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## “Paradoxical Undressing” in Fatal Hypothermia

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Death from exposure to cold presents one of the threats to the survival of man in arctic and subarctic regions. Yet we do not have much actual knowledge of the clinical events leading to fatal hypothermia. Apart from the experiments performed by the Nazis at the Dachau concentration camp [1] most of our knowledge has to be gathered from such sources as memoirs, historical accounts, police reports, and hospital files.

What little scientific material is available is contained in various case reports, mostly of successful treatment of hypothermic victims. The conclusions drawn from these cases are very often incomplete and obscure since the demand for treatment naturally overrules scientific curiosity. The pathophysiology of hypothermia is normally conjectured from experimental observations of cold-induced physiological changes. But it must not be forgotten that the conclusions drawn from these observations are based on hypothermia seldom falling below a body temperature of 34 or 35°C.

The most conspicuous features in advancing hypothermia are shown in Fig. 1. It should be stressed, however, that the symptoms display a very wide individual variety.

“Paradoxical undressing” is a term that refers to an irrational mode of behavior: the cold-exposed hypothermic person takes off his clothes. The phenomenon seems to be a terminal event in some fatal cases of hypothermia. A few reports of individual cases have been published, indicating that the phenomenon is a rarity [2,3]. A more extensive survey has never been published, except for a preliminary communication based on the present material and an extensive report in Swedish [4].

This bizarre act probably occurs while the victim is in a state of mental confusion, when the body temperature is low, but the real cause or sensation leading to undressing is unknown. Paradoxical undressing is significant in forensic medicine because the appearance of the body might imply a criminal act, especially rape.

In view of the lack of more comprehensive studies of this subject, reports of cases showing paradoxical undressing were collected and analyzed to gather information about the factors involved. Special attention was directed to the external circumstances, concomitant illness, and the presence of drugs.

### General Information

Thirty-three cases of accidental hypothermia showing paradoxical undressing were collected from Swedish police sources by one of us (B. W.). Most of the cases dated from the period 1964 through 1973; there were two earlier cases, and an additional case from 1976 is given as a case report but is not included in the tables.

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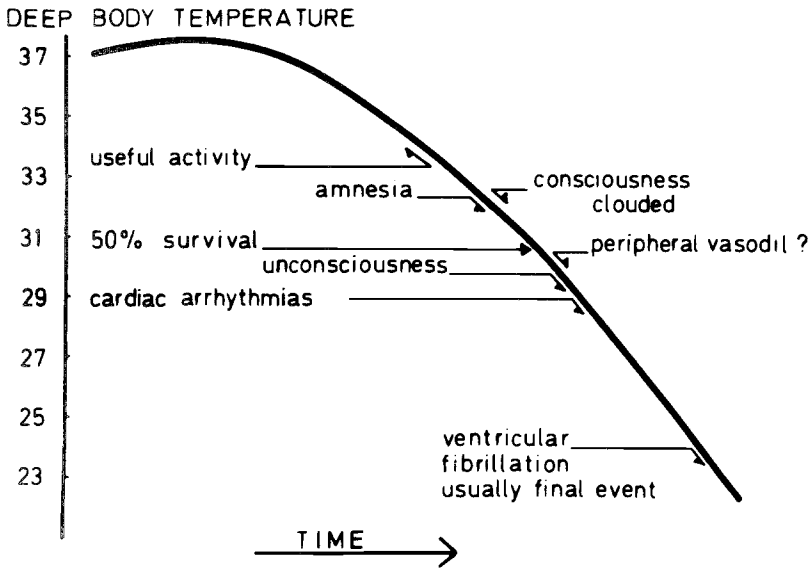


FIG. 1—Clinical symptoms and signs in advancing hypothermia.

This survey is based on police records, necropsy protocols, and postmortem chemical analysis for drugs. The following variables were studied:

- (1) age and sex of the victims,
- (2) geographical location,
- (3) character of the scene of death (such as open field, forest, or city area),
- (4) time of year,
- (5) ambient minimum temperature the night before (12 h before) the discovery of the body or during the days in which the victim had disappeared (this information was obtained either from meteorological statistics or from police records; rain or snow during the previous night [12 h before] was also registered),
- (6) illness as mentioned in the police record and necropsy protocol,
- (7) necropsy findings, and
- (8) presence of ethanol and other drugs as stated in the necropsy protocols.

