joint, and carpals of the upper body were checked, and in the lower body, the movements of the hip joint, knee joint, ankle joint, and tarsals were examined. Fixation and non-fixation of lividity were observed in a supine position by pressing the thumb on the backside of the body, except the dependent portion, for 30 sec and then noticed for around one minute. The presence of blanching does not confirm the fixation of lividity.

Age, gender, musculature, height, weight, clothing, the actual time of death, time of hospitalization, and various general details were noted in the preformed proforma. For the measurement of the humidity and temperature of the environment where the autopsy was conducted, a decent quality digital hygrometer was utilized. Exact time of death as well as whether the body was hospitalized or not were noted from the hospital record, inquest reports, and hearsay of their respected relatives, friends, or investigating police officer. The usual autopsy was performed to ascertain the cause and mode of death.

RESULTS AND OBSERVATIONS

102 cadavers were included in the study, with a significant proportion of them being hospital deaths as well as cases where the time of death was just approximative but was certified by medical officers. These cases included both medicolegal and

certified deaths, in which the precise time of death was documented.

In 0 to 12 hrs after death, 34 cadaver were examined in which 3 cadavers had partially developed rigor mortis, 31 cadavers had fully developed rigor mortis, and zero cadaver were identified to be devoid of rigor mortis. TSD ranging from 13 to 24 hrs, 47 cadavers were observed. Throughout this period, 4 cadavers had partially developed rigor mortis, 41 cadavers were found with fully developed rigor mortis, and 2 cadavers were found to have no evidence of rigor mortis. 14 cadavers were inspected between 25 to 36 hrs following death, and all of the cadavers had completely developed rigor mortis. After more than 36 hrs, only one cadaver had moderately developed rigor mortis, 4 cadavers exhibited completely developed rigor mortis, and 2 cadavers exhibited no rigor mortis.

0 to 6 hrs after death, 5 cadavers had developed post-mortem lividity but had not been fixed, and zero cadaver had completely developed lividity with fixation. It was assessed in 16 cadavers between 7 to 12 hrs after death that lividity had developed but hadn't yet fixed in, whereas in 12 cadavers it had completely developed and fixed. 63 cadavers with a TSD of more than 12 hrs had post-mortem lividity that was completely established and fixed. There have been 6 cadavers observed in which lividity was not seen owing to a variety of factors like severe burning, and muddy skin. Therefore, it can be noticed that maximum lividity was seen between 6 to 12 hrs and completely fixed lividity was seen 10 hrs after death however it was found to be fixed till 75 hrs throughout the Winter season. There were 21 cadavers with developed but not fixed lividity out of a total of 102 cadavers.

Table 1: Relationship between TSD and development of rigor mortis (RM)

TSD (Hrs.)	Frequency			
	Total	RM partially present	RM fully present	RM absent
0-12	34	03	31	00
13-24	47	04	41	02
25-36	14	00	14	00
>36	07	01	04	02

Table 2: Relationship between TSD, development and fixation of lividity

TSD (Hrs.)	Frequency			
	Total	Developed but not fixed	Fully developed and fixed	Not observable
0 - 6	05	05	00	00
7 - 12	29	16	12	01
13 - 18	20	00	20	00
19 - 24	27	00	24	03
> 24	21	00	19	02

