A Study in Purple and Haze version 2015

Demo, M.Sc.

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. An early study on corneal turbidity was almost completely forgotten: B. Wroblewski & M. Ellis 1970. Later studies were published in Japanese: see table. These studies were more or less repeated by others research groups with very similar results in later years.

	study	corneal turbidity	blanching lividity	number of cases	year
A	Wroblewski et al	+		300	1970
B	Ogura	+		310	1982
C	Furukawa et al	+		74	1985
D	Funao et al		+	158	1985
E	Furukawa et al		+	110	1988
F	Honjyo et al	+	+	212	2005
G	Bath et al		+	417	2006
H	Kumar et al	+		238	2012
I	Salam et al	+	+	70	2012
J	Poposka et al		+	120	2013

Table 2: Main studies used in this review

By use of a classification, the mentioned phenomena can be subjected to a more or less quantitative approach. 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 characterized 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 3: 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:

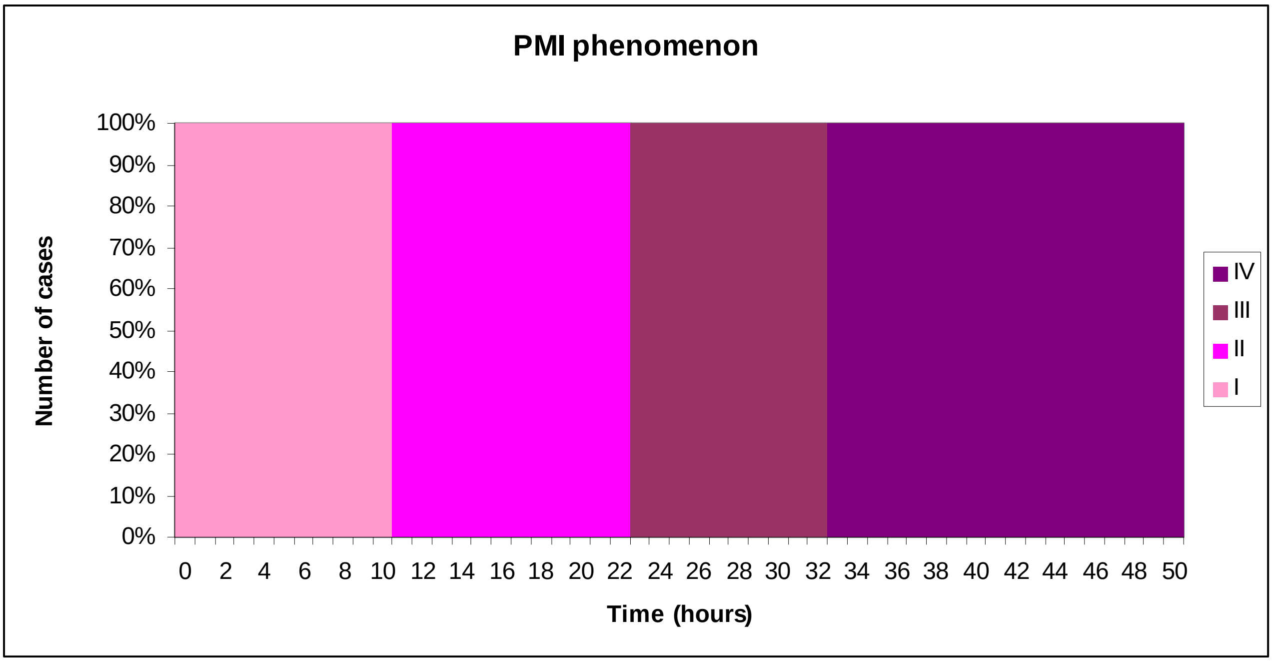


Diagram 1: Succession of phases during the study of one single PMI-case.

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

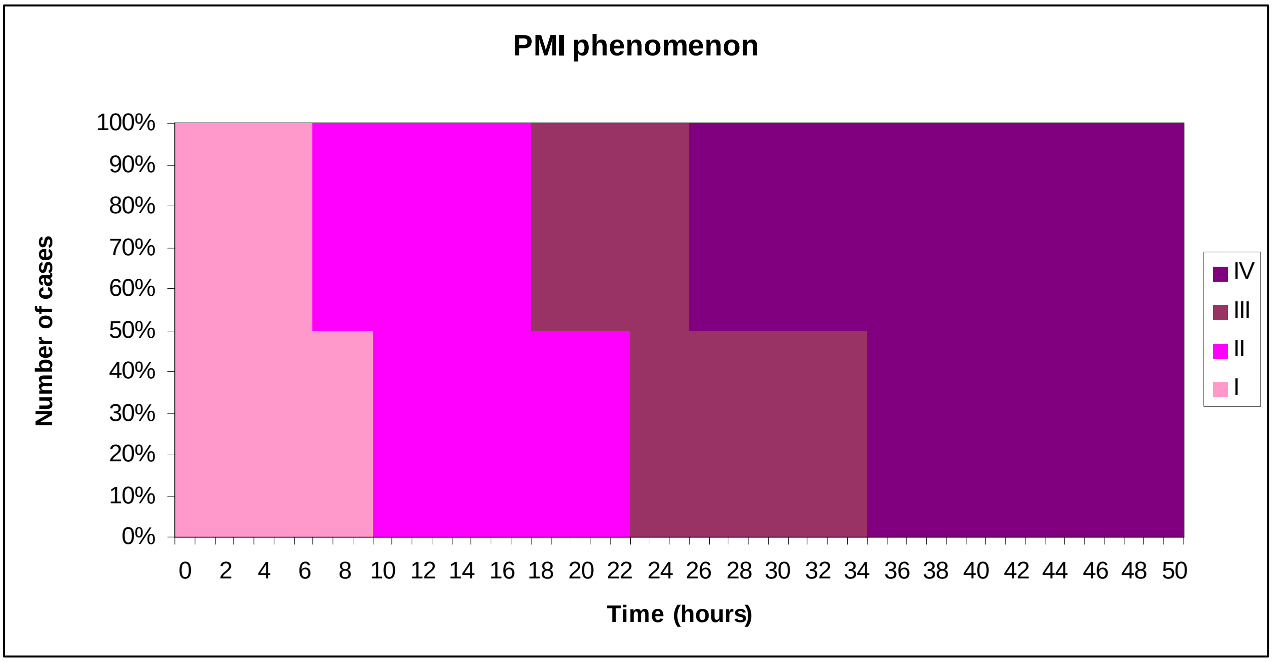


Diagram 2: Succession of phases during the study of two single PMI-cases.

Leading to a chart for hundreds of cases:

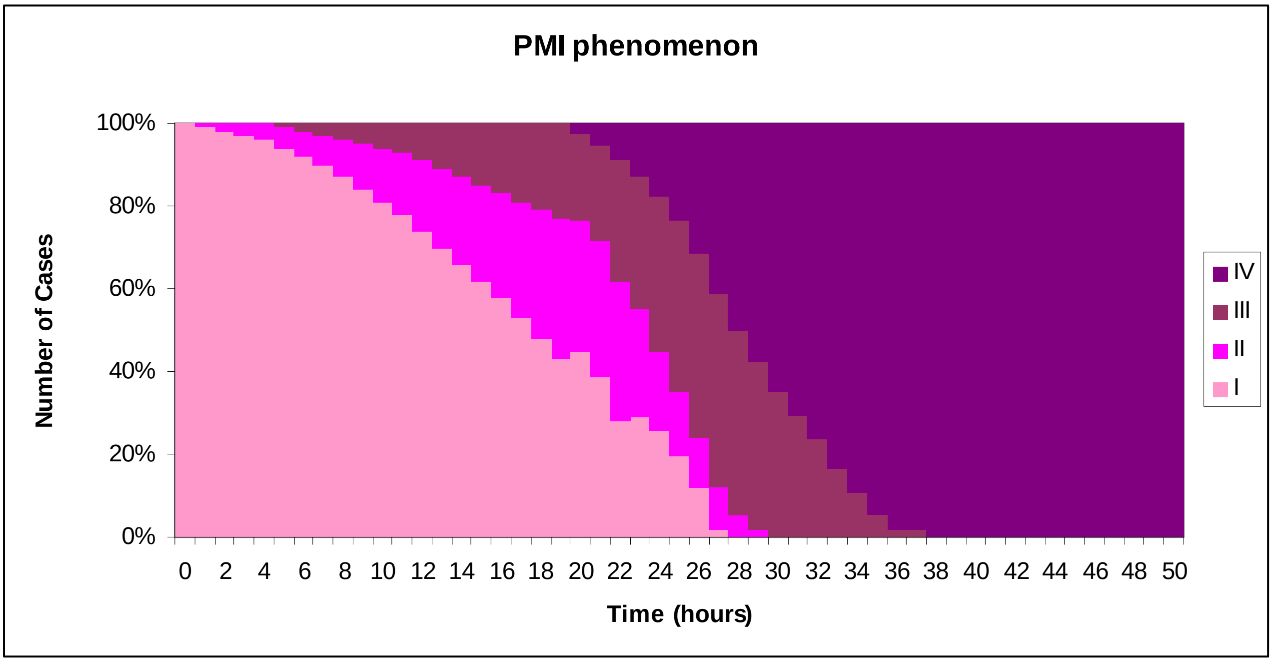


Diagram 3: Succession of phases during the study of hundreds PMI-cases. Stacked diagram.