#### *Age and Sex*

The cases consisted of 24 males and 9 females. The ages of the males varied from 13 to 87 years, with a mean of 56 years. The females were 34 to 78 years old, with a mean of 52 years (Table 1). The age distribution of cases was even.

#### *Appearance of the Body*

Paradoxical undressing could be more or less variable—from complete nakedness to cases in which the hypothermic victim had merely undone his belt and drawn his trousers down or in which the female had taken off her shoes and stockings and raised the skirt. When the victim was found in snow, the impressions in the snow sometimes seemed to indicate that the victim had been rolling around in the snow as if trying to cool himself.

TABLE 1—Distribution of the cases into age groups.

Age, years	Males, <i>n</i>	Females, <i>n</i>	Total, <i>n</i>
20	1	0	1
21-30	2	0	2
31-40	2	3	5
41-50	3	1	4
51-60	4	2	6
61-70	7	2	9
71-80	3	1	4
over 80	2	0	2

### Geographical and Meteorological Conditions

Cases of paradoxical undressing had occurred all over Sweden, but the overwhelming majority, 31 cases, came from the southern and middle part of the country, and only two cases came from the northern regions (Fig. 2). A  $\chi^2$  test showed, however, that the incidence of the cases was in direct relationship to the density of the population.

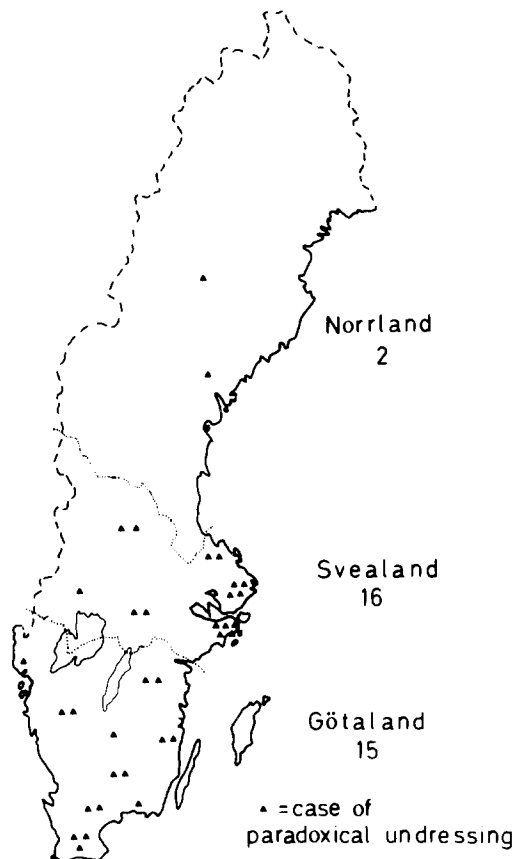


FIG. 2—The location of cases of paradoxical undressing. The incidence closely follows the density of the population.

Seventy percent of the cases occurred from November to February, but solitary incidents were also seen in warmer periods of the year (Fig. 3). Only July and August had no incidents. The number of cases at various ambient temperatures is given in Table 2. Paradoxical undressing had occurred at various temperatures, not necessarily below 0°C. There was some accumulation of male cases below -10°C. Female cases had occurred more frequently at higher temperatures. It was raining or snowing during the exposure in 14 cases and probably in a further 8 cases. In Cases 18 and 24 wet clothing had accelerated cooling. The scene was more frequently open field and forest than a city area (Tables 3 and 4). It was clear, however, that paradoxical undressing could occur regardless of the nearness of houses.

#### *Illness and Other Contributory Factors*

Universal arteriosclerosis and alcoholism were the most frequent illnesses (Tables 3 and 4). At old age arteriosclerosis was the predominant illness: 7 victims out of 11 older than 63 years were classified under this diagnosis. Alcoholism was more typical in middle-aged victims, especially in males (Table 3). Between 33 and 62 years, 8 of 12 male victims were regarded as alcoholics. In females the proportion was only 1 of 9 between 34 and 62 years. Other illnesses were present in only one case each: epilepsy, schizophrenia, and diabetes. One victim was pregnant.