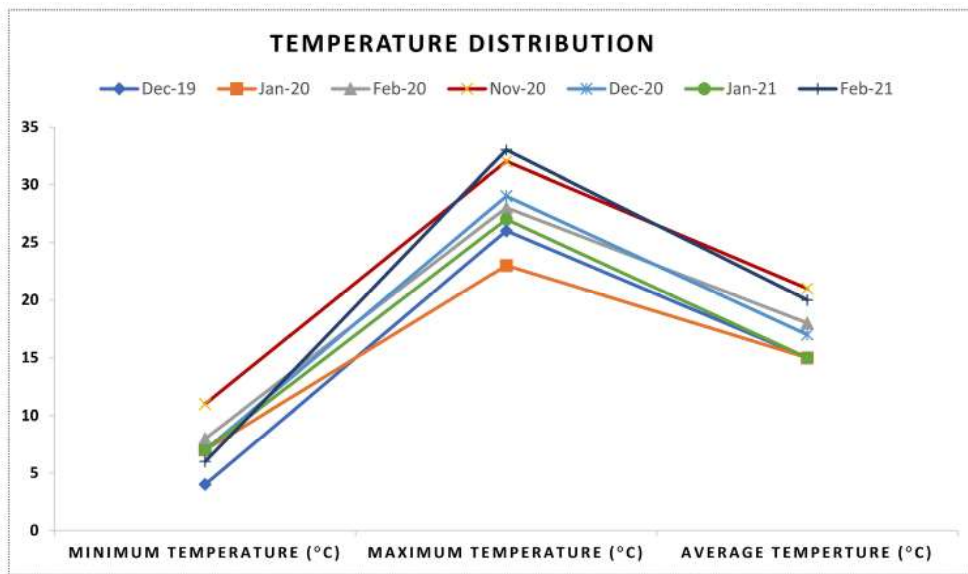


Fig. 1: Temperature distribution during different months of research.

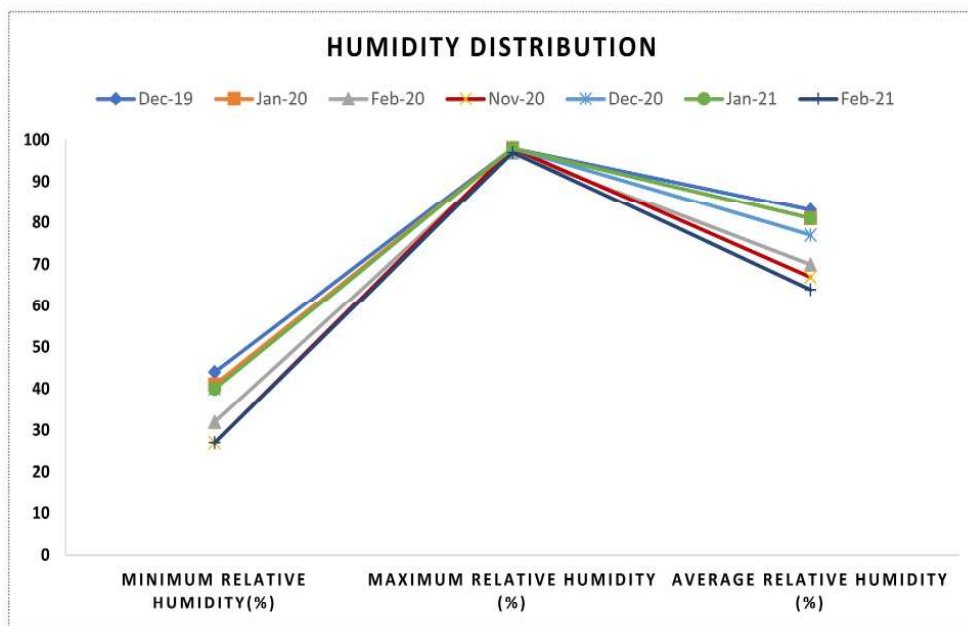


Fig. 2: Relative humidity distribution during different months of research.

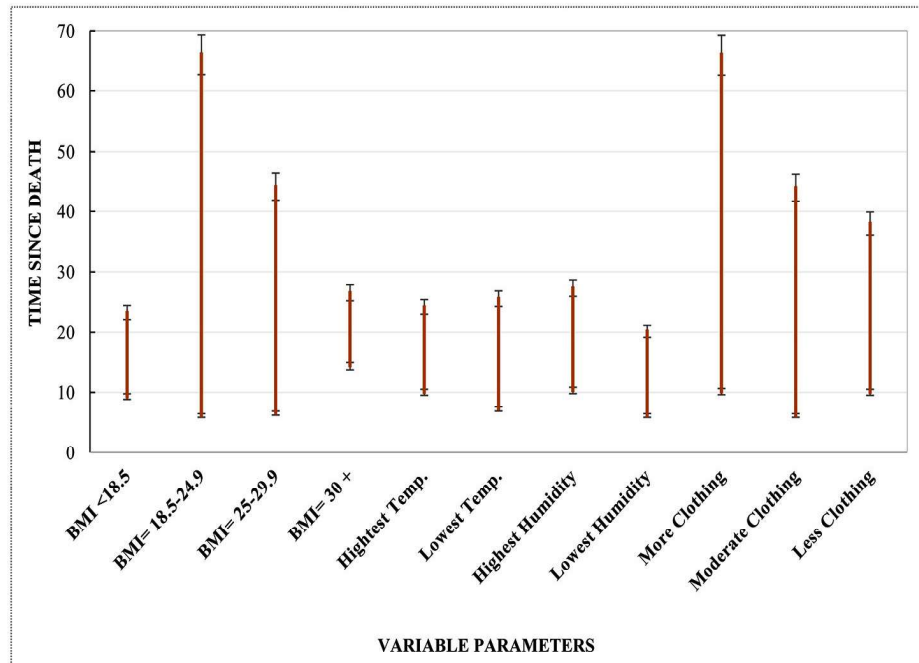


Fig. 3: Relationship between variable parameters like BMI, temperature, humidity and degree of clothing and, TSD in hours when completely developed rigor mortis was found.

