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# The pathology of human temperature regulation: Thermiatrics

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Comparative physiology shows that most animal species regulate their body temperature ($T_b$). The bigger species generally regulate their body temperature at values lower than of the smaller species. The range of tolerated body temperature narrows with the advancement of the phylogenic evolution of the species. The question arises as to

why body temperature is regulated, and why the phylogenically more recent species are not able to tolerate large variations of body temperature. It is likely that the absolute value and range of body temperature results mainly from 3 selective influences:

1) A constant physical environment within the body is advantageous for its cells. The influence of temperature on cellular life in various physicochemical and enzymatic processes will be reviewed elsewhere in this special issue (Yousef, pp. 14–19).

2) To permit heat loss $T_b$ must be higher than ambient temperature ($T_a$). In addition, the higher the $T_b$ the larger the range of tolerated $T_a$. It is therefore likely that $T_b$ selected by evolutionary pressure is the highest possible for each species taking into account $T_a$, body mass, peripheral insulation, and high metabolic rate [17]. Mean ambient temperature on the surface of the earth is 22 °C. In temperate climates mean temperature seldom exceeds 19 °C in summer, and remains far below this value in winter. Thermal neutrality in humans is around 28 °C.

3) As a result, the central nervous system of endothermic species has developed a close dependence on temperature. Below 35 °C the functioning of the CNS is impaired. On the other hand, during heat exposure serious tissue lesions occur when local internal temperature exceeds 40.5 °C in the brain [22, 66]. The selective pressure for development of the CNS in mammals therefore narrows the range of tolerated body temperature and enhances the autonomic and behavioral defenses against changes in ambient temperature.

The result from the three conditions above is that high body temperature is advantageous but homeotherms become dependent. These have therefore developed a function of temperature regulation which defends and maintains a constant deep body temperature. This function generates regulatory responses in order to maintain homeostasy. The mechanisms of temperature regulation are called autonomic when they determine changes within the body (shivering, sweating, vasodilation); they are called behavioral when they guide voluntary changes in the subject's behavior.

Local or general variations of body temperature can jeopardize various vital functions and a whole pattern of pathology results from imperfect temperature regulation. This chapter is limited to a nosographic review of the various diseases caused by, or resulting in, modifications of body temperature. It concerns only one species: the human.

Table 1 summarizes the four main symptoms due to thermal aggression when the pathogenic agent acts locally or generally. Burn and frost-bite are the cases in which the organism cannot successfully protect itself against local thermal aggression, and these result in local tissue lesions. On the other hand, hyper- and hypothermia are more complex cases concerning the whole body. They can be the common symptom of 3 totally different etiologies; 1) the ability to thermoregulate is intact but is overwhelmed by extreme $T_a$; 2) the means of temperature regulation are impaired and result in a body temperature change at neutral $T_a$; 3) the nervous system is disturbed or lesioned, with resulting loss of regulation. Various etiologies can thus lead to the same symptom, modified $T_b$. When deep body temperature is raised or lowered, the etiological diagnosis is therefore of paramount importance, since the etiological diagnosis should determine the therapeutic strategy. Let us examine these three categories of pathological situation.

## *1. Overwhelmed temperature regulation: the symptoms*

### *Hypothermia*

When ambient temperature falls below 26 °C in air, or 33 °C in water, the body at rest loses more heat than it produces, and deep body temperature tends to decrease[38, 46]. As a consequence, autonomic responses consist of an increase in metabolic rate and a decrease in heat loss.

*Physiological responses.* At thermal neutrality, the human skin is in the state of vasoconstriction. During cold exposure, the skin blood flow further decreases and tends towards zero; this rheological response is enhanced by the increase of the viscosity of blood when its temperature falls. The low conductibility of peripheral tissue thus decreases heat loss, which is directly proportional to the difference between skin temperature and ambient temperature. The drop in skin temperature also lowers radiative heat loss. The peripheral vascular response during cold exposure therefore tends to decrease the volume of the thermal core, i.e. the mass of tissue with constant temperature. In this case peripheral tissues act as a thermal insulator.

