A Study in Purple and Haze

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Introduction

A number of post mortal phenomena is irreversible in time, so they can be used to deduce an indication of the post mortal interval (PMI). The PMI is defined here as the time difference between time of death and the moment of examination of the deceased.
A number of these phenomena can be characterized as a step-by-step process, so there is a possibility to use a classification. In some cases, the result of the examination itself is a number.

Phenomenon	Result	Particularity
Algor mortis	Decreasing internal temperature	Needs temperature of environment
Eye pressure	Pressure in cm Hg	Needs original eye pressure
Corneal transparency	Some classification of transparency	
Livor mortis	Classification of discolouration by pressure	By finger pressure or an instrument like a scalpel
Vitreous humour	Na/K-ratio	Sampled from the inner eye

Table 1: Some easy to classify or establish post mortal phenomena

In this article, the quantitative methods are left aside, here we are to discuss the two methods in need of some kind of classification: corneal transparency and livor mortis (lividity). Both methods were studied in some detail, without receiving a lot of attention (these studies were published in Japanese): Shiori Ogura 1982, Masataka Furukawa, Tadataka Funao and Yasushi Nagasaki 1985, Masataka Furukawa and Tadataka Funao 1985 and Masataka Furukawa, Tadataka Funao and Yasushi Nagasaki 1988. By use of a classification, they can be subjected to a more or less quantitative approach.

In this case, some precaution must be taken to cover for the weak spots of this approach in order to profit from the strong ones.

In both cases, this classification is characterised by a similar number of rather similar classes:

Phase classification	Phase in general	Phase in cornea transparency	Phase in discolouration of lividity on pressure
I	No change	Fully transparent	Complete discolouration
II	Some change	Weak turbidity	Partial discolouration
III	Serious change	Moderate turbidity	Slight discolouration
IV	Complete change	Strong turbidity	No discolouration

Table 2: Classification of subsequent phases in two post mortal phenomena. See also: Kohji Honjyo et al. 2005.

The distinction between the phases II and III is almost completely subjective and by consequence of little use. But it is rather easy to discriminate between phases when not adjacent. Furthermore phases I or IV are rather distinct.

Model approach

In a case study with only one victim, we can easily predict the format of the outcome:

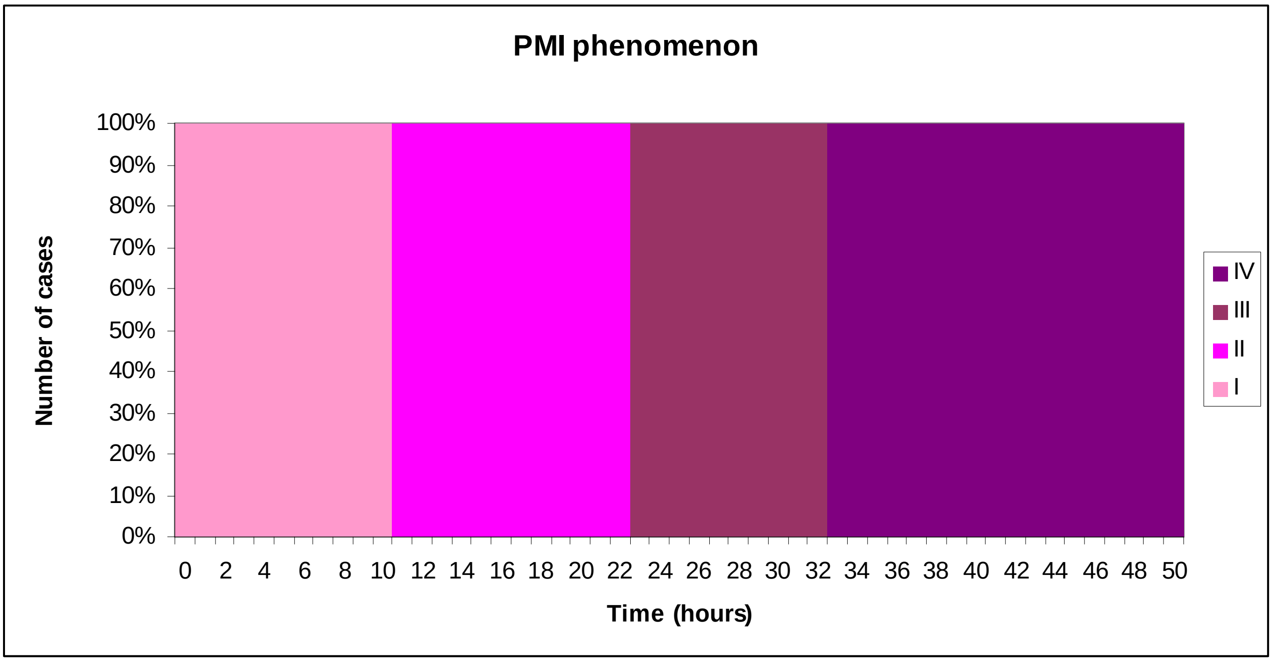

Diagram 1: Succession of phases during the study of one single PMI-case.