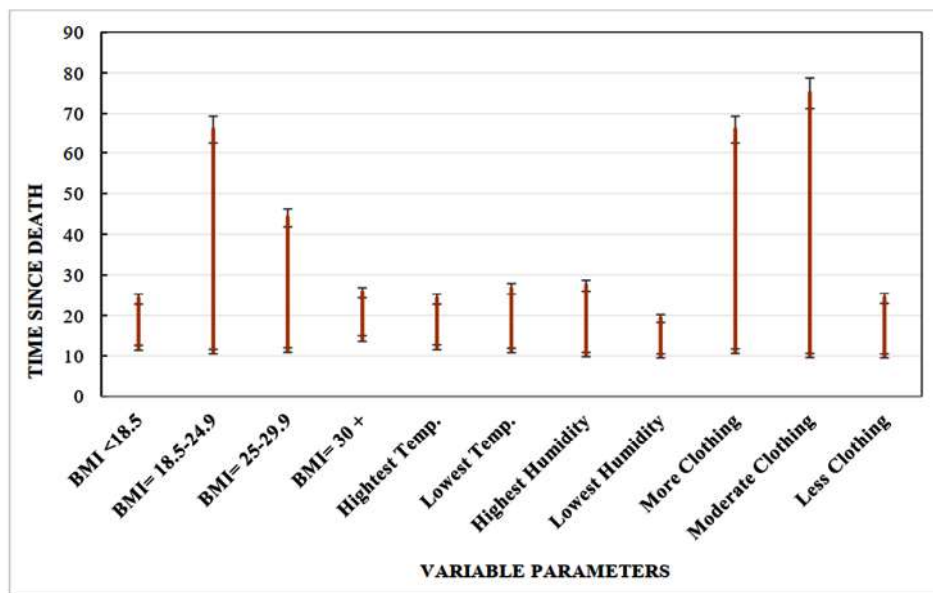


Fig. 4: Relationship between variable parameters like BMI, temperature, humidity and degree of clothing and, TSD in hours when completely developed livor mortis was found.

Body Mass Index

The body mass index (BMI) is a fraction of height and weight that is used to calculate the amount of fatty tissue in adult men and women. BMI was determined by using the following formula: weight (kg) divided by square of the height (m). BMIs were classified as underweight (<18.5 kg/m²), healthy weight (18.5–24.9 kg/m²), overweight (25.0–29.9

kg/m²), and obese (≥30.0 kg/m²).^{10,11}

Out of 102 cadavers, 6 underweight cadavers exhibited completely established rigor mortis in the least TSD of 9 hrs and 30 min, and the highest time after death at 23 hrs and 25 min 58 cadavers with normal weight had a minimum TSD of 6 hrs 12 min and a maximum TSD of 66 hrs 7 min, whereas 32 cadavers with overweight had a minimum TSD

of 6 hrs 50 min and a maximum TSD of 44 hrs 17 min, which had fully developed rigor mortis. 6 obese cadavers acquired completely developed rigor mortis at a minimum of 14 hrs 31 min and a maximum of 26 hrs 53 min after death.

Underweight cadavers with nonfixed lividity were recognized at a maximum time of hrs 30 min after death and were entirely fixed after 12 hrs; moreover, the longest duration after death at which lividity stayed fixed was found at 24 hrs. Although lividity was not fixed at 3 hrs 38 min after death in normal weight cadaver, it was fixed at 11 hrs 6 min and found remained fixed at 66 hrs 7 min after death. In overweight cadavers, 5 hrs 30 min after death lividity was not found to be fixed but it was found to be fixed at 11 hrs 45 min and found remained fixed at the maximum time since the death of 44 hrs. During this study, no cadaver with obesity were found with unfixed lividity, whereas fully fixed lividity was found at 14 hrs 31 min, and the highest duration was 25 hrs 53 min after death of a cadaver when lividity was determined to be fixed.

