Hypostasis and Time Since Death

State of the Art in Italy and a Novel Approach for an Operative Instrumental Protocol

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Abstract: Hypostasis is a common postmortem change, whose presence or absence is used by forensic pathologists as a means of determining the approximate time of death. This assessment plays a primary role in Italian forensic practice, but blanching of hypostasis is still estimated only on the basis of subjective impressions. To understand how forensic pathologists test livor mortis on the crime scene and during forensic daily practice in Italy, an inquiry was made into lividity testing. Subsequently, with the aim of proposing a more objective approach, a study on postmortem lividity was performed; 101 cadavers were analyzed, and the color of hypostasis was measured by a colorimeter. Different conditions of time and pressure on hypostasis were tested. Linear regression analysis was performed to determine the relationship between postmortem interval and the color of the skin after a predefined intensity and duration of pressure. Herein we propose a novel operative instrumental protocol using new, more standardized conditions for the analysis of hypostasis, thus providing pathologists with a more rigorous approach to postmortem interval estimation.

Key Words: forensic pathology, hypostasis, conventional method, new method, time since death

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A recurrent problem in forensic medicine is the need to fix the time of death within the limits of probability. Postmortem changes are strongly influenced by unpredictable endogenous and environmental factors, and so it is self-evident that the longer the postmortem interval (PMI), the less precise the estimation of the time of death will be.

Like algor and rigor mortis, livor mortis is usefully and widely adopted to estimate the PMI,[1] and this is common daily practice in Italy. Lividity is a dark purple discoloration of the skin resulting from the gravitational pooling of blood in the veins and capillary beds of the lowest parts of the body after cessation of the circulation. The medicolegal assessment of postmortem lividity is based on its color and distribution. Visual observation is the most common method of analysis and is still widely used among forensic pathologists to assess lividity.[2] However, in view of the extreme subjectivity of visual observation and the progression of livor mortis, it is difficult to make a correct, rigorous description of the color and degree of hypostasis. Moreover, assessment of the blanching produced by applying finger pressure to lividity also relies on whether or not the pressure produces visible blanching.[2,3] Techniques based on more objective methods have already been proposed to replace this subjective evaluation of hypostasis.[4–13] The present manuscript proposes a novel operative instrumental protocol to test lividity based on colorimetric measurement of pressure-induced blanching of livor mortis, using a new, optimized standard intensity and duration of pressure.

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MATERIALS AND METHODS

Questionnaire

The first phase of the study consisted of running a survey on how hypostasis is generally evaluated. A questionnaire was administered to 35 forensic pathologists and fellows in training at a single forensic institution (Sezione di Medicina Legale, Università degli Studi di Bari). Together with the survey, a scheme of the back of the corpse, subdivided into 14 different areas of interest, was also administered; the scheme represented possible hypostasis distributions in a cadaver in supine position (Fig. 1).

The questions were as follows: (1) Which areas do you usually press to test hypostasis? (2) What finger do you use to apply pressure? (3) Do you press more than once and in more than 1 area? (4) How long do you apply pressure on the same spot? and (5) How much pressure do you apply with your finger? Then, each pathologist was asked to press on a digital scale (Acculab SVI-10A, Germany) using different amounts of pressure (designated as slight, medium, or strong); values were recorded on the digital scale. The scale was covered with a soft pad to make the perception more like that of a human body.

Subjects

During the study (conducted from January to May 2011), 101 corpses were analyzed. Their use was approved by the ethics committee of the University Hospital of Bari. Brain death was legally certified, and cadavers were admitted to the morgue of the local department of legal medicine within 2 hours after death, awaiting autopsy or funeral. The bodies had been kept in supine position, unclothed, from the time of death. The PMI was known for all cases and ranged between 30 minutes and 23 hours.

At the time of the measurements, the environmental temperature ranged from 9.4°C to 23.5°C. Humidity ranged from a minimum of 27% to a maximum of 84%.

The study group included 49 males and 52 females of ages ranging from 23 to 96 years (mean, 74.5 years). Body weight also ranged very widely, classified according to the body mass index as severely underweight (9%), underweight (18%), normal weight (34%), overweight (23%), and obese (16%). Death was due to the following natural causes not involving significant hemorrhage: tumors (26%), cardiovascular diseases (46%), infectious diseases (11%), kidney diseases (5%) gastrointestinal/dysmetabolic diseases (9%), and neurological diseases (3%). The extent of lividity was described as less marked (53%), normal (37%), and intense 10 (10%) (Table 1).