Studying two cases, we will find some variation in the transitions between phases:

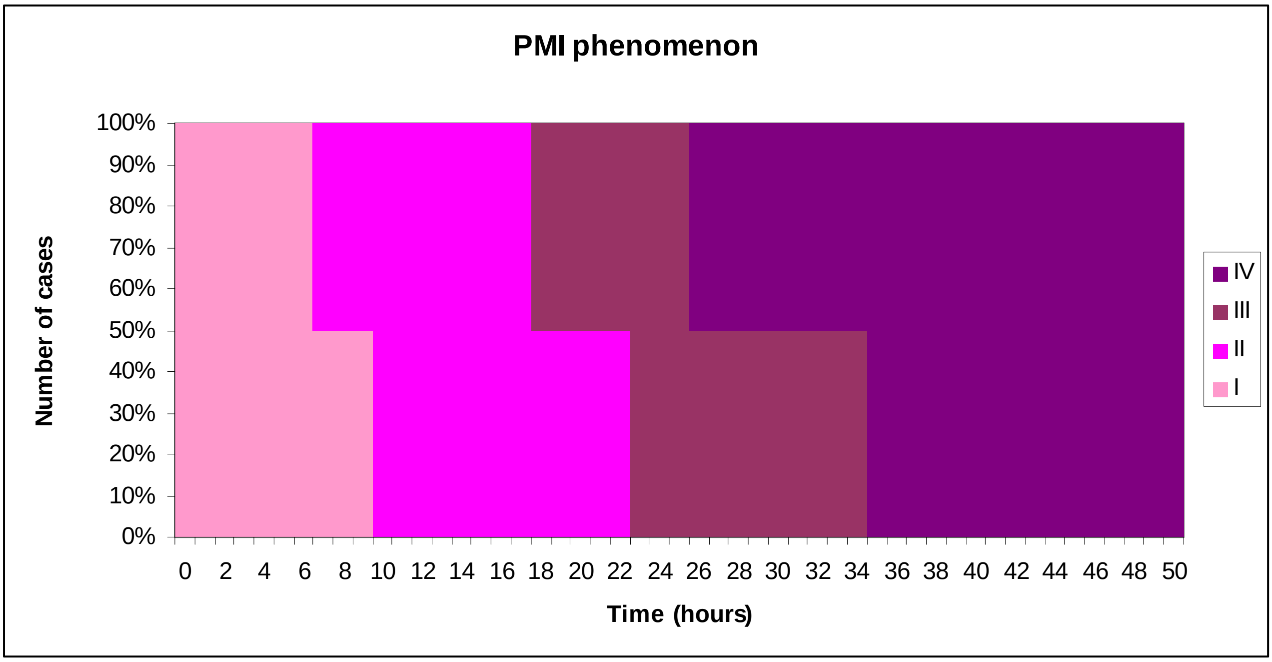

Diagram 2: Succession of phases during the study of two single PMI-cases.

Leading to a chart for hundreds of cases:

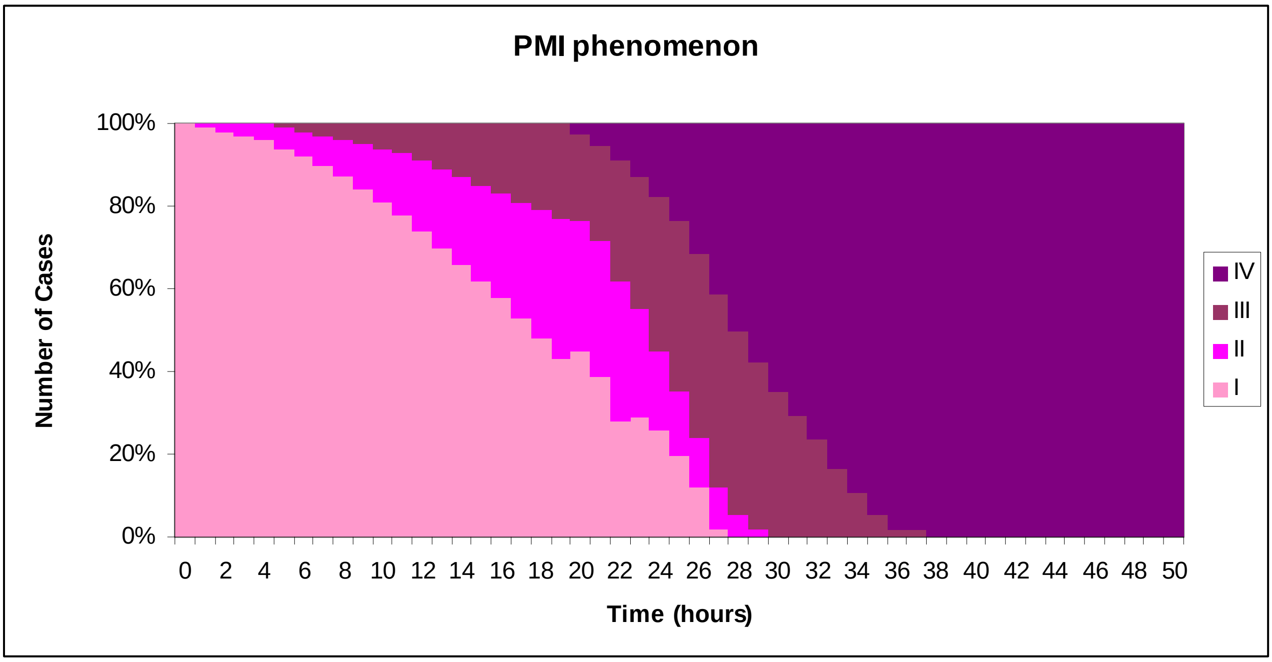

Diagram 3: Succession of phases during the study of hundreds PMI-cases. Stacked diagram.