Temperature

Temperatures ranged from 4°C to 33°C throughout the research period. Rigor mortis was observed to be completely formed on the lowest temperature day, with the least TSD at 7 hrs and 20 min and the highest TSD at 25 hrs and 57 min. On the other hand, on the hottest day, the minimum TSD was 10 hrs and the maximum was 24 hrs and 19 min. During the lowest temperature days, lividity was not completely fixed up to 9 hrs after death but was found to be completely fixed after 11 hrs 35 min and remained fixed until 26 hrs 53 min whilst on the highest temperature days, lividity was not completely fixed up to 10 hrs after death but was completely fixed after 12 hrs 14 min and stay fixed until 24 hrs after death.

Humidity

During this study, the relative maximum and minimum humidity levels were 98% and 27%, respectively. On maximum relative humidity days, rigor mortis was completely established, with the shortest period after death being 10 hrs 30 min and the longest being 27 hrs 31 min, and on minimum relative humidity days, the longest time after death

was 20 hrs 15 min and the shortest was 6 hrs 12 min. On highest relative humidity days, lividity was not completely fixed until 7 hrs 20 min after death but was completely fixed after 10 hrs 33 min and remained fixed until 27 hrs 31 min after death, whilst on lowest relative humidity days, lividity was not completely fixed until 10 hrs but was completely fixed after 10 hrs and stayed fixed until 19 hrs 24 min after death.

Clothing

Out of 102 cadavers, 13 cadavers with fewer clothes were discovered to have completely developed rigor mortis with a minimal TSD of 10 hrs and a maximal TSD of 38 hrs. Lividity was not completely fixed up to 10 hrs and is determined to be fixed after 10 hrs till 24 hrs and 13 min. 33 cadavers with moderate clothing were found to have completely developed rigor mortis with a minimal TSD of 6 hr 12 min and a maximum TSD of 44 hrs. At a minimal of 7 hrs and a maximal of 23 hrs after death, rigor mortis was found to be partially developed. More than 75 hrs after death, there was no sign of rigor mortis. Lividity was not found to be completely fixed until 10 hrs 10 min after death, and the highest duration after death when lividity was noticed to be fixed is 75 hrs. There were 28 cadavers identified with more clothing, with the lowest and highest TSD where fully developed rigor mortis was seen at 10 hrs 11 min, and 66 hrs, respectively. Lividity was not fixed up to 7 hrs 20 min after death, while the highest duration after death at which lividity was observed to be fixed was 66 hrs 7 min.

The average minimum and maximum temperature were found to be 11.08°C and 21.48°C, respectively, whilst the overall average temperature was 15.95°C. However, the relative humidity was 49.83% on average in this study. Throughout the research period, 102 cadavers were studied for rigor mortis, and all parts of the body were affected by rigor mortis in the majority of cases.

They had an average PMI of 18.67 ± 9.43 hrs. Post-mortem lividity fixation was investigated on cadavers and found that there were 21 (20.59%) cases of post-mortem lividity that had not yet been fixed before or at 10 hrs after death, while 76 (74.51%) cases of postmortem lividity had already been fixed after 10 hrs. 5 (4.9%) cases of post-

mortem lividity were found to be not observable.

DISCUSSION

Temperature and humidity levels fluctuated significantly over the research period. During this research, the lowest temperature was recorded at 4°C, and the highest temperature was recorded at 33°C, with the average minimum temperature and average maximum temperature being 11.08°C and 21.48°C, respectively. The lowest and highest relative humidity measurements, respectively, were 27% and 98%. It was noticed that the minimum average relative humidity was 64% and the maximum average relative humidity was 83% over the research period. Due to the fact that this examination took place during the winter, we classified the cadavers into four categories depending on their amount of clothing. Among those under investigation, 31% of cadavers had more clothing; 37% had moderate clothing, 15% had less clothing, and 17% had no clothing. More clothing here refers to winter clothing, which is comprised of 2-3 layers of normal and warm clothing, medium clothing consists of one layer of warm clothing in addition to basic normal clothing, and less clothing encompasses a layer of normal clothing and/or undergarments.