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:

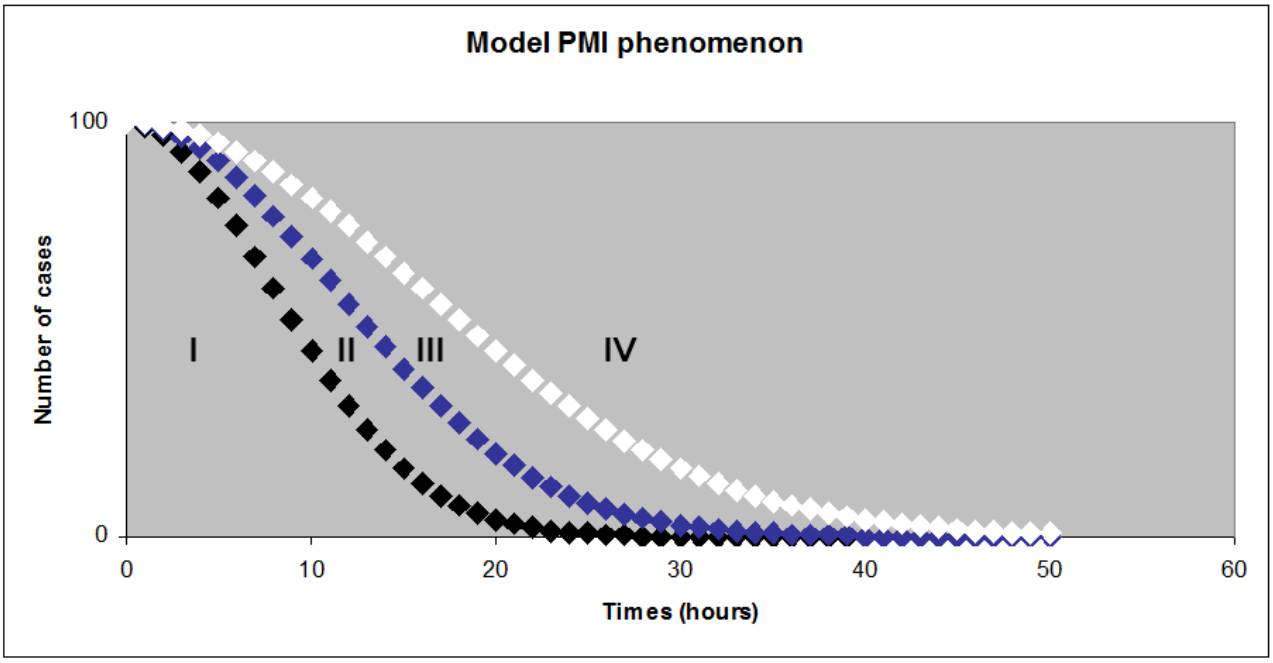


Diagram 4: A model study of phased PMI-cases n=1, m=1 see text.

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. In the described cases, a phenomenon is 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. Some transitions are catalyzed by molecules, produced post mortem (autolysis). Passing through these processes will require time. Catalytic action will increase with time. So the chance of arriving at the last stage of such a train of processes will correlate to 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 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. See diagram 5.

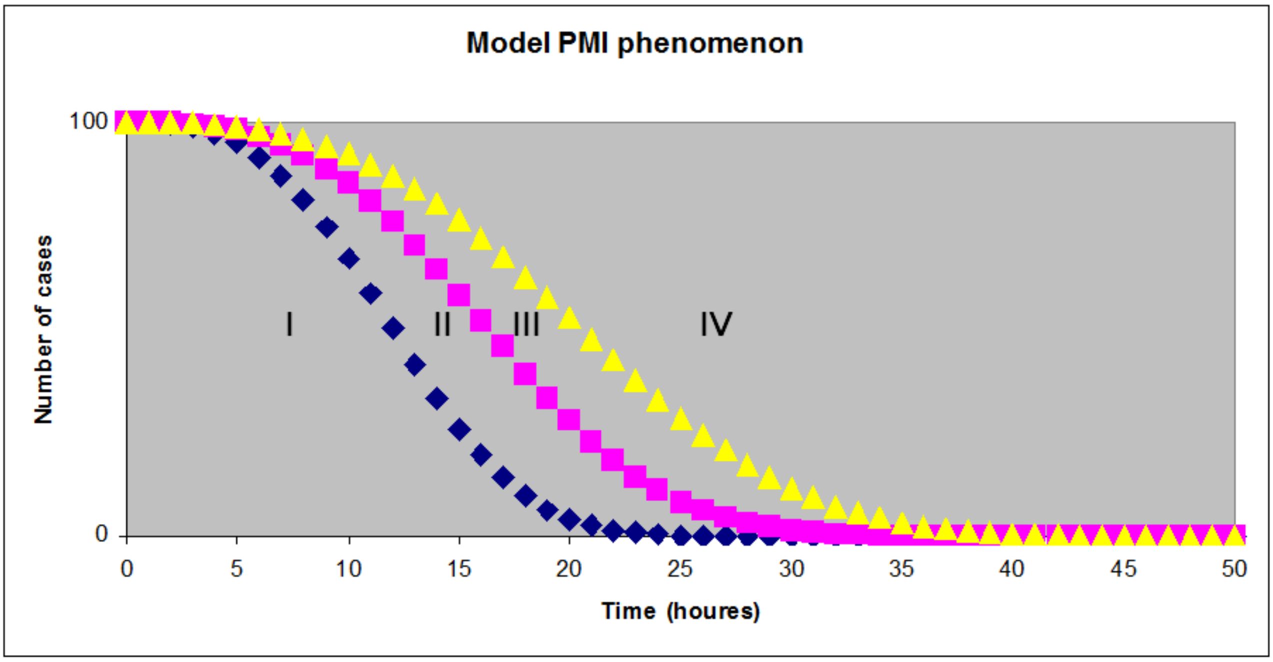


Diagram 5: A model study of phases in PMI-cases n=1 m=2 see text.

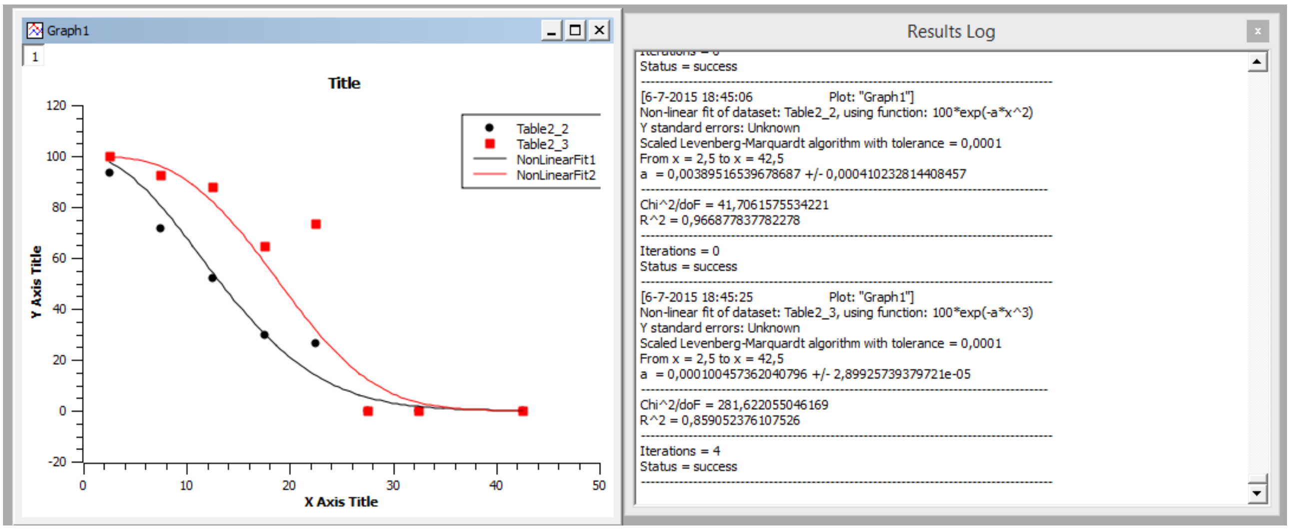


Diagram 6. Example of a statistical analysis, using the SciDAVis software. Black: percentage of transparent corneas. Red: stacked percentage of transparent and weakly clouded corneas.

Sigmoid function

As can be seen in all examples, the plots of the results are sigmoid, as are the found equations here above. They start at 100% en decay to 0% in the long run. On top of that, the plots starts with an (almost) horizontal slope and ends with a horizontal slope. So sigmoid functions will be suitable. The best candidate in the available application for curve-analysis (SciDaVis, a plotting program from sourceforge.net) appeared to be the following Boltzmann - function with is in essence a logistic function:

$$(A1-A2)/(1+\exp((x-x0)/dx))+A2$$

In our case (A1=100, A2=0), this formula has been simplified to:

$$100/(1+\exp((x-x0)/dx))$$

Thus, the plot will travel between 100 and 0 %. See diagram 7 for an example.