The latter chart should resemble the unknowable reality more closely than the prior ones. From this principle, we can reconstruct this reality as good as possible, by postulating a model:

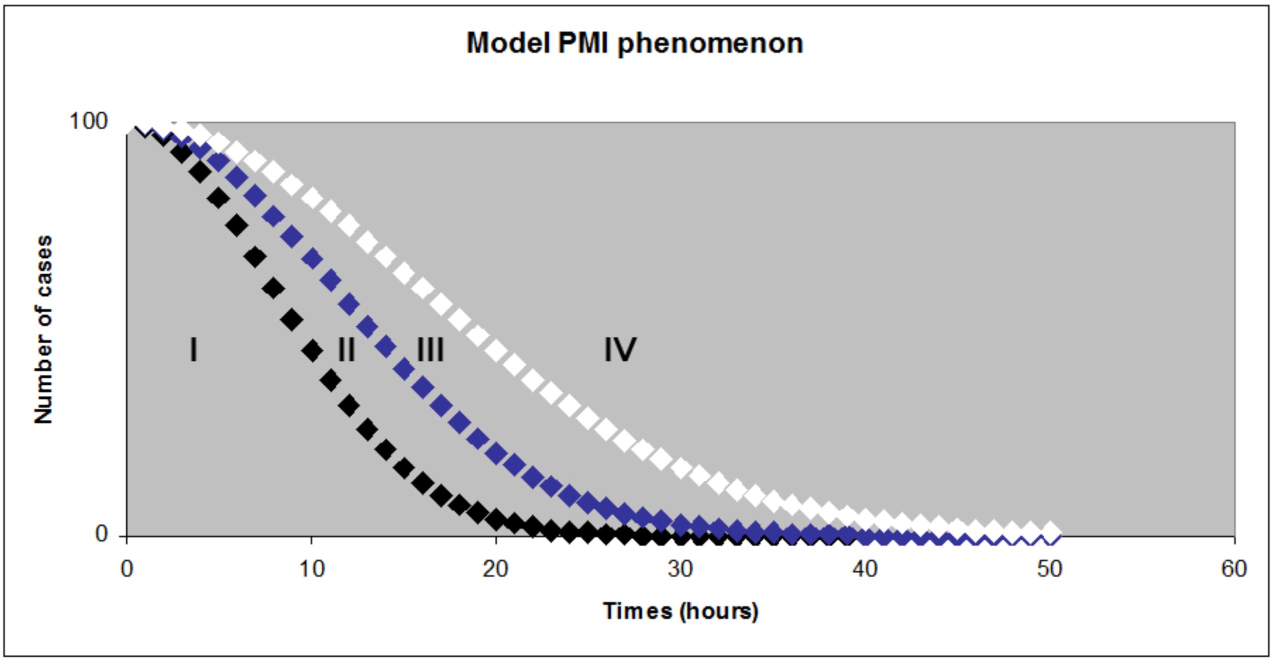

Diagram 4: A model study of phased PMI-cases n=1, m=1 see text.

In this chart, the transitions between phases are calculated, rather then the number of cases. The result is similar: the transitions appear as sigmoid curves, as is seen in the real observations and as is expected on the basis of two assumptions:

1. The rate of transition of a phase A into a phase B is proportional in some way to the number of cases in phase A (and phases prior to phase A).
2. The rate of transition increases with time.

The first condition is trivial, although it contains a necessary simplification. The second one needs explaining. A phenomenon is only the appearance of certain set of observations. Normally, the transition of one set (phase) to another will involve a great number of processes of diverse nature, but mainly biochemical. Passing through this processes will require time. So the chance of arriving at the last stage of such a train of processes will be a matter of passed time.

Mathematical approach

Mathematical, this leads to:

$$\frac{dp_a}{dt} = -b.p_a{}^n.t^m$$

where p_a stands for the number of cases in a certain phase A, including the phases prior in time; b is a constant, t is time. This leads to:

$$\int \frac{1}{p_a{}^n}\,dp_a = -b\int t^m.dt$$

which, for n=1 en m=1 solves to:

$$\ln p_a = -\frac{1}{2}b.t^2 + c^{st} \text{ so : } p_a = 100.e^{-c_a t^2},$$

because p_a travels between 100 and 0%; c_a is an appropriate constant, to be chosen with each transition for the best fit. See diagram 4.

Giving more weight to time (m=2, 3), this leads to:

$$p_a = 100.e^{-c_a t^3} \text{, etc.}$$

leading occasionally to curves with a better fit, as will be shown. See diagram 5.