At rest and thermal neutrality, the basal metabolic rate is around 70 W. During muscular exercise heat production may undergo a 10-fold increase. During cold exposure and subsequent decrease of deep body temperature, shivering occurs and the muscles, just like a 100% efficient boiler for central heating, transform chemical energy into heat. Shivering may be slight, and only just perceptible in the muscles of the trunk. Intensive shivering by the whole body renders the subject unable to articulate (dysarthria) or to write (agraphia). Newborn babies are also equipped with brown fat, a tissue whose function and purpose is heat production only.

*Symptoms.* During more intense cold exposure, when the metabolic rate is at its plateau, heat production cannot compensate for heat loss and in spite of intense peripheral vasoconstriction and maximal heat production, deep body temperature tends to decrease. If cold exposure continues, pathological symptoms occur: at $T_b$ 34 °C the level of vigilance decreases, and aphemia is likely to occur; at $T_b$ 30 °C maximal metabolic rate is no longer maintained and starts to decline. This accelerates the fall in core temperature. At $T_b$ 27 °C spontaneous and voluntary motricity disappear. Pulmonary ventilation persists down to $T_b$ 25 °C, but it is of little efficacy and leads to hypoxemia and respiratory acidosis. Ventricular fibrillation may occur if cold exposure continues. This danger is supposed to cease, or at least to decrease, when core

Table 1. Classification of the pathological symptoms resulting from environmental thermal aggression

| Environment | Pathology | |
|---|---|---|
| | Local | General |
| Heat | Burn | Hyperthermia |
| Cold | Frost | Hypothermia |

temperature falls below 19 °C. Survival after therapeutic hypothermia at 9 °C[80] or accidental hypothermia at 16 °C[64, 65, 84, 104, 113] have been reported. A sharp and profound drop of body temperature may be self-protective, since Van t'Hoff's law also applies to the brain, the tissue most vulnerable to hypoxemia. Under deep hypothermia, the tolerance of anoxia by the brain is considerably extended. Artificial brain hypothermia is used during brain surgery. Cases of revival after lasting accidental immersion in icy water, especially in children with small body mass, have repeatedly been reported[64, 65, 84, 104].

*Therapy* for such hypothermia consists in warming the patient as soon as possible and as quickly[81, 113], because ventricular fibrillation may occur during the warming of the patient, in the same body temperature range as during the temperature drop.

### *Hyperthermia*

Hyperthermia occurs when internal heat production and/or external heat uptake surpass heat loss.

*Physiological responses.* Vasodilatation and sweating are autonomic responses of heat dissipation. At thermal neutrality and rest, the arterio-venous anastomoses of the skin are normally closed (vasoconstriction). During heat exposure or endogenous hyperthermia, vasodilatation occurs and heat is lost to the environment if this is colder than the skin; e.g., the heat loss from a single hand immersed in water may rise from 2 W when a subject is hypothermic to 70 W when the subject is hyperthermic. Sweating is the second important autonomic response to hyperthermia. It begins as soon as vasodilatation occurs at the same set-point of core temperature. Its efficacy depends on the evaporative power of the environment and on the mass of excreted water. The amount of water sweated depends on the particular area of skin and the degree of hyperthermia; it varies between 15 and 90 g/$m^2 \cdot h$[83]. Sweating and vasodilatation increase proportionally with the difference: core temperature minus set-point. The hyperthermic subject can therefore be defined as a vasodilated and sweating subject with high core temperature.