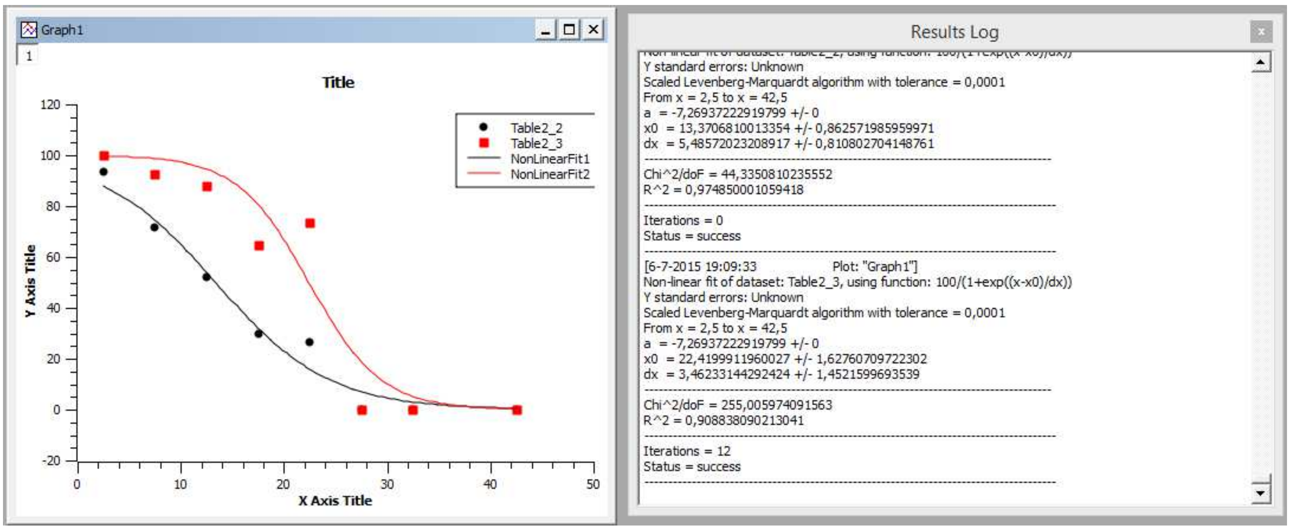


Diagram 7. Example of a statistical analysis, using the SciDAVis software. Black: percentage of transparent corneas. Red: stacked percentage of transparent and weakly clouded corneas. Correlations are generally higher in this approach.

The case for purple

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 turns the colour of the haemoglobin to purplish
3. Relaxation of muscles in the skin releases blood in the skin vessels

Together, they cause a 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 after a certain threshold (PMI = post mortem interval). In this stage, lividity is said to be fixed.

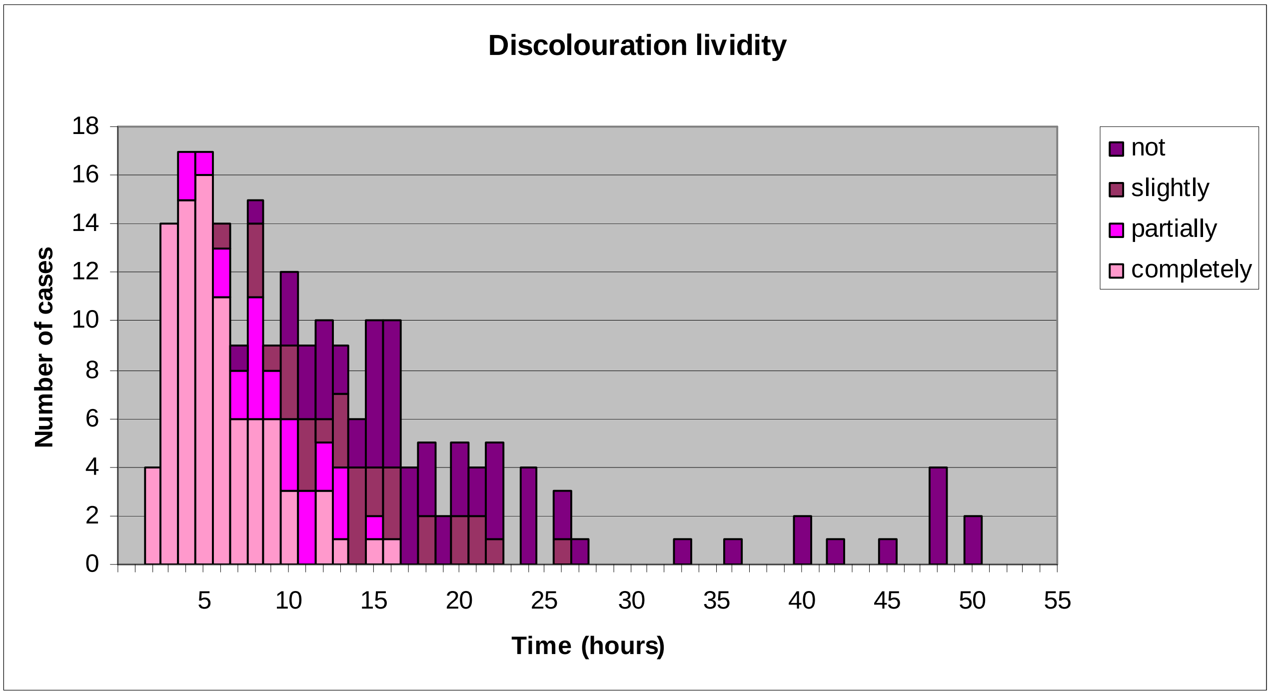


Diagram 8: Data from Japanese study mentioned.

Diagram 8 shows actual data from an investigation at Kitasato University (Masataka Furukawa and Tadataka Funao 1985) of 158 cadavers.
To compose diagram 9, the combined data of four studies (D,E,F and J) were plotted, using timeframes of 5 hours. The relevant sigmoid fitting curves were added.

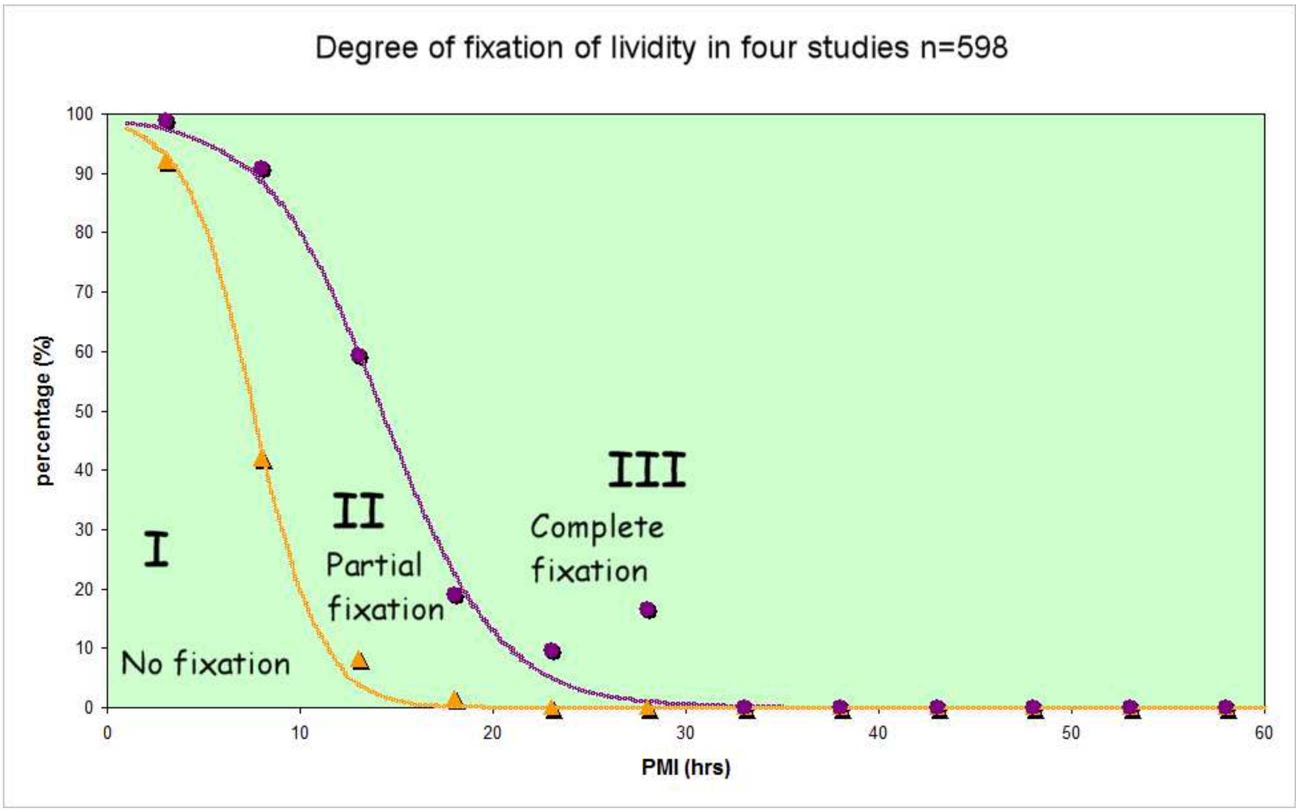


Diagram 9: Lumped data of four studies (n= 562) and proposed fitting curves. I: complete discolouration, II: partial discolouration, III: no discolouration (complete fixation)

Use in establishing a PMI

Using the found fitting curves, one can calculate the chance to find some degree of fixation after for instance 20 hours:

I (none): 0,08% II (partial):12,8% III (complete): 87,1%

As can be seen in the diagram, '*complete fixation*' tends to be the dominant result after about 15 hours.
Acoording to the fitting curve, , I and II (some degree of discolouration) add to only 0,6 %, after 30 hours while the highest PMI with some degree of discolouration in these studies was found after 26 hours. After 36 hours, the plot reveals a chance of 0,08% for some degree of discolouration, so complete fixation adds to 99,9 %.
Therefore the observation of some degree of discolouration can confidently be used to restrict the PMI to less then 36 hours, just as the rule of thumb states, cf. Mallach 1964 in plate 1.