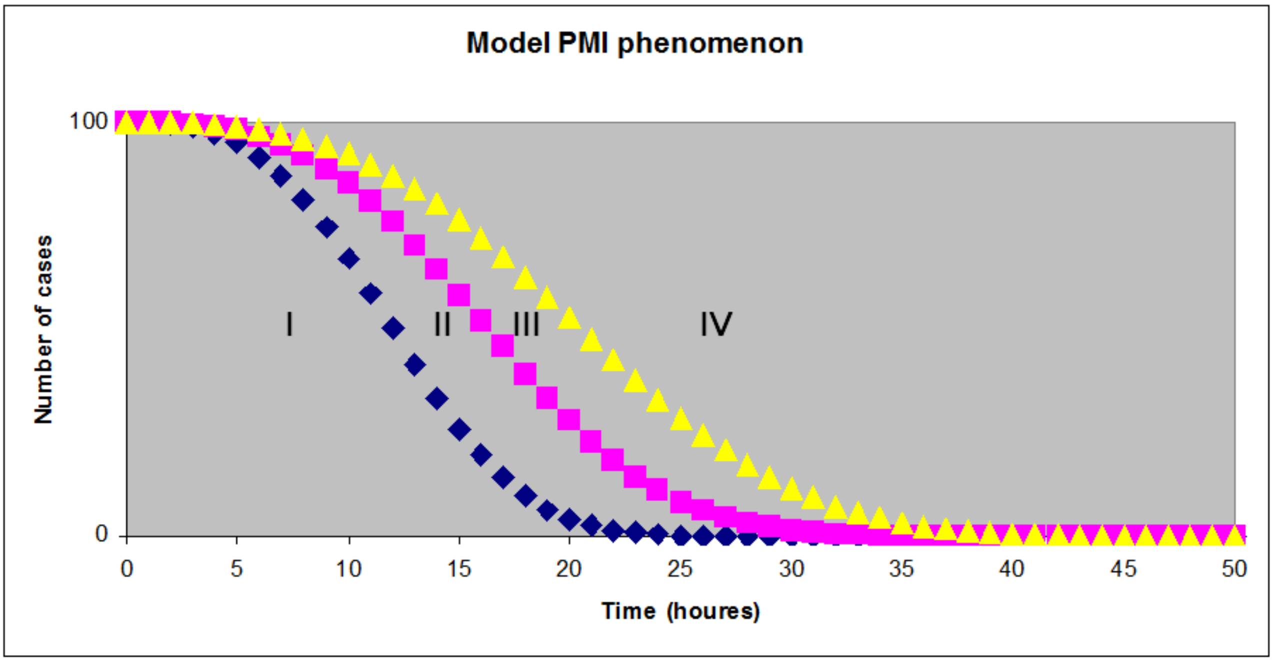

Diagram 5: A model study of phased PMI-cases n=1 m=2 see text.

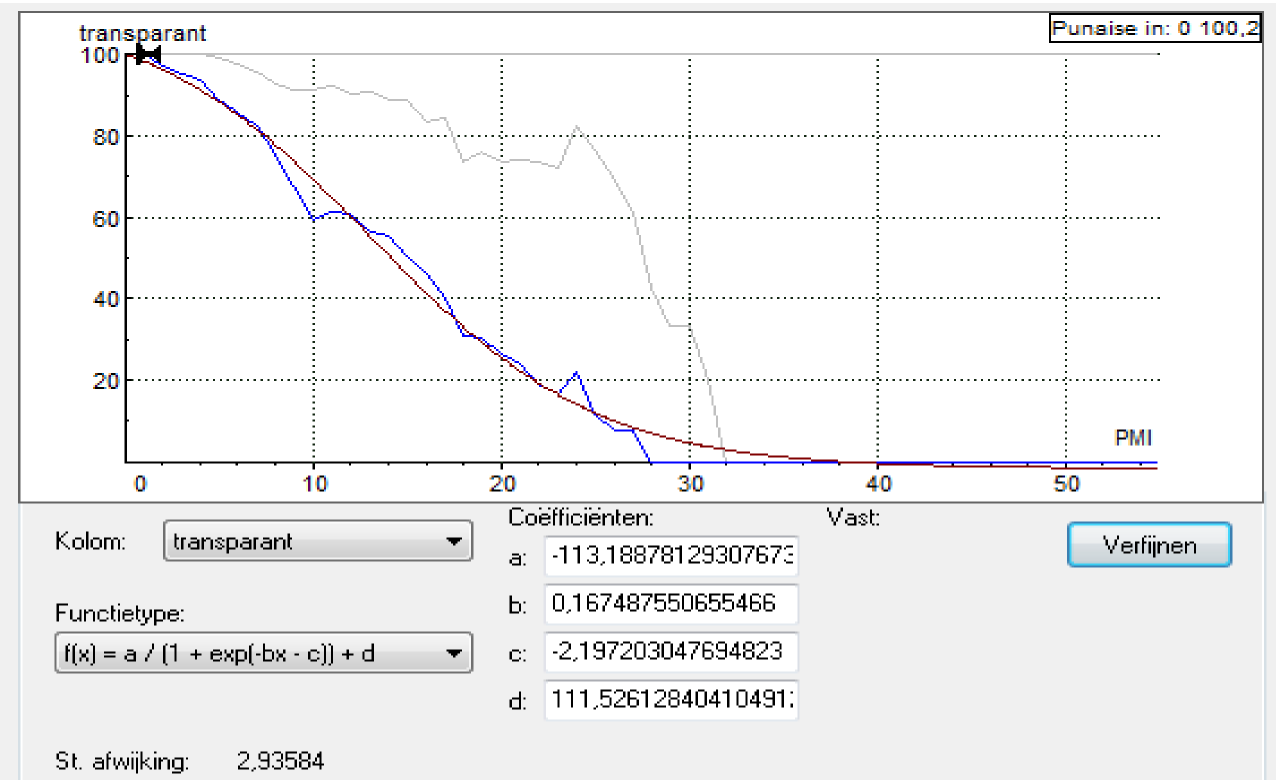

Diagram 6. Example of a statistical analysis, using the Coach 6 software.

Statistical approach

Another way to search for an extrapolation of the experimental data towards the hypothetical overall reality is using a blind fit. So regardless of any proposed model and using all sorts of functions imaginable. In this case, sigmoid functions will be suitable. The best candidate in the available application for curve-analysis (Coach 6; Centre for Microcomputer Applications 2004-2006) appeared to be the following function:

$$f(x) = \frac{a}{1+e^{-bt-c}} + d\ ,$$

of which the results are added in the discussions as 'statistical'. See diagram 6 for an example.