#### *Drugs as a Contributory Factor*

Ethanol or other drugs were found at the postmortem examination in 16 of 24 male victims, that is, in 67%. The respective figures for the females were 7 of 9, that is, 78% (Tables 3 and 4). Ethanol was found more frequently in men, 13 of 24 (54%). Hypnotics, ataractics, neuroleptics, antidepressants, and stimulants were detected predominantly in females, mostly in various combinations. The incidence of illness, including alcoholism, as well as the concentration of ethanol in the blood and the names of the drugs are given in Tables 3 and 4. The mean blood alcohol concentration in males was 0.16%, and in females, 0.18%. The respective values in the urine were 0.27 and 0.30%.

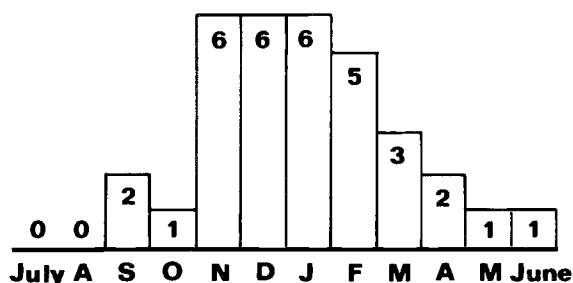


FIG. 3—Distribution of paradoxical undressing within a year.

TABLE 2—Ambient temperature and paradoxical undressing.

	< -10°C	-10 to -5°C	-5 to 0°C	> 0°C
Males, <i>n</i>	10	4	5	5
Females, <i>n</i>	3	1	1	4
Total, <i>n</i>	13	5	6	9

TABLE 3—Facts about the cases of paradoxical undressing: males.

Case	Age	Place	Month	Ambient Temperature, °C	Rain/Snow, mm	Illnesses <sup>a</sup>	Alcohol Concentration, %		Drug
							Blood	Urine	
1	87	rural	09	+19.8 to +3.7	0.8	AS	...	...	...
2	82	city	12	-9.8 to -12.2	...	AS	...	...	...
3	78	rural	03	+3.0 to -5.2	...	AS	...	...	...
4	77	rural	12	-15.0 to -17.0	...	...	0.23	0.29	meprobamate
5	73	rural	02	+0.9 to -8.0	...	AS	0.07	0.17	...
6	70	rural	11	-5.0 to -15.0	snow	schizophrenia	...	...	...
7	69	city	01	-7.6 to -12.3	...	...	0.09	0.23	...
8	66	city	01	-10.7 to -10.8	...	...	0.07	0.22	...
9	64	city	11	+3.8 to -7.1	1.3	AS, diabetes	...	...	...
10	62	rural	11	+11.5 to +3.2	...	alcoholism	0.16	0.34	...
11	62	rural	01	-0.8 to -13.5	...	...	0.05	0.12	...
12	61	city	02	-9.4 to -15.0	...	alcoholism	"inebriated"	...	...
13	56	rural	06	+27.5 to -4.0	10.0	alcoholism	...	...	acetone
14	54	city	12	+0.6 to -11.8	...	alcoholism	0.24	...	...
15	51	rural	11	+5.2 to +5.0	9.7	...	0.26	0.43	...
16	51	city	01	-16.0	10.0	alcoholism	0.32	0.54	...
17	46	rural	01	-11.6	snow	alcoholism	...	0.09	methanol
18	45	city	11	+5.6 to +1.8	16.5	...	0.15	0.26	methotrimeprazine
19	42	rural	04	+7.4 to -4.0	...	...	...	...	acetone
20	39	city	01	-4.0	snow	alcoholism	...	...	chlordiazepoxide + aprobartal; codeine
21	33	rural	12	+2.0 to -1.0	...	alcoholism	0.10	0.30	diazepam
22	30	rural	03	-5.0 to -7.0	...	...	...	...	...
23	29	city	11	+4.2 to -2.0	...	alcoholism, epilepsy	...	...	...
24	13	rural	05	+0.8 to +0.3	36.2	...	...	...	...

<sup>a</sup> AS = arteriosclerosis.

TABLE 4—Facts about the cases of paradoxical undressing: females.