Mallach HJ (1964) Zur Frage der Todeszeitbestimmung. Berl Med 18 : 577-582

Time course lividity according to textbooks	average	SD	2 x SD		Range of scatter		Number of quotations
			Lower limit	Upper limit	Lower limit	Upper limit	
Development	¼	½	-	2	¼	3	17
Confluence	2½	1	¼	4¼	1	4	5
Greatest distension and intensity	9½	4½	½	18½	3	16	7
Displacement:							
1. complete on thumb pressure	5½	6	-	17½	1	20	5
2. incomplete on sharpe pressure (forceps)	17	10½	-	37½	10	36	4
Displacement after turning body:							
1. complete	3¼	1	2	5½	2	6	11
2. incomplete	11	4½	2¼	20	4	24	11
3. only little paler	18½	8	2½	34½	10	30	7

Plate 1: Discolouration of lividity and typical observations in relation to the PMI according to an early literature survey. Note, that Mallach made the correct distinction between fixation on pressure and fixation after turning the body (gravity). Under the latter condition fixation appears in an earlier stage.

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 10 and compared to similar data from De Bilt:

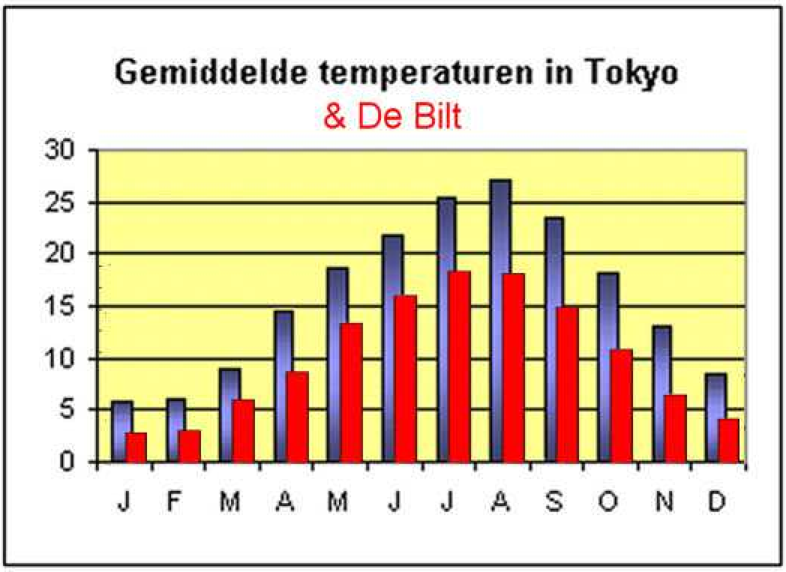


Diagram 10: Mean monthly temperatures in Tokyo (blue) and De Bilt (Netherlands; red).

As shown, there is much variation in temperatures in Tokyo. So the found data and margins can be applied in many circumstances. Only in cases, where extreme (low) temperatures are encountered, there can be some reason to doubt the general outcome. The study of Kohji Honjyo et al. (2005) - also based on Japanese data - explicitly mentions environmental temperatures during all the findings: minimum: 4.0°C; maximum: 31.0°C; mean: 18.9°C ± 6.1°C.

The effect of temperature can be demonstrated in another way. The study of Bath et al (2006) shows results for bodies in cooled storage. It shows no indication, that lower temperatures delay the fixation threshold - see the data between 20 and 40 hours. Fixation starts sooner and after 30 hours, fixation is complete here too according to the collected data.

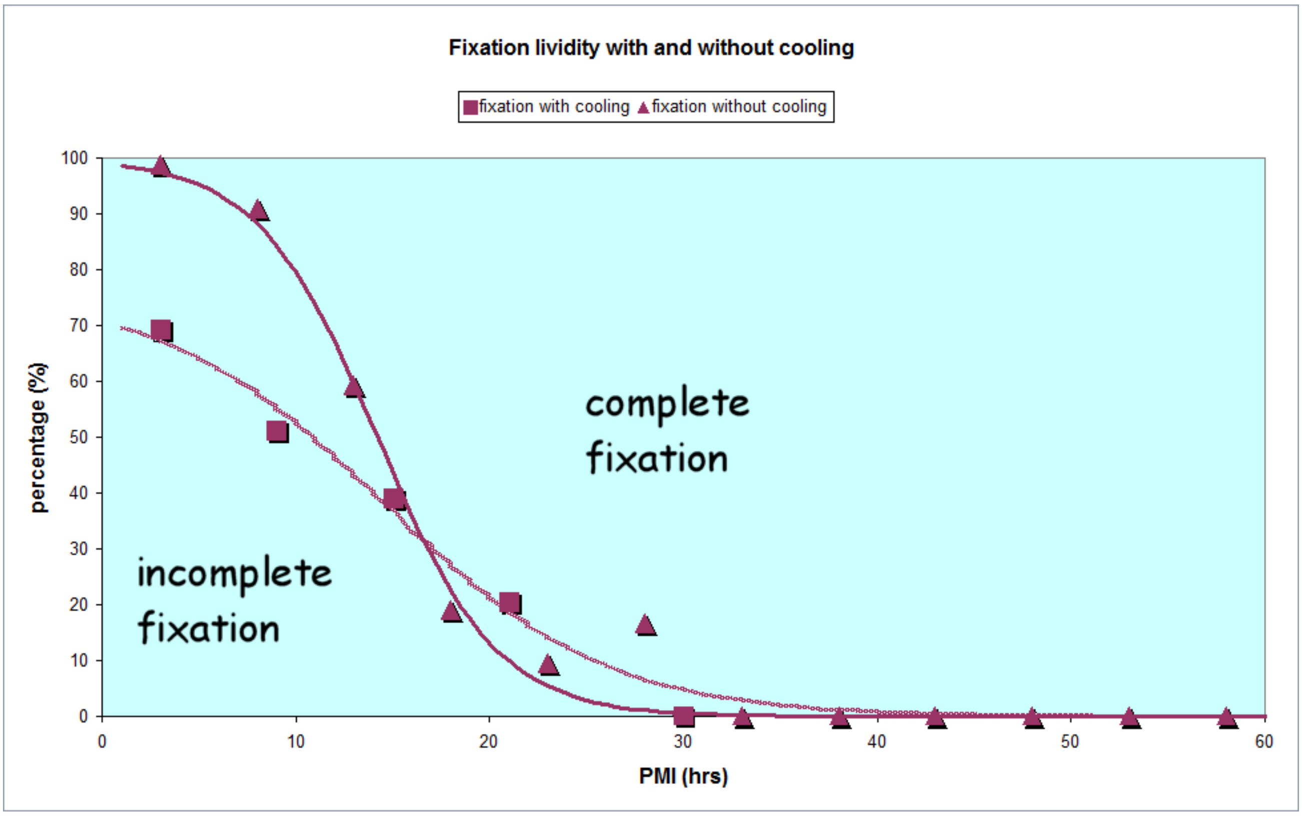


Diagram 11: Comparison of lividity fixation on pressure in cooled and not-cooled bodies in the studies G (n=417) versus DEFJ (n=590). Squares: cooled bodies.

The transition from non and partial fixation to complete fixation is the clearest phenomenon in lividity available to establish the limits of the post mortem interval (PMI). Diagram 11 demonstrates the consistency of this transition in four separate studies. Note that the study by Honjyo et al 2005 is restricted to the first 24 hours, so the plot there is not "forced" to approach the baseline.