The case for lividity

Livor mortis (= hypostasis = lividity) sets in shortly after death. There are at least three dominant factors:

1. The heart stops, the erythrocytes tend to sink, caused by the slightly higher density
2. Respiration stops, the shortage in oxygen discolours the haemoglobin to purplish
3. Decontraction of muscles in the skin releases blood in the skin vessels

Together, they cause an striking purple pattern emerging in the dependent parts of the body.
As long as colouration is made up by the erythrocytes in narrow blood vessels, the effect can easily be pressed back, the so called discolouration by pressure, comparable to the reaction on pressing of a skin after sun burn. Later on, the purple colour leaks out of cells and vessels by autolysis and so discolouration by pressure will be impossible past some moment.

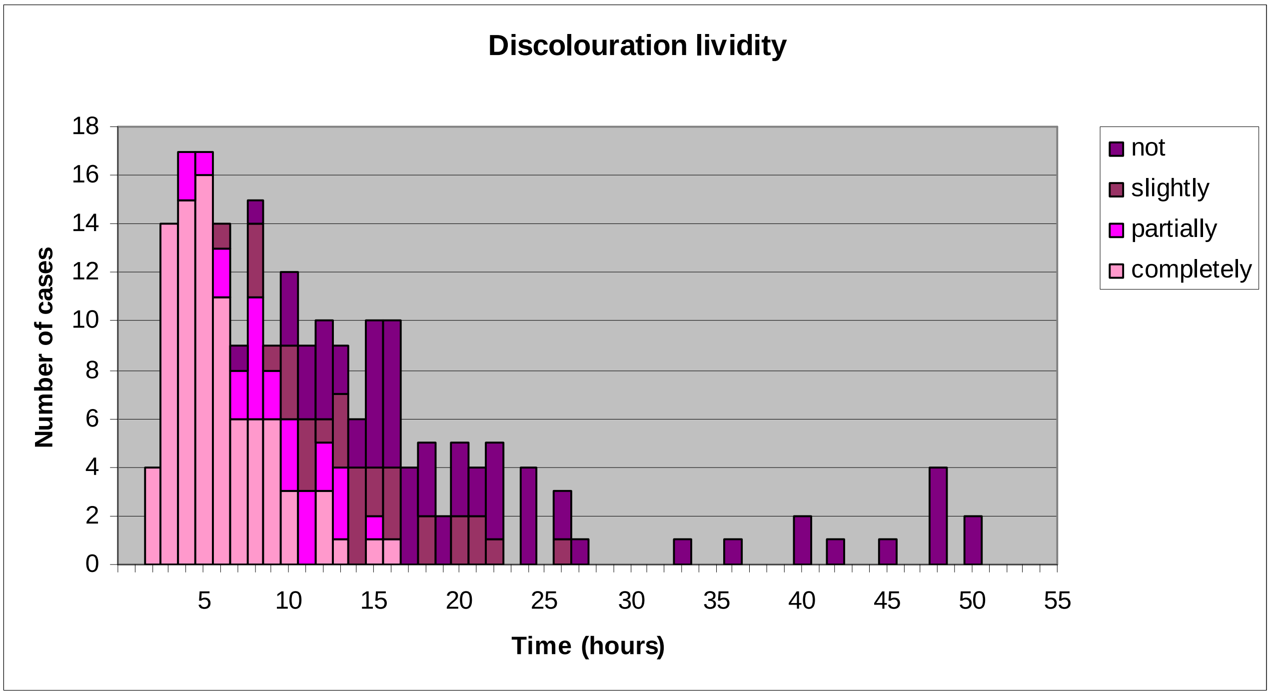

Diagram 7: Data from mentioned Japanese study.

Diagram 7 shows actual data from an investigation at Kitasato University (Masataka Furukawa and Tadataka Funao 1985) of 158 cadavers. To compose diagram 8, the data were smoothed, using overlapping timeframes of 3 hours, increasing to 12 hours with increasing PMI. The relevant fitting curves were added.

Smoothing diminishes the discriminating power of the results; in the original data, all observations past 26 hours showed complete absence of discolouration of lividity by pressure. In the smoothed data, this limit is placed at 30 hours, reasonable consequence of the apparent scarcity in observations at longer PMI. In 1988, the same team repeated the investigation, with all results (110) between the limits of the original results. The study of Kohji Honjyo et al. (2005) shows somewhat tighter results in 212 cases within the first 24 hours, so again effectively within the limits found in the present study.
By using the fits, it is now possible, to make statements about the odds of doing some observation. The parameters in the formulae are sought for, using the coach 6 software, leading to:

$$p_I = 100e^{-0{,}00106t^3} \; ; \; p_I + p_{II} = 100e^{-0{,}000484t^3} \; ; \; p_I + p_{II} + p_{III} = 100e^{-0{,}000167t^3}$$

(P_I = complete discolouration, P_{II} = partial discolouration, P_{III} = slight discolouration, P_{IV} = no discolouration, calculated as 100 - (P_I+ P_{II}+ P_{III})%)