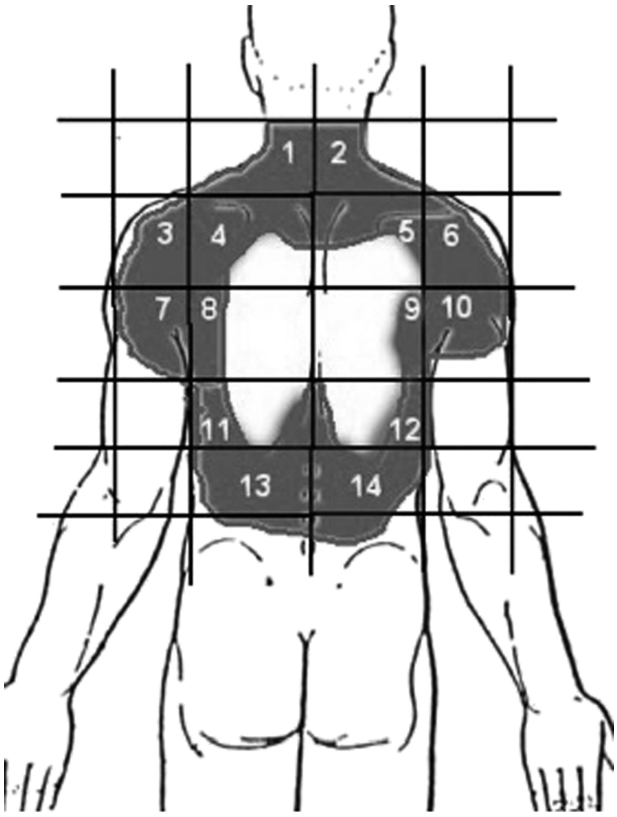

FIGURE 1. Scheme of the hypostasis distribution in a cadaver in supine position used in the questionnaire.

Instruments

A dynamometer (NK-500 Analog Force Gauge) with a maximum load capacity of 50 kg/cm^2 was used for pressure measurements. A digital chronometer was used to calculate the duration of each pressure. For colorimetric assessment, we chose the X-Rite 404 Color Reflection Densitometer, an instrument that measures color differences based on the spectral method.

Measurement Procedure

Corpses were turned over from supine position to 1 side, and specific sites on the dorsal thorax and lumbar regions were selected for measurements (areas 1, 4, 8, 11, and 13, as shown in the body scheme; Fig. 1). Skin without postmortem lividity was used as control.

It is well known in forensic practice that livor mortis becomes fixed after several hours (12 or so, depending on the reference and the circumstance). When livor mortis is not yet fixed, this is demonstrated by applying pressure (usually finger pressure) to a dependent discolored area and noting the subsequent blanching at the point of pressure; after removing the pressure, the blanched area refills with blood. Lividity can be considered nearly fixed if blanching is not easily produced when pressure is applied or fixed if finger pressure cannot produce blanching.

Values of the skin color were measured with the colorimeter (optic density was used as the unit for the measurements) in each selected area before the application of pressure. Readings were also made in sites with no sign of hypostasis, and these values were defined as "blank" values.

Measurements were then made on the selected areas by pressing the measuring head of the dynamometer by hand up against the skin surface. The intensity of pressure applied started at 0.5 kg/cm^2 (minimum value) up to 10 kg/cm^2 (maximum value; intermediate values: 1.5, 2.7, 3.5, and 4.3 kg/cm^2), whereas the duration of the application varied from 1 to 10 seconds (intermediate values: 3, 5, 7 seconds).

The colorimeter was then applied to the pressed region so that contact of the aperture with the skin was achieved with minimal pressure (the instrument was calibrated just before each measurement). Subsequent readings of the skin color were taken at the same location, applying a progressively increasing force with the dynamometer, as well as an increasing duration of the pressure. Measurements were stopped when blanching reached the blank value, with a cutoff of 0.07 optic density.

The measurements were recorded in a file together with the following information: day and hour of measurements, personal data of each subject, body size, hypostasis extent, environmental temperature, humidity, cause of death, PMI, and time needed for refilling after application of pressure in standard conditions (2.7 kg/cm^2 for 3 seconds in area 4; Fig. 2).

RESULTS

The results of the questionnaire showed that forensic pathologists perform hypostasis evaluation and apply pressure on the basis of personal experience and personal methods (Table 2).