Case	Age	Place	Month	Ambient Temperature, °C	Rain/ Snow	Illnesses <sup>a</sup>	Alcohol Concentration, %		Drug
							Blood	Urine	
1	78	rural	09	+21.0 to	+8.2	AS	...	...	...
2	65	rural	03	+11.9 to	-1.2	AS?	...	...	...
3	63	rural	12	+6.4 to	+5.0	...	...	...	methaqualone
4	56	rural	04	+7.6 to	+0.7	...	...	...	methaqualone + diazepam
5	52	city	02	+2.0 to	-7.6	alcoholism	0.15	0.29	barbiturate
6	50	city	02	-10.0 to	-14.2	...	0.24	0.33	...
7	37	city	12	-7.4 to	-14.8	...	0.16	0.28	benzodiazepine, salicylic acid
8	37	city	02	-8.8 to	-13.0	...	...	...	mepiperidine
9	34	rural	10	+9.0 to	+3.0	...	...	...	propiomazine chlorpromazine, barbiturate

<sup>a</sup>AS = arteriosclerosis.

### *Observations at Necropsy*

The necropsy protocols of 28 of the victims were available. Most of the necropsies had been performed by specialists in forensic pathology. The findings were compiled from the reports by one of us (J. H.). The most important observations are given in Table 5. The most frequent and perhaps most conspicuous external sign was discoloration or purple spots on the hands, elbows, feet, and knees. The spots were not hematomas, but they showed hyperemia and accumulation of tissue fluid in the subcutis. The spots and discoloration were probably first-degree frostbites, which also showed as swelling of the hands and feet. Minor excoriations, especially on the hands and probably caused by crawling along the ground, were also quite frequent. The bed of such an excoriation was often bright red owing to the high oxyhemoglobin content of the blood occurring at low temperature.

Internal changes were less frequent. Pulmonary edema was seen most often in the present series, making acute cardiac failure the most likely mechanism of death in hypothermia. The incidence of gastric ulcerations or hemorrhages was surprisingly low, only 14%. The reason for this is not clear, but one explanation could be that many of the victims were drugged and died rather rapidly, and therefore ulcerations did not have time to develop. This could also explain why pancreatic hemorrhages were not found in these cases. Microscopic examinations did not add further information.

### **Discussion and Conclusions**

Analysis of the 33 cases of paradoxical undressing in fatal hypothermia enabled us to reach certain conclusions concerning this peculiar phenomenon and find some probable causes.

Paradoxical undressing can occur in both sexes. Male cases are more numerous, but it is generally known that accidental hypothermia is more common in the male population. When a female is found, and especially when she is undressed, a crime is more likely to be considered. Some of the female victims in our series were completely naked, with their clothes spread over a wide area. This kind of scene indicates a rape, but, as shown by the police and medicolegal investigations, the undressing can be an act performed by the hypothermic victim herself.

Undressing can occur in any place. Victims have been found in the middle of a town as well as in open country, indicating a total lack of rational behavior resulting from apparent disintegration of brain function in hypothermia. The hypothermic condition itself seems to be the main disposing factor, although intoxication of some kind or other might predispose the victim to bringing himself into a situation in which he is threatened with hypothermia.

TABLE 5—*Most frequent findings as compiled from the necropsy protocols (28 protocols were available).*

Findings	<i>n</i>	%
External		
Purple spots or discoloration on extremities	20	71
Excoriations on hands or feet	13	46
Red skin or livores	6	21
Internal		
Pulmonary edema	7	25
Erosions or hemorrhages in the gastric mucosa	4	14

Paradoxical undressing was seen at various ambient temperatures, even above 0°C. But it should be kept in mind that temperature itself is not the only environmental factor that can lead to a hypothermic condition. A combination of wind, rain, and only moderate cold can impair normal muscular function and thus lead to hypothermia [5], and Pugh [6] showed that the insulating properties of clothes can be reduced by more than 50% when they are soaked with water. One third of our cases had been exposed to rain or wet snow, thereby greatly increasing the effect of exposure to cold.