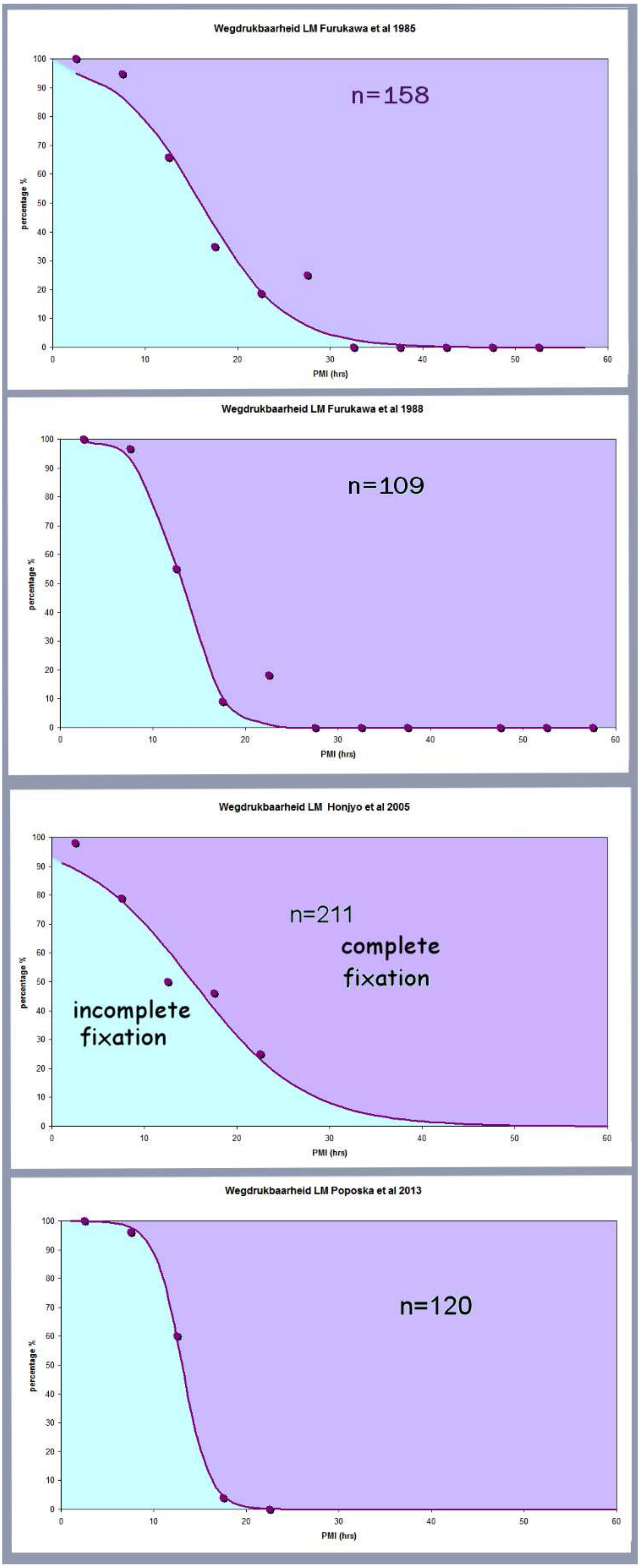


Diagram 12. Transition from partial fixation to complete fixation in four separate but comparable studies.

			odds of maximal PMI (hrs)					
study	N	R^2	50%	5%	1%	0,5%	0,1%	in study
D	158	0,969	16	30	37	41	48	26
E	109	0,980	14	20	23	25	28	24
F	211	0,927	16	34	44	48	58	22
J	120	0,985	14	18	20	21	24	18
total	598	0,981	15	24	29	31	36	26

Table 4: Predictions of appearance of total fixation of lividity post mortem. For instance, the period to find less then 1% occasions of displacement of lividity starts somewhere between 20 and 55 hours, mean 29 hours. The mean chance to find a majority of movable lividity (>50%) is between 0 and 15 hours. See also the diagrams 9 and 12.

The case for haze

Clouding of the cornea or corneal turbidity/opacity is a PMI indicator 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 possibility of classification. It was investigated in the same Japanese institute as mentioned in the lividity studies (D & E) and again in two consecutive studies. And once again it the first studies were almost forgotten (Shiori Ogura 1982; Masataka Furukawa *et al.* 1985).

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

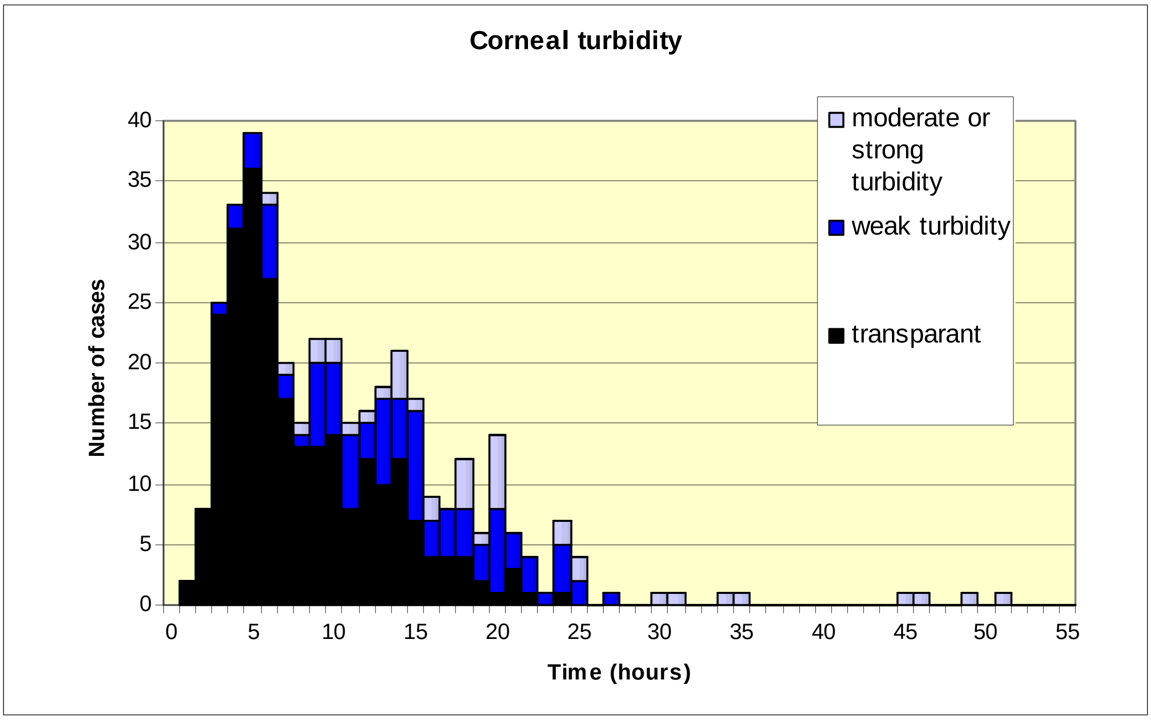


Diagram 13: Data from two studies (B & C) into corneal turbidity; 388 cases.

Because of the rather limited number of observations of higher turbidity, the two 'highest' phases (moderate and strong turbidity) 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 some cases of transparency can persist even until 24 hours. The latter

observation is in agreement with many citations in literature, stating that the occurrence of transparency is *limited* to the first 24 or maximal 36 hours.
In a later study of 212 cases (wherein only the first 24 hours were studied), all observations on the (transitions between) phases of corneal turbidity fell within the limits of the results presented in the earlier studies (Kohji Honjyo et al. 2005). So the data were added to a final analysis. As was done with a recent study (Kumar et al 2012).
The significance of these studies lies in the confirmation and specification of the conclusion mentioned here above and can be extended by expressing the odds of the occurrence of the different stages of turbidity in numbers.
Again, the results are lumped (using the timeframes as proposed in Kumar et al 2012) and fits are sought for, using dedicated software for curve-analysis as before.

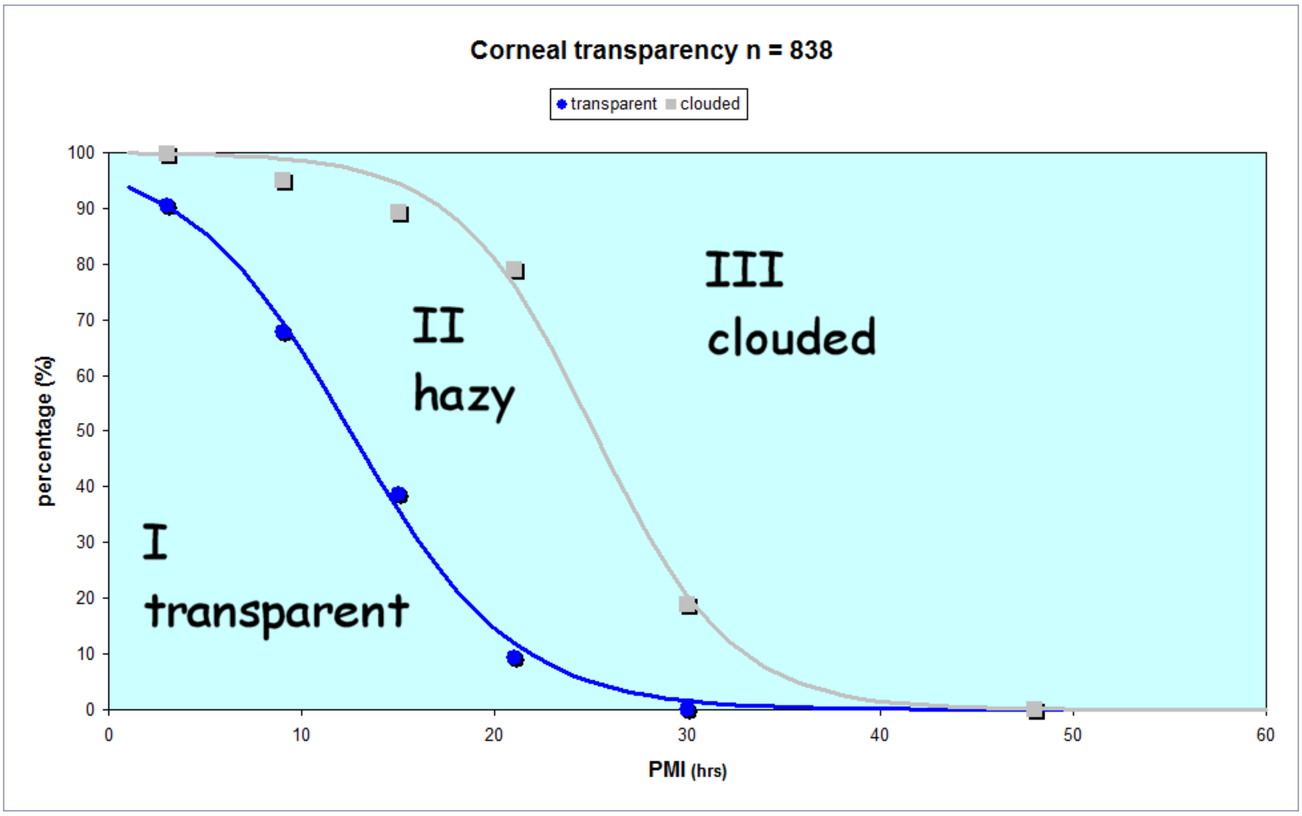


Diagram 14: Combined data from four studies and proposed fitting curves.