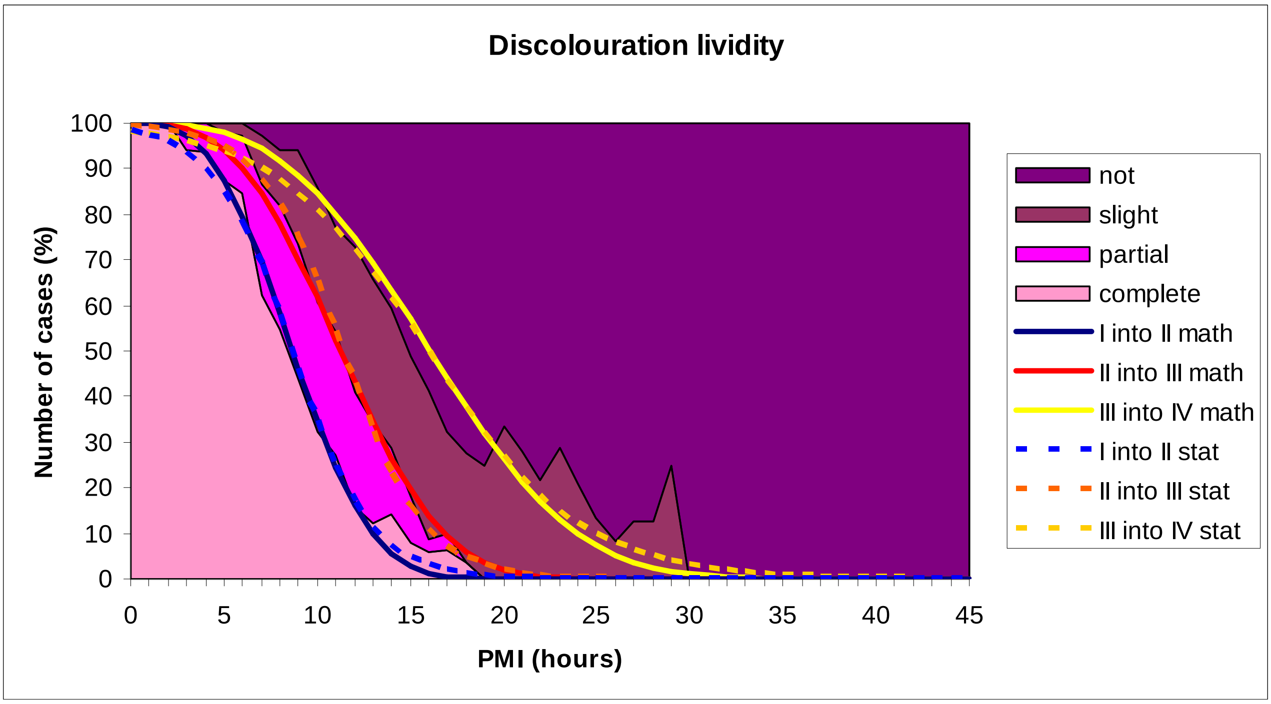

Diagram 8: Smoothed data Japanese study and proposed fitting curves.

Usability

Using this formulae, one can calculate the chance to find some degree of discolouration after for instance 20 hours:

Mathematical: P_I = 0,02%; P_{II} = 2,1% ; P_{III} = 24%; P_{IV} = 74%
Statistical: P_I = 0,5%; P_{II} = 1,5%; P_{III} = 25%; P_{IV} = 73%

As can be seen in the original data, 'no discolouration' tends to be the leading result after about 15 hours.
After 30 hours, P_I+P_{II}+P_{III} amounts to 1,1% (stat. 3,1%), after 40 hours only to 0,002% (stat. 0,3%). So some degree of discolouration can be used to fix the PMI to less then 36 hours as a rule of thumb on a solid base.

PMI-phenomena are prone to variation by temperature. Therefore, it is useful to examine the mean temperatures in the investigation area: Tokyo, Japan. They are shown in diagram 9:

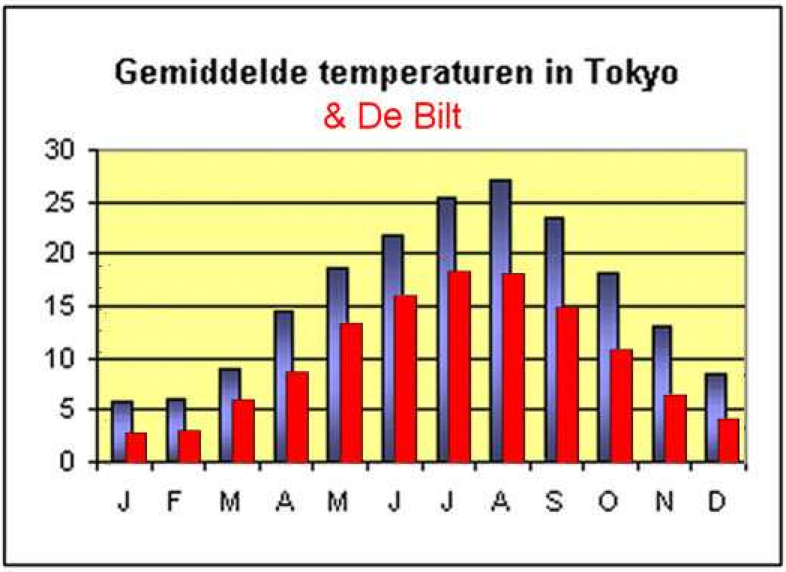

Diagram 9: Mean monthly temperatures in Tokyo and De Bilt (Netherlands).

As shown, there is much variation in temperatures in Tokyo. So the used data 'cover a lot of ground'. Only in cases, where extreme (low) temperatures are encountered, there is some reason to doubt the general outcome. The study of Kohji Honjyo et al. (2005) -also in Japan- explicitly mentions the environmental temperatures during the findings: minimum: 4.0°C; maximum: 31.0°C; mean: 18.9°C ± 6.1°C.

The case for haze

Clouding of the cornea or corneal turbidity is a PMI character in use since long. After the rise in interest of organ donations and transplantations, its main focus shifted from forensics to medical applications.
With lividity it shares its irreversibility and the opportunities of classification. It was investigated in the same Japanese institute as lividity and again in two consecutive studies. And once again it was almost forgotten (Shiori Ogura 1982; Masataka Furukawa *et al.* 1985).