From the data collected, it was generally observed that when the hypostasis was mobile or confluent, a low-pressure intensity (<2.7 kg/cm^2) and a short duration (1 seconds) were sufficient to determine a colorimetric value comparable to the blank value of more or less 0.07 (our control); in the same condition, refilling time was less than 60 seconds. When lividity was nearly fixed, the intensity and duration of the specific pressure required to reach the blank value were higher (>2.7 kg/cm^2), and the mean time of application was 3 to 5 seconds; in this condition, refilling time was between 60 and 120 seconds. When lividity was fixed, the pressure needed to induce blanching of the livor mortis was greater than 2.7 kg/cm^2 with a duration of at least 7 to 10 seconds; refilling time was more than 120 seconds.

Only data collected from area 4 (an area with a higher probability of onset of hypostasis and ease of execution of the procedure because of the relative lack of hair, skin spots, and surface

TABLE 1. Distribution of Sample Classified by Age, Cause of Death, and Body Weight

Age, y	Male/Female	Cause of Death	n (%)	Body Weight	n (%)	Hypostasis Extent	n (%)
0–30	1/0	Tumors	26 (26)	Severely underweight	9 (9)	Absent	0 (0)
31–50	3/3	Cardiovascular diseases	47 (46)	Underweight	18 (18)	Less marked	54 (53)
51–60	6/6	Infectious diseases	11 (11)	Normal weight	35 (34)	Normal	37 (37)
61–80	30/20	Kidney diseases	5 (5)	Overweight	23 (23)	Intense	10 (10)
>81	13/19	Gastrointestinal/dysmetabolic diseases	9 (9)	Obese	16 (16)		
Total	101	Neurological diseases	3 (3)				

DATE OF MEASUREMENT _____

CASE N°_____ NAME_____ AGE_____ SEX [M] [F]

BODY SIZE: severely underweight [ ]; normal weight [ ]; over weight [ ]; obese [ ]

HYPOSTASIS EXTENT: absent [ ]; less marked [ ]; normal [ ]; intense [ ]

CAUSE OF DEATH_____

TIME OF DEATH_____; environmental temperature _____°C; humidity _____%

TIME OF MEASUREMENT:

1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th

(every hour for the first 6 hours, then every two hours)

BLANK_____;

REFILLING TIME

zone	hypost. at 0 Kg/cm2	Kg/cm²x3sec	sec
4		2.7x3	

	PRESSURE (KG/CM²)							
Area	0.5	1.5	2.7	3.5	4.3	10	hypost. at 0 Kg/cm²	duration of pressure (sec)
1								1
1								3
1								5
1								7
1								10
4								1
4								3
4								5
4								7
4								10
8								1
8								3
8								5
8								7
8								10
11								1
11								3
11								5
11								7
11								10
13								1
13								3
13								5
13								7
13								10

FIGURE 2. Scheme of the form used to collect data during the analysis. Values of the color of the skin after applying pressure were measured with the colorimeter in selected areas and reported in the table for each cadaver.

irregularities due to bones) were considered for the subsequent statistical analyses. Among the specimens, 16 cases did not show any lividity in area 4, so the data collection and statistical processing were restricted to 86 cases.

Pressure-induced changes in the skin color were analyzed for all the different pressure intensities (0.5, 1.5, 2.7, 3.5, 4.3, and 10.0 kg/cm^2) and for all the different pressure spans (1, 3, 5, 7, and 10 seconds). The difference between the value of the skin color after the application of pressure and the value of the control (blank) was calculated (Δn), and the reference value was set at $\Delta n = \pm 0.07$.

We then evaluated a possible linear correlation between the PMI and the Δn reference values in each case. Linear regression analysis of the Δn reference values relative to each pressure intensity and each duration of pressure was performed.

Statistical analyses of the collected data established that the pressure intensity that determines the best correlation with the PMI was 1.5 kg/cm^2 ($P = 0.007$, Fig. 3); the best duration of pressure was 3 seconds ($P = 0.005$; Fig. 4).

DISCUSSION

The first description of livor mortis appeared in literature in 1787, when Ploucquet[14] reported lividity, referring to putrefaction. Until the twentieth century, only few authors described a time scale of lividity that could help to estimate the PMI.[15] In 1901, the first manuscripts focused on the mechanism of production of hypostasis were published.[16,17]

Up to now, the diagnosis of lividity has been based on a visual qualitative estimation of its macroscopic features and above all the color. Color is a perception, and so the assessment and description of the color of postmortem lividity have been based on subjective color recognition. Martin[18] was the first author to consider the method of applying pressure with the thumb or forceps to

TABLE 2. Results of the Questionnaire Administered to 35 Forensic Pathologists and Fellows in Training

Chosen Areas	%	Finger Used	%	Pressure Applied	%	Duration of Pressure, s	%
1	1	Right thumb	51	Light (1.52 kg/cm^2)	3	1	3
2	1	Right index	43	Medium (2.66 kg/cm^2)	68	1.5	8
3	1	Left thumb	3	Strong (4.34 kg/cm^2)	29	2	8
4	13	Left index	3			2.5	17
5	10					3	12
6	2					3.5	8
7	0					4	6
8	17					4.5	6
9	14					5	17
10	0					6	3
11	12					7.5	3
12	10					10	3
13	11					15	3
14	8					20	3

understand the degree of hypostasis; this procedure relies largely on subjective interpretation and on the experience of the observer. Despite this drawback, it is still the only method used nowadays in forensic daily practice. The results of the questionnaire administered at the beginning of our study confirm the subjectivity of the current procedure of analysis.