Use

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

I = 6,3%; II =49,6%; III = 42,1%

and after 36 hours:

I = 0,4%; II =4,1%; III = 95,5%

From this, one might conclude that the rule of thumb, that transparency halts before 36 hours after death, is reliable.
In the study of Kumar et al 2012, a differentiation in cold and warm weather at the time of the recovery of the body was made. I received the detailed data, used in Honjyo et al 2005 (courtesy Kosei Yonemitsu) and added these data, to produce diagram 15. In both cases, the mentioned rule of thumb stood out as reliable (blue points and fitting curves).

			prediction of maximal PMI (hrs)					
study	N	R^2	>50%	>95%	>99%	>99,5%	>99,9%	in data
B	310	0,975	14	30	39	43	52	22
C	78	0,975	16	26	32	34	40	24
F	212	0,931	15	28	35	38	45	18
H	238	0,990	12	19	23	25	29	18
F&H <22	250	0,999	13	21	26	28	33	18
F&H >22	200	0,994	10	22	29	32	38	18
total	838	0,997	14	27	34	37	44	24

Table 5: Prediction of appearance of clouded eyes from used data collections on corneal turbidity. For instance, the period to find more then 99% clouded eyes starts somewhere between 23 and 39 hours, mean 34 hours. The mean change to find a majority of transparent eyes (>50%) is between 0 and 14 hours. See also diagrams 14 and 17.

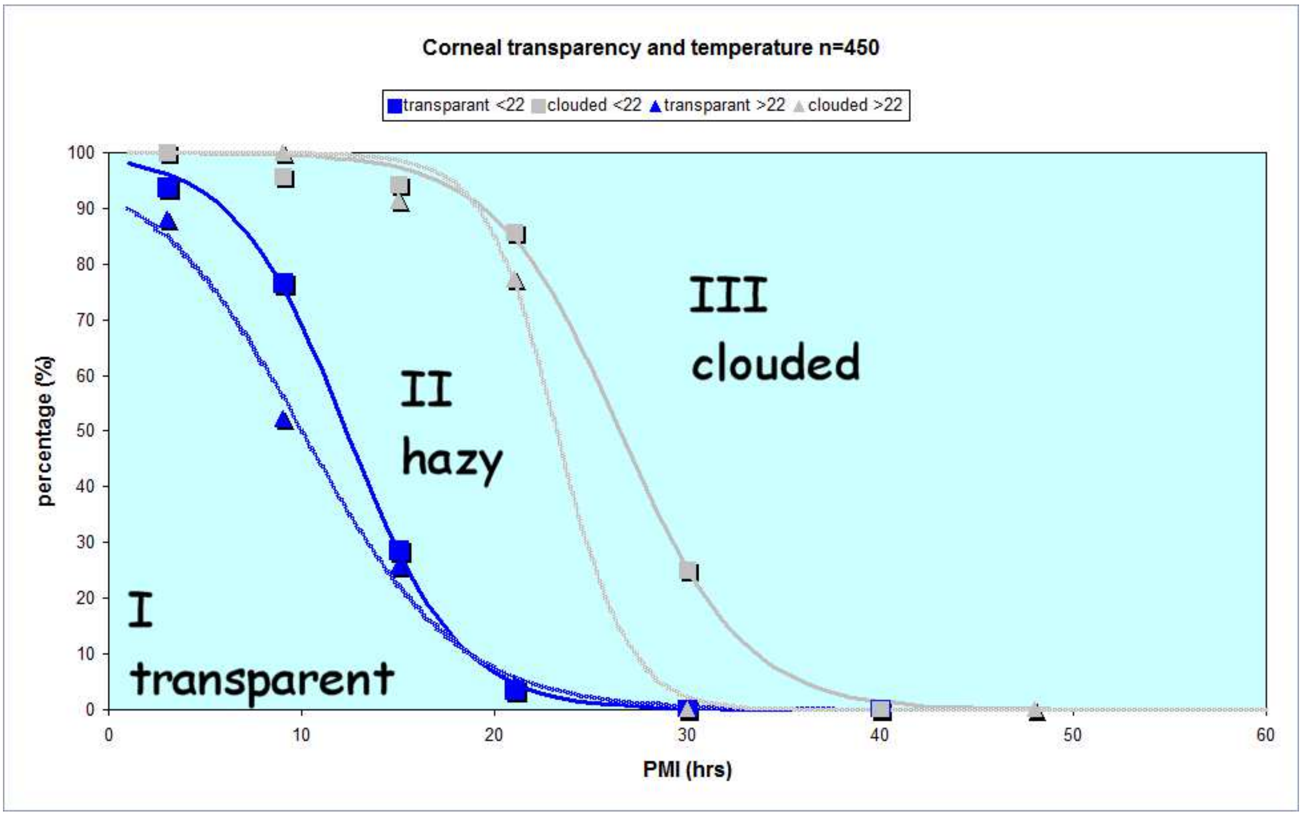


Diagram 15: Comparison of transitions in cold (squares) and warm weather (triangles), lifted from the studies F and H. Only the appearance of severly clouded corneas is significantly advanced in higher temperatures.

In all cases mentioned here above, the assessment of turbidity was made by simple observation of the pupil of the eye. Already in 1970, Wroblewski and Ellis (A) used a somewhat different technique.
They examined the fundi of the eye through an ophthalmoscope and established the transparency of the cornea on the basis of this examination being possible or not. Unfortunately, their data were not specified in time from 2 hours PMI. So I presumed, the median PMI here was 9 hrs, as in the other studies available. Nevertheless, the basic trend is the same, as shown in diagram 16. Apparently, it is easier to detect beginning clouding with an ophthalmoscope. And of course, these results also depend on the state of the more inner eye, not only of the cornea.

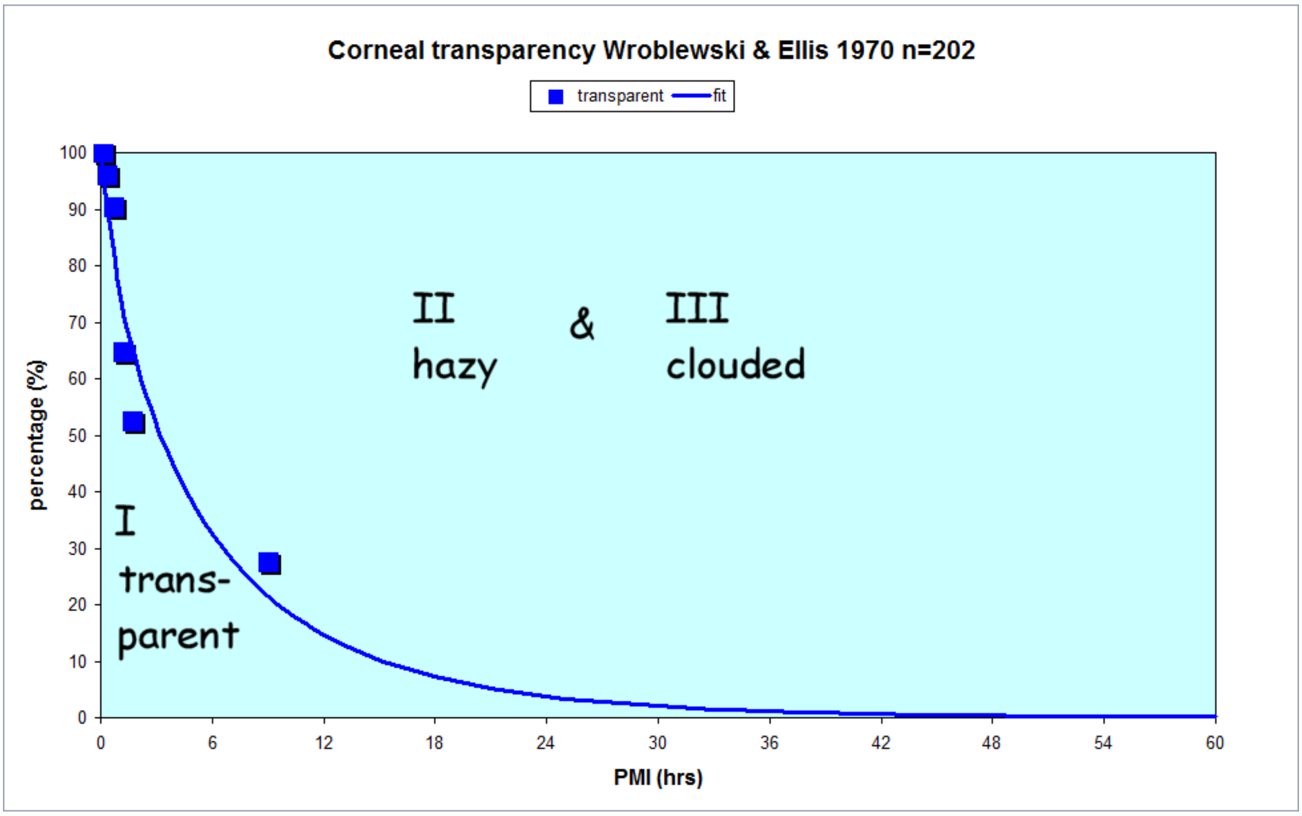


Diagram 16: Transition seen through an ophthalmoscope.