The method is the same, first a diagram with 'raw' data:

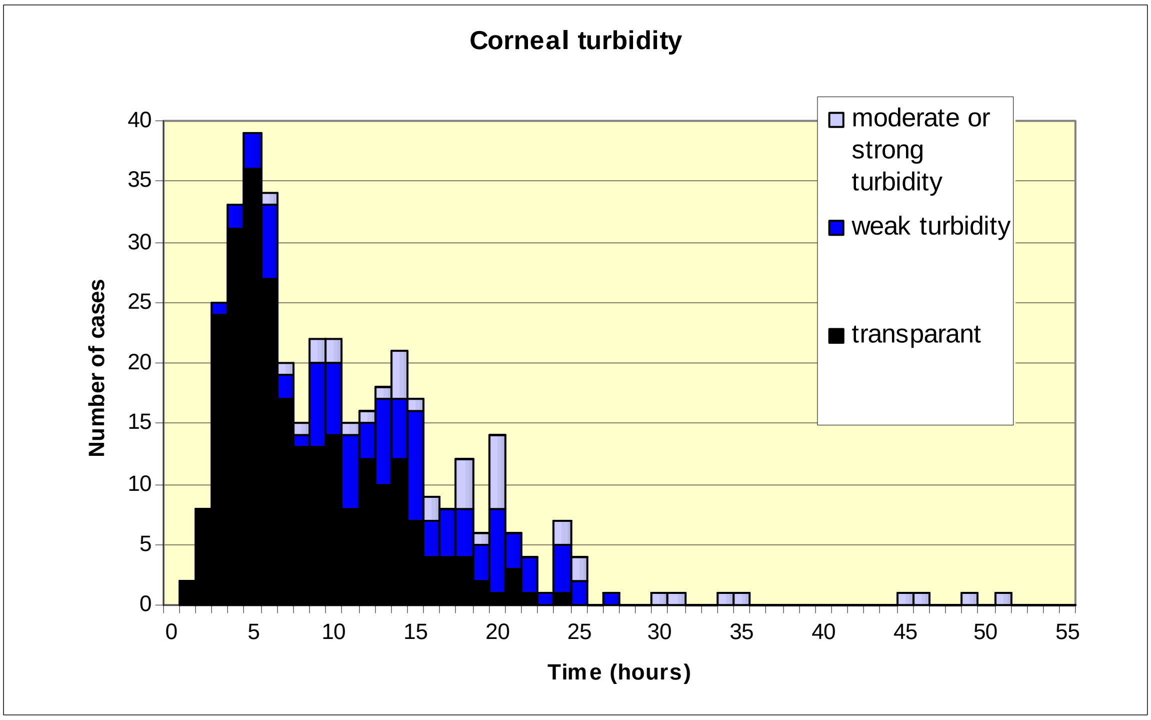

Diagram 10: Data from two studies into corneal turbidity; 388 cases.

Because of the rather limited number of observations of higher turbidity, the two 'highest' phases are lumped together.
The study was initiated, to discover a relationship between the rise of turbidity and PMI. As is seen at a glance, such a relationship does not appear. In several cases, moderate turbidity appears after only as long as 6 hours, while cases of transparency can persist even past 24 hours. The latter observation is in agreement many citations in literature, stating that the occurrence of transparency is *limited* to the first 24 to maximal 36 hours.
In a later study of 212 cases (only the first 24 hours were studied), all observations on the phases of corneal turbidity fell within the limits of the results used here (Kohji Honjyo et al. 2005).
The significance of these studies lies in the confirmation and specification of this useful conclusion and can be extended by expressing the odds of the occurrence of the phases of turbidity in numbers.
Again, the results are smoothed, and fits are sought for, using dedicated software for curve-analysis (Coach 6; Centre for Microcomputer Applications 2004-2006), leading to:

$$p_I = 100e^{-0,0035t^2} \text{ ; } p_I + p_{II} = 100e^{-0,0000015t^4}$$

To get a reasonable fit, the dependency of time had to be estimated in different ways at each transition, as is already reflected in the underlying material, see diagram 11.