In our cases the same contributory factors normally present in victims of hypothermia admitted to hospitals were also found. Old age with concomitant chronic, degenerative illnesses has previously been associated with the occurrence of accidental hypothermia [7]. In old people in particular the normal protective reactions to body cooling are impaired [8]. Observations at necropsy were similar to those stated in earlier reports [9], the most frequent findings being discoloration, excoriations on the extremities, and lesions in the gastric mucosa.

Some drugs, especially psychotropic drugs, are known to have depressant effects on the behavioral or physiological thermoregulation in animals and man [10]. In this series some drugs were found which to our knowledge have not hitherto been reported as being associated with accidental hypothermia. These are benzodiazepine, methaqualone, chlor-diazepoxide, and methotrimeprazine. This finding also suggests that these drugs might affect thermoregulation in man, but it is impossible to say without animal experiments if they influence more the behavioral thermoregulation or if they also have a "more special" effect on the monoamine mechanisms in the hypothalamus that regulate the physiological responses to cold [11].

Not much is known about the changes cold and hypothermia might bring to bear on the action of various drugs; Kruhøffer et al [12] demonstrated how the distribution of a drug (for example, ethanol) after intake is determined by the irrigation coefficient of the various body compartments. Thus in a resting individual the arterial (=brain) concentration of ethanol rose to nearly double the level when the same subject performed muscular exercise. After more than 1 h the arterial concentrations reached the same values regardless of exercise or rest. This implies that under the influence of cold, with marked peripheral vasoconstriction, the brain concentration, which in the case of most drugs closely follows the arterial concentration, might be much higher than the values calculated on the basis of body weight and venous concentrations. The pharmacological effects can thus be quite different from those seen when the same amount is taken in warm or neutral conditions.

It might be argued that ethanol has a cutaneous vasodilatory effect even in the person exposed to cold. It has, however, been shown by Vanggaard [13] that ethanol in subjects with an arterial (=brain) concentration of about 0.15% did not abolish the cold-induced peripheral vasoconstriction. Blood alcohol concentration has usually been more than 0.15% in victims of accidental hypothermia [9], an observation also made in this series.

In terms of survival, paradoxical undressing is both unnatural and irrational. Gormsen [3] has proposed that drugs could be the cause of the confusion. They might contribute to bringing the person into a situation in which he exposes himself to cooling; however, the fact that in the present series paradoxical undressing was also seen in subjects where drugs could not be traced, and where no psychiatric disorder was known, shows that this cannot be the sole explanation. That the bizarre behavior could also be due to the mental disorder for which the drugs were prescribed can likewise be ruled out. Suicidal exposure to cold naturally seems to be a reasonable explanation, but the random way in which clothes are often scattered about militates against such an intentional act.

Can paradoxical undressing be explained from our knowledge of hypothermia? During exposure to cold an intense vasoconstriction, especially in the extremities, results in an increased total insulation of the subject. The skin temperature falls, and in the extremities might approach that of the environment. As cooling proceeds and the central body temperature falls, it is thought that vasodilation of the peripheral vessels occurs when



either the hypothalamic control over the arterioles cannot be maintained or the muscles in the vessels are paralyzed. A sudden opening of the blood vessels in the periphery could, in the hypothermic person, give rise to an exaggerated sensation of heat with an overwhelming desire to undress. Vejens [14] also reported the not-unpleasant sensation of warmth that might arise in the deeply hypothermic person.

But the sudden opening of peripheral blood vessels would lead to a cooling of the warmer blood from the body core and result in a sudden drop in deep body temperature. Since consciousness disappears at a body temperature of around 30°C, the undressing seems to be the last effort made by the victim.

One might argue why this "paradoxical heat sensation" has not been reported in more cases of people who have been rescued from hypothermia. The explanation may lie in the fact that amnesia normally ensues from a deep body temperature of 33°C [15].

### Case Report

To illustrate paradoxical undressing a case that shows nearly all the characteristics of the phenomenon will be given.

On 10 Feb. 1976, a 23-year-old man was found dead, completely frozen stiff, lying on his back almost naked in 10 to 15 cm of snow in a ditch at the edge of a wooded area. The man had disappeared from his companion on 30 January. The two men were motoring in the middle of Sweden, and probably using narcotics. During their last night together they had slept in the car but had had a disagreement in the morning.