It was found that 102 cadavers stored at room temperature were analysed in this investigation. Of these, 77% were male, and 23% were female. The study found that the majority of male cases were between the ages of 21 to 40 years (46.27%), followed by those between the ages of 41 to 60 years (20.89%), 61 to 80 years (18.27%), and 0 to 20 years (14.57%). 42.86% of the female cases (i.e., maximum number) fell between the age ranges of 21 to 40 years, with the remainder falling within the ranges of 0 to 20 years (35.71%) and 41 to 60 years (21.43%). Based on police inquest data, we found that 83% of cases came from rural areas around Varanasi, whilst 17% came from urban areas. Roadways were the most common location of incidents, accounting for 49.5% of all incidents, followed by residences at 31.07% and 19.43% others. The most common cause of death was accidental (68.14%), followed by suicide (23.07%), homicidal (3.86%), and natural death (4.93%). In 102 cases, 4.9% of people were underweight, 62.75% were normal weight, 26.47% were overweight, and 5.88% were obese in contexts

of BMI of the cadavers.

Rigor and livor mortis were tested using simple methods that were straightforward to repeat. Even if it is impossible to get an accurate qualitative analysis from these procedures, they are the most prevalent method employed for the inspection of dead bodies on a day-to-day basis, as detailed in certain publications.^{1,2,12}

Lividity, also known as livor mortis, is a dark purple coloration of the skin induced by blood accumulating in the affected area. At around 8 to 12 hrs, livor mortis occurs not only as a consequence of blood pooling in the vessels but also as a result of blood seeping into surrounding tissues owing to vessel wall disintegration and hemolysis; this precludes blanching in response to finger pressure. Therefore, finger pressure will produce no color change in advanced livor mortis. This condition is known as fixed livor mortis. This helps determine how long it has been since the death and whether or not the body has been moved after death.^{13,14}

Arikeri et al.¹⁵ performed a prospective cross-sectional descriptive study for six months at the mortuary of a tertiary care teaching hospital. In their investigation, the lividity was fixed after 9–18 hrs. The study found the earliest fixation of post-mortem staining at 4 hrs after death and the longest fixation at 21 hrs after death. From September 2016–March 2018, Ranjan et al.¹⁶ conducted a prospective and observational study at IGIMS mortuary in the central Patna region. They observed that lividity was fully established and fixed in all cadavers assessed between 6 to 24 hrs following death. Rayamane et al.¹⁷ also published a study on livor mortis and reported that postmortem lividity was fixed between 7 and 9 hrs since the death. Myofibrils in the muscles of the deceased are chemically altered, resulting in rigor mortis, a postmortem stiffening of the muscles. Numerous variables influence the onset and duration of rigor mortis. When assessing the TSD in India, circumstances are different than in temperate nations. According to Indian textbooks, rigor mortis initiates in 2-3 hrs, develops in approximately 12 hrs, stays for a further 12 hrs, and thereafter passes away in around 12 hrs.¹⁸

Joshi et al.¹⁹ conducted research between May and August in a tertiary care hospital in the Malwa province of Punjab, India, to estimate the TSD by

rigor mortis. The minimum average temperature in their research was 33.7°C and the maximum average temperature was 41.3°C, however, the average humidity fluctuated from 62.6% to 29.3%. They reported that the longest and shortest PMIs were 43 and 10 hrs, respectively. Sugatha and Ramana² performed research to evaluate the TSD by applying the rigor mortis approach during autopsies performed at Osmania General Hospital's mortuary. They observed that from October to December, completely developed rigor mortis persisted from 16 hrs 25 min to 61 hrs 5 min whilst from January to March it remained from 19 hrs 5 min to 50 hrs 15 min. The highest temperature varied from 13.6°C to 35.4°C over these months, whilst the lowest temperature ranged from 2.6°C to 20°C, with a relative humidity of 97% to 65%. Varetto and Curto²⁰ examined the knee mobility of 146 bodies held at a constant temperature of 4°C at Torino's city mortuary. They revealed that complete rigor persisted for a minimum of 10 days in all of the cadavers retain under examination, and in one cadaver, rigor persisted for 16 days.

CONCLUSION

Assessment of time since death, or post mortem interval, is helpful for the purpose of clarifying potential criminal conduct and deciding suitable civil repercussions. Early post-mortem physiological changes, such as livor mortis and rigor mortis, have minimal predictive potential due to the effect of different contributory variables on the development of rigor and fixation of lividity. India's climate is more unpredictable than that of temperate nations. So, it is crucial to consider this data whenever a cadaver is discovered under comparable environmental conditions to those used in our study to avoid being misled by variations in the development of rigor mortis and fixation of livor mortis when assessing the time of death.

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Ethical clearance: Nil

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