Eyes closed, eyes open

Some commentators make different assessments in case of findings with eyes open or closed. They mention the appearence of weak turbidity within two hours or earlier, cf Ogura 1982 table 2. They overlook some problems. Suzutani et al 1978 addressed those problems in great detail, using a dataset of 410 cases. First of all they concluded, the difference only mattered within the first 12 hours, a period not in study here. Secondly, they pointed out the following problem:
If eyes during the find are open or closed, there still remains a number of possibilities:

1. the eyes were closed all the time
2. the eyes were open all the time
3. the eyes opened up after some delay

And in the latter cases, the eyes will close after some - variable - time, most likely within 24 hours PMI, but always *within 36 hours PMI.*
Ogura 1982 published some data on this issue. In a number of cases, he noted if the eyes were closed or opened. In other cases , this specification is absent. So, his data can be divided in three categories, as is shown in diagram 18. Ogura considered only transparent and light hazy corneas, so the result in diagram 18 cannot completely be compared to the general results (including strong turbidity cases too). Nevertheless, diagram 18 tentatively shows both categories declining to zero before 30 hours PMI approximately in much the same way.

The transition from transparent to clouded corneas is a useful phenomenon to establish the limits of the post mortem interval (PMI). Diagram 17 demonstrates the consistency of this transition in four separate studies. See also the notes with diagram 12 relating to Honjyo et al 2005.

None of the studies revealed a transparent cornea after 30 hours post mortem.

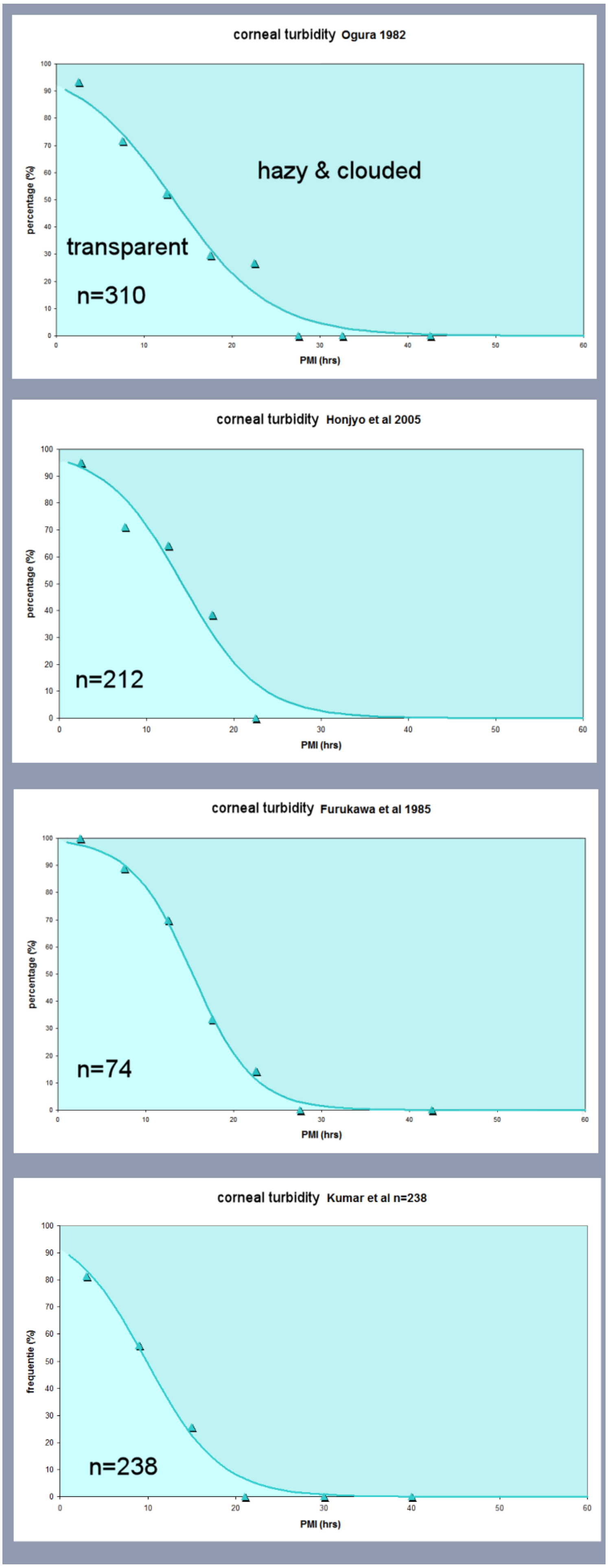


Diagram 17. Transition from transparent to clouded corneas post mortem in four different studies.

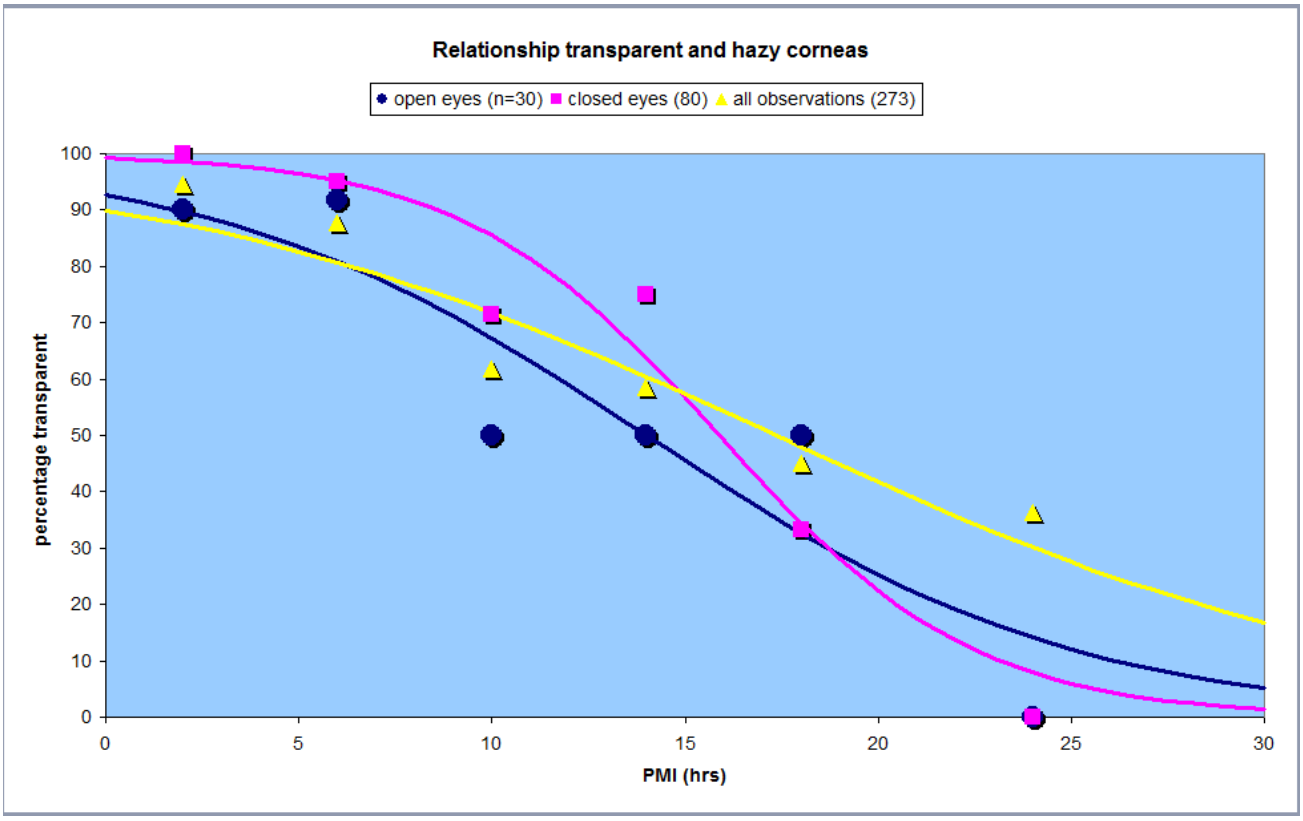


Diagram 18. Transition from transparent to hazy corneas post mortem with open and closed eyes.

An evaluation

Comparison of diagram 12 and 17 makes it clear that both phenomena - fixation of lividity and corneal turbidity - are linked in some way. Both are symptoms of a chain of biochemical reactions, going astray after death cut off food, water and oxygen supply and the halted the nervous system (autolysis).

A number of authors pointed out the usefulness of different methods in combination, e.g. Henssge et al 2002. In two cases, Honjyo et al 2005 and Salam et al 2012, the phenomena studied here were integrated with other indicators into a single formula, meant to calculate the post mortem interval. By combining several indicators, they obtained a better fit, than when using for instance the cooling of the body alone. Henssge 2002 advanced body cooling as the primary method, but proposed to refine its outcomes with other indicators, as studied here, to get a tighter time frame for the post mortem interval.