Livor mortis is also characterized by a great variability as a consequence of many influencing factors (body size, skin thickness, fatty tissue, blood volume, cause of death, environmental temperature, humidity, etc).

Therefore, there is clearly a need for a more objective method. Some authors have proposed new techniques to standardize test parameters, such as the intensity and duration of pressure and the degree of blanching.[4–13] Kaatsch et al[8,9] developed a new measuring system that quantifies both the pressure applied and the resultant color changes.

Our method proposes a novel approach because it combines the 2 parameters (intensity of pressure and degree of blanching) with other important elements such as the duration of pressure and the time needed to obtain the "refilling" of blanching.

Our data confirm the first findings of Hunnius et al[4] stating that the pressure required to produce blanching of livor mortis increases exponentially with time. In addition to their data, we point out that the longer the PMI, the longer the duration of pressure needed to induce blanching and the longer the refilling time.

Results of our statistical analyses suggest that a pressure of 1.5 kg/cm^2 is the most appropriate intensity of pressure to be used to induce blanching in livor mortis, whereas a duration of pressure of 3 seconds seems to be the best time of application. Based on the application of these specific optimized parameters during a forensic investigation, it may be possible to make a more objective estimation of an unknown PMI based on a more standardized analysis of the livor mortis.

Our study shows that an imprecise subjective visual observation or pressure application (intensity or duration) can be misleading and cloud not only the interpretation of data but also the reliability of the entire investigation.

The protocol proposed in this article combines both conventional and instrumental methods. Visual assessment and thumb pressure are not discarded, but they are followed by objective methods (photometric measurement of color changes as a function of pressure and time). Although a specific device that combines a colorimeter and a dynamometer is already available in some institutions,[8] this study suggests the importance of adding a chronometer to the investigator's tools.

In view of the main role played by lividity evaluation in Italian forensic practice, the knowledge obtained in this study suggests new quantitative criteria that can be used for a more reliable estimation of the PMI and lays the basis for further studies. The need for

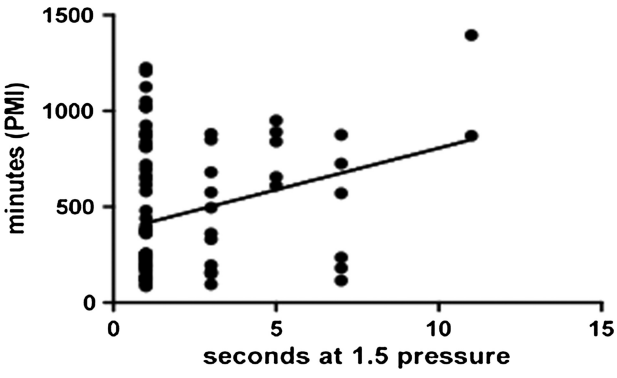

FIGURE 3. Linear regression between PMI and Δn reference values obtained with a pressure of 1.5 kg/cm^2 ($P = 0.007$).

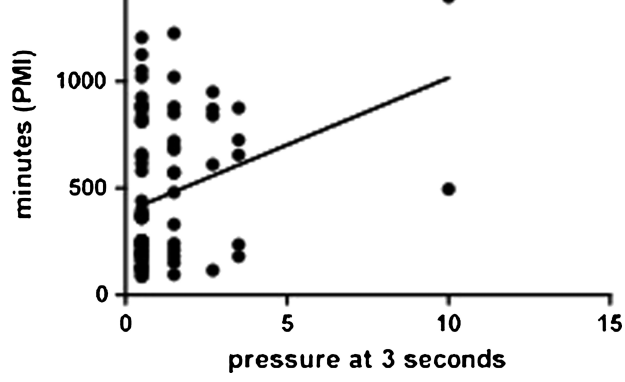

FIGURE 4. Linear regression between PMI and Δn reference values obtained with a duration of pressure of 3 seconds ($P = 0.005$).

uniformity in the forensic field in terms of data collection in lividity assessment for PMI estimation is stressed.

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