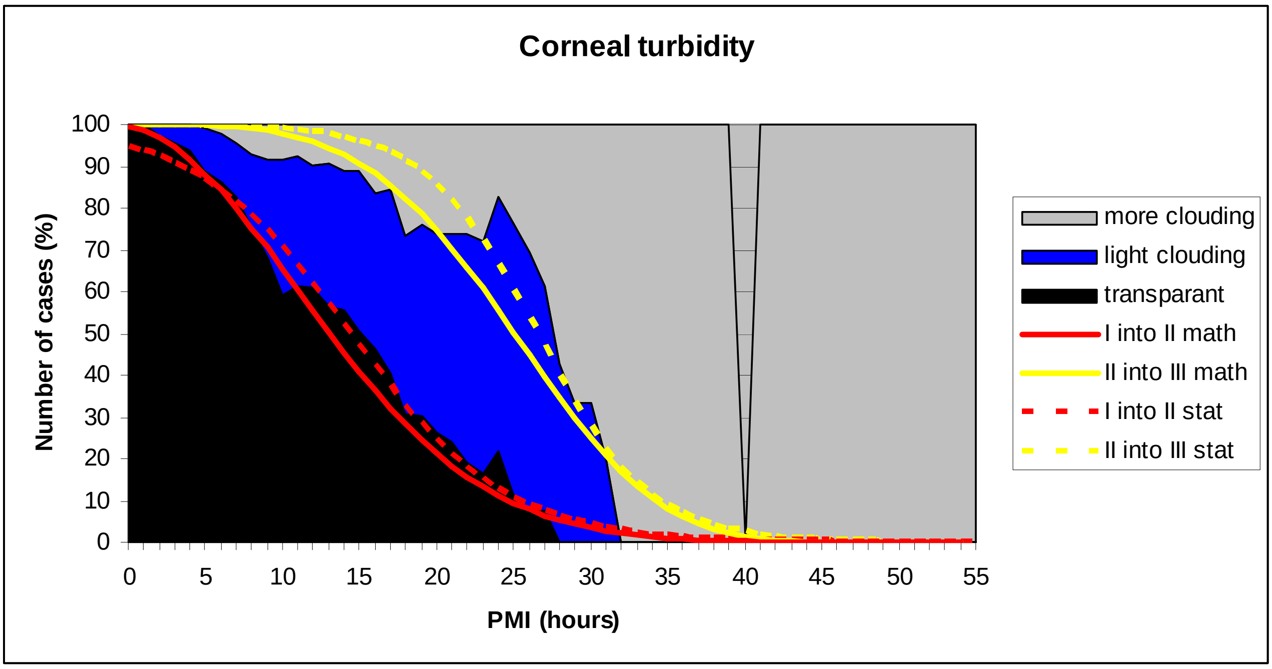

Diagram 11: Smoothed data from Japanese studies and proposed fitting curves.

Usability

Using the formulae, one can calculate the chance to find some degree of turbidity after 24 hours:

Mathematical: $P_I = 13\%$; $P_{II} = 47\%$; $P_{III} = 39\%$
Statistical: $P_I = 13\%$; $P_{II} = 54\%$; $P_{III} = 33\%$
and after 36 hours:
Mathematical: $P_I = 1{,}1\%$; $P_{II} = 7\%$; $P_{III} = 92\%$
Statistical: $P_I = 1{,}3\%$; $P_{II} = 6\%$; $P_{III} = 93\%$

From this, one might conclude that the rule of thumb, that the occurrence of transparency halts before 36 hours, is reliable.

Deventer Murder Case, an application

Corneal turbidity

At noon of Saturday September 25th 1999, the body of the widow Wittenberg was found in her house. After some investigation, the police decided, she was murdered Thursday the 23rd at about 21:00 hours. No forensics indicators were used, to reach to this conclusion. If this finding is correct, the victim was photographed after a PMI of 40 hours and her eyes looked like this:

Plate 1: Eye of the victim. Drawn after the original photograph, taken at September 25th 1999, presumably at 13:00 hours. Iris and pupil in original colours and colour intensity

Not a trace of turbidity is to be seen in the picture. Furthermore, the eye is brightly shining, suggesting a moist surface of the eye ball. And there is not a single sign of deformation by loss of pressure.

According to the model, described above, the chance to find turbidity after 40 hours is *higher then 99%*. The other observations of the eye are consistent with a PMI of only about 12 hours.
Mean temperature in the house, according to meteorological reconstructions was about 20^{o}C or higher, especially on Friday the 24th. It was an indian summer with all time high temperatures. With higher temperatures, the transitions between phases tend to occur faster, so the official time of death is even more "out of bounds".

Lividity

Clear lividity can be seen at the crime scene after the discovery of the victim. In the face and in the left hand. The distribution in the hand sticks out: it does not show a horizontal plane as separation of the lividity. Furthermore, the separation is not sharp, indicating a recent disturbance of the body (Brinkmann & Madea 2004, pag. 110). This in accordance with other findings at the crime scene.

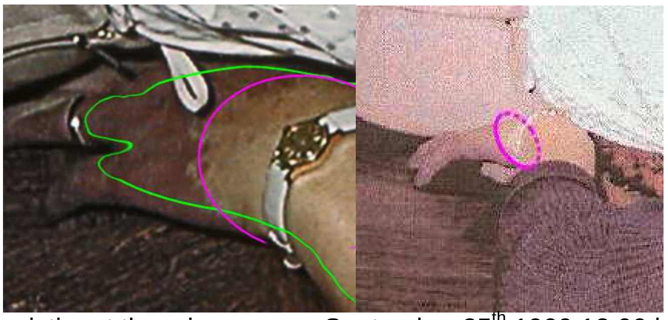

Plate 2: Left hand of the victim at the crime scene September 25th 1999 13:00 hours. Green line shows horizontal plane. Cyan line shows actual separation of zone of lividity. From another angle, the unnatural position of the hand is shown.

Later on, the victim was moved to a mortuary, and one day later autopsy was performed. So, this would be approximately 64 hours after the murder according to the police. At the occasion, the performing pathologist made an disturbing observation: the livor mortis on the back was still slightly discolouring on pressure, so it was phase III.
According to the model curve, any grade of discolouration has a chance of occurrence after only 48 hours of 10^{-6} % and the statistical curve predicts 0,04%. So this observation leads to *a sheer impossibility*.

Other indicators

What about other indicators? During the autopsy, September 26th, at noon, only the first signs of putrefaction (start of green colouring of the abdomen, absence of putrefaction in the internal organs) were discovered and at the same time a maximal rigor mortis in the jaw, both observations strongly indicating a PMI of 24-36 hours *at the time of the autopsy*. The original livor mortis pattern had disappeared, so the pattern seen at the crime scene, was not fixed yet, also indicating a time of death in the night of Friday on Saturday.

Summary

Japanese studies into two PMI-indicators reveal the possibility to classify qualitative observations into quantitative numbers. In doing so the odds to observe some phenomena after a certain amount of time can be calculated.
Thus, these indicators can be used to put limits to the presumed PMI.
Had such be done in the Deventer Murder Case, this case would have had another outcome.

Literature

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