Salam et al. 2012 found the correlation between the PMI and physical post mortem changes to be the strongest in the development of corneal opacity (r=0,81), thus higher than with fixation of lividity (r=0,57) and rigor mortis (r=0,40).

The aim of this study is not provide such an outcome. Nor to provide a method to pinpoint the time of death within a certain time frame. Here, the aim is to show a method to *exclude* certain possibilities and from there to establish the limits of the post-mortem interval.

The following case will demonstrate this operation, based on the principle of falsification.

Deventer Murder Case, an application

Corneal turbidity

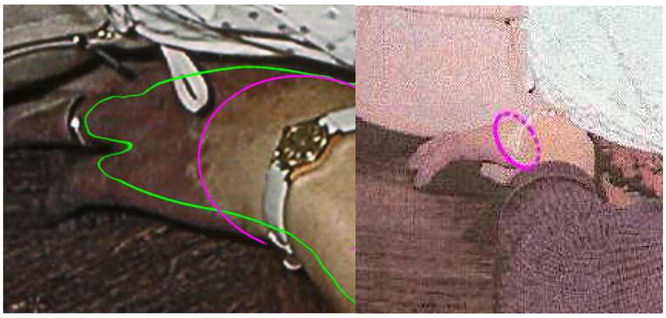
At noon of Saturday September 25th 1999, the body of the widow Wittenberg was found in her house. After some investigation, the police and the public prosecutor decided, she was murdered Thursday the 23rd at about 21:00 hours. No forensics indicators were used, to reach this conclusion. If these findings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

Plate 2: Right eye of the victim. Drawn after the original photograph, taken at September 25th 1999 at 13:30 hours. Iris and pupil in original colours and colour intensity. Note, that after resting of the body in the mortuary (thus cooling may be expected) for another 24 hours approx, the corneas were still transparent at the start of the post mortem. In the mean time the eye pressure had notably slackened, leaving wrinkles on the corneal surface.
The preservation of transparent corneas during storage in a mortuary is in accordance with the findings in Kocatürk et al 2007.

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 at the crime scene.
According to the model, described above, the chance to find some degree of turbidity after 40 hours is *higher then 99%*. The other observations of the eye are consistent with a PMI of only about 12 hours. The longest PMI in the reviewed data collection, showing transparent corneas was only 24 hours (table 5) . The latest weak opacity occurred after 30 hours. Those limits are irrespective of the eyes being open or closed. In fact, Suzutani et al 1978 found, that opened eyes could only be seen after a PMI between 0 and 36 hours (or after 4 days).
Mean temperature in the house, according to meteorological reconstructions was about 20°C or higher, especially on Friday the 24th. The weather is best been characterized as an Indian summer with all time high temperature records for the period. Therefore, the occurring temperatures coincided with the mean temperature in the data collections as reviewed in the preceding chapters.

Lividity

Prominent lividity can be seen at the crime scene in the face of the victim and in both hands. The distribution in the hands sticks out: it does not show the expected horizontal plane as demarcation of lividity. Furthermore, the separation is not sharp, indicating a recent disturbance of the body (Brinkmann & Madea 2004, pag. 110). This in accordance with other forensic findings at the crime scene (notably wet spots in hall and in the room, where the body was found, position of clothing).



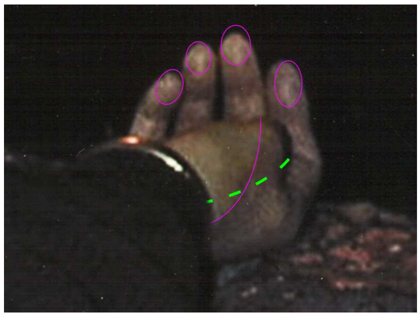


Plate 3: Left hand of the victim at the crime scene September 25th 1999 13:30 hours. Green line shows horizontal plane. Cyan line shows actual separation of zone of lividity. From another angle, the unnatural position of the hand is shown.
Plate 4: Right hand of the victim at the crime scene September 25th 1999 13:30 hours. Green line denotes the horizontal plane. Cyan line shows actual separation of zone of lividity. There is indication of blood withdrawing from the fingertips.

Later on, the victim was moved to a mortuary. 24 Hours after the discovery of the body, an autopsy was performed. So, this amounts to approximately 64 hours PM according to the police and the public prosecutor. At the autopsy, the performing pathologist made the following observation: the livor mortis on the back was still slightly discolouring on pressure, so it was not completely fixed. According to the fit for the transition from incomplete to complete fixation, any grade of discolouration after 48 hours has a chance to occur of less then 0,1%. And this is only theoretical, because the highest PMI for such a case, found in the data collection, was only 26 hours. 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. At the same time a maximal rigor mortis in the jaw - preventing the pathologist to inspect her mouth - was observed. Both observations are strong indicators a PMI of 24-36 hours *at the time of the autopsy*. The rigor mortis in arms and legs was already passing, but the manipulations of legs and arms both by the perpetuator and the investigators account for that (Brinkmann & Madea 2004, pag. 99). The livor mortis pattern as seen 24 hours earlier had faded notably at the autopsy, so the pattern seen at the crime scene, was not fixed yet, also indicating a time of death some 12 hours prior to the finding of the victim (see plate 1, entry 3).

Summary

A number of studies into two PMI-indicators reveals the possibility to classify qualitative observations into quantitative numbers. In doing so the odds to observe some phenomena after a certain amount of time after death (PMI) can be calculated.
In this way, 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

Vrinda J Bhat, Vikram Palimar, Pradeep Kumar G. Reliability of Postmortem Lividity as an indicator of Time Since Death in Cold Stored Bodies. Medico-Legal Update. Jan-March, 2006, Vol.6, No. 1

Brinkmann & Madea (Eds.). Handbuch Gerichtliche Medizin. Springer Verlag, Berlin Heidelberg New York. 2004.

Catalin Dogaroiu, Andrei Zarojanu, Razvan Scurtu, Gabriel Morosanu, Calin Petru Tataru & Anca Cristina Puscasu. Postmortem corneal changes evaluated by fluorescent staining. Rom J Leg Med [22] 13-20. 2014

Masataka Furukawa, Tadataka Funao and Yasushi Nagasaki. A New Estimation of Time since Death by Corneal Turbidity. Kitasato Med., 15: 364-367, 1985.

Masataka Furukawa and Tadataka Funao. Studies on the Estimation of the Time after death using a New technique. Kitasato Med.: 15: 50-60, 1985.

Masataka Furukawa, Tadataka Funao and Yasushi Nagasaki. Studies on the Estimation of the Hours after Death by Area of the Postmortem Lividity. Kitasato Med.: 18: 525-535, 1988.

Henssge C, Knight B, Krompecher T, Madea B, Leonard Nokes. The estimation of the time since death in the early postmortem period. 2nd ed. London, UK: Arnold; 2002.

Kohji Honjyo, Kosei Yonemitsu and Shigeyuki Tsunenari. Estimation of early postmortem intervals by a multiple regression analysis using rectal temperature and non-temperature based postmortem changes. J Clin Forensic Med.: 12: 249-53, 2005.

Dr. Bülent Kenan KOCATÜRK, Dr. Yasemin BALCI, Dr. Cengiz BAL. The Evaluation Of The Findings Of Macroscopic Eye Examination With Regard To Post-mortem Interval (pmi) In 200 Cases Known Death Time. Adli Tip Volume: 4 No:3. 2007.

Binay Kumar, Vinita Kumari, Tulsi Mahto, Ashok Sharma, Aman Kumarl. Determination of Time Elapsed Since Death from the Status of Transparency of Cornea in Ranchi in Different Weathers. J Indian Acad Forensic Med 34 (4), 336-8. 2012

Mallach HJ. Zur Frage der Todeszeitbestimmung. Berl Med 18:577-82. 1964

Shiori Ogura. The Relation of Corneal Turbidity to the Lapse of Death. Kitasato Med.,12:17-22, 1982.

HodaFouad Abdel Salam, Eman Ahmed Shaat, Manal Hassan Abdel Aziz, Abeer Abdel MoneimSheta, Heba Abdel Samie Mohammed Hussein. Estimation of postmortem interval using thanatochemistry and postmortem changes. Alexandria Journal of Medicine (2012) 48, 335–344

Poposka V., Gutevska A., Stankov A., Pavlovski G., Jakovski Z. & Janeska B. Estimation of Time Since Death by using Algorithm in Early Postmortem Period. Global Journal of Medical Research (K) Volume XIII Issue III Version I Year 2013

Suzutani T, Ishibashi H, Takatori T. Studies on the estimation of the postmortem interval. 5. The turbidity of the cornea. Hokkaido Igaku Zasshi. 53(1):7-13. 1978.

B. Wroblewski & M. Ellis. Eye changes after death. Brit. J. Surg, 57(1). 1970

Acknowledgements

I thank Kosei Yonemitsu for providing me with the raw data, used in the study of Honjyo et al 2005.
I thank Verica Poposka for providing me with the raw data, used in the study of Poposka et al 2013.
I thank Dr. Yasemin Balcı for providing me with the raw data, used in the study of KOCATÜRK et al 2007.

July 17th 2015
The Hague
Demo M.Sc.