The lowest night temperatures on 30 and 31 January were  $-10$  and  $-11^{\circ}\text{C}$ , and during the following period until 9 February the lowest temperature was  $-9^{\circ}\text{C}$ . During this period the day temperature was never as high as  $0^{\circ}\text{C}$ .

The deceased was lying with his face turned upwards. His eyes and his mouth were closed. His forearms were lying across his chest. The trunk, thighs, and calves were naturally stretched and parallel. The snow under the body had melted, especially under his shoulders, back, and buttocks. Recent abrasions up to 10 cm long were seen on the lateral sides of his arms, on the outer side of his left thigh, on the front of both knees, and on both crura. These were, no doubt, lesions caused by crawling on the earth. No evidence of fighting was seen.

The last moves of the deceased are shown in Fig. 4. At Locations 2 and 4 he had been lying in the snow, at Location 2 between a spruce tree and a big stone, and at Location 4 on the edge of the ditch. At Locations 4 and 5 he had been crawling.

His jacket was found at Location 2 together with his shirt and undershirt, which had been taken off simultaneously and were found one inside the other, inside out. Only the lower button of the shirt was undone. His jeans were almost totally removed. Only the right trouser leg was around the crus. His right boot was in a normal position (Fig. 5). At Location 5 a piece of textile from his underwear was found on barbed wire.

The deceased was a drug addict; 0.8 mg amphetamine and about 2.1 mg methamphetamine were found in 100 ml urine. Analysis showed no barbiturates or meprobamate in liver tissue. There was no reaction to alcohol in blood or in urine.

### Conclusion

Paradoxical undressing in fatal hypothermia is a phenomenon that seems to be related to the hypothermic condition. It might be explained as a result of a further sudden fall in deep body temperature in a hypothermic person when peripheral vasoconstriction is followed by vasodilation. As shown by police records, the act seems to be performed immediately prior to unconsciousness and death. The effect of various drugs, especially psychotropic medicines and ethanol, might play a role in the events leading to the actual exposure but cannot on its own explain the undressing.

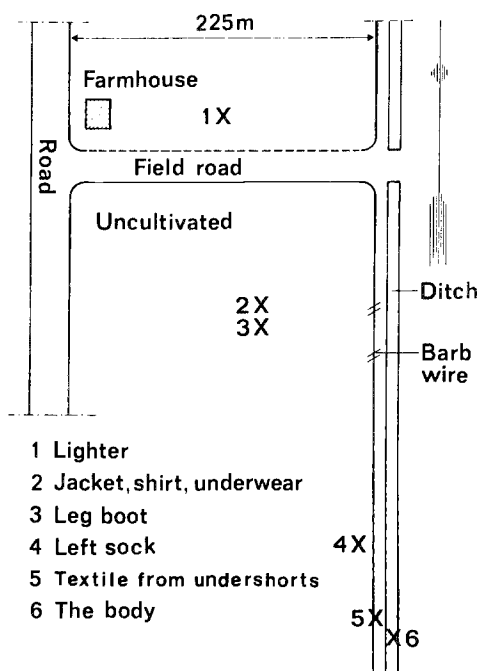


FIG. 4—The area where an undressed victim was found (see the case report).



FIG. 5—The final position and appearance of the body.

### Summary

The phenomenon called paradoxical undressing has been described from 33 cases of hypothermia collected from Swedish police reports.

The cases were almost evenly distributed with regard to sex, age, and geographical

distribution. The cases occurred more frequently in open land although cases from town areas were also found. Most incidents were recorded from November to February at low ambient temperatures, although cases were also reported at temperatures above 0°C.

Arteriosclerosis and chronic alcoholism were important concomitant illnesses, the latter being frequent in middle-aged men. Epilepsy, diabetes, and pregnancy were present in single cases.

Ethanol and other drugs were present in 67% of the males and in 78% of the females, ethanol predominating in men and various psychotropic agents in women. The mean blood ethanol concentration in males was 0.16% and in females, 0.18%. Most frequent findings at necropsy were purple spots or discoloration on the extremities, pulmonary edema, and gastric hemorrhages.

It is concluded that paradoxical undressing might be explained by changes in peripheral vasoconstriction in the deeply hypothermic person. It represents the last effort of the victim and is followed almost immediately by unconsciousness and death.

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