*Symptoms.* The exacerbation of heat dissipation tends to increase blood vessel capacity and to decrease plasma volume. Both may challenge blood pressure, and this can lead to a blackout even at core temperatures below 40 °C. Sodium depletion caused by chronic sweating during prolonged heat exposure is accompanied by nausea and painful muscular cramp. Dehydration caused by profuse and abundant sweating induces intense asthenia when water loss exceeds 6% of total body weight[1]. Heat stroke occurs at a core temperature of 40.5 °C, which is the highest temperature the brain can tolerate[22, 26]. Beyond this value, the only protection of the human brain against hyperthermia is the maximal blood flow in the emissary veins of the head. The blood cooled at the forehead and the calvaria by sweating flows to the endocranial venous network and especially to the sinus cavernosus by the ophthalmic and emissary veins, cooling in this way the overheated arterial carotid blood[18, 23]. The power of this cephalic cooling system is emphasized by its ability to lower core temperature and limit discomfort to the same extent as areas of other noncephalic territories which are 7 times larger[43, 45, 61, 63, 102, 103, 116]. When this mean of heat protection of the brain is overwhelmed and brain temperature exceeds 40.5 °C, the patient becomes bewildered and confused. In such cases, delirium and convulsions can lead to death[2, 60]. A first episode of pathological hyperthermia renders the patient more fragile during further heat exposure and relapses are more frequent[99]; this may be due to irreversible brain lesions[78].

*Therapy* for hyperthermia consists of rehydrating and cooling the patient, especially the face and the head.

The involvement of thermoregulatory means depends on the subject's core temperature. The occurrence of hyperthermia or hypothermia therefore signifies that the body's defenses against thermal aggression are overwhelmed.

The treatment of hypo- or hyperthermia depends on the cause of the disease. Therapy requires in all cases the control of ambient temperature, which enhances recovery. The pathology of temperature regulation may affect either autonomic or behavioral responses to the thermic challenge ('the causes') or the nervous system of the physiological thermostat ('central command').

Table 2. Classification of diseases resulting from a pathological modification (decrease or increase) ot the thermoregulatory responses (periphery)

| Pathology | Responses | | | |
|---|---|---|---|---|
| | Thermogenesis | Vasodilatation | Evaporation | Behavior |
| Decrease | Endocrine<br>– hypothyroidism<br>– adrenal insufficiency | Reynaud's disease<br>Arteritis | Anhidrosis<br>Paraplegia | Acute schizophrenia<br>Congenital indifference to pain |
| | Muscular<br>– poliomyelitis<br>– paraplegia<br>– autoimmune amyotrophy<br>– curarization | Paraplegia | Atropine<br>Scars | Aging |
| | Aging | | | |
| Increase | Endocrine<br>– hyperthyroidism<br>– pheochromocytoma | Erythrodermia<br>Vasodilating drugs | Hyperhidrosis<br>Burns | Psychosis |
| | Muscular<br>– tetanus<br>– malignant hyperthermia | Sympathectomy<br>Hypnosis | | |

*2. Pathology of the peripheral thermoregulatory response: the causes*

The responses to hyper- and hypothermia tend to restore $T_b$ by increasing heat loss or heat production. Increased heat loss results from peripheral vasodilatation and sweating; increased heat production from shivering.
Another response to heat or cold exposure of the homeothermic organism is behavior, which economizes expensive autonomic responses of thermoregulation. In this way, the human continually modifies heat exchange, i.e. the thermal gradient between his skin and the air. Posture, clothes, or airconditioning are examples of behavioral responses to temperature. The effectiveness of thermoregulatory behavior is shown, in particular, by the avoidance of permanent shivering in those latitudes with so-called temperate climates, where the ambient temperature rises to thermal neutrality for only a few hours of a few days in summer.
Lesions of peripheral responses may concern metabolic or muscular heat production, vasodilation, sweating, or behavior. Each of these factors can be either increased excessively or lessened. Table 2 presents the list of diseases with disturbances of peripheral responses, and shows whether the latter are increased or reduced.

*Heat production*

*Decrease or suppression.* Metabolic rate may be decreased either by endocrine diseases like hypothyroidism or adrenal insufficiency, or by the reduction of the active muscular mass as observed in auto-immune muscular diseases or in the cases of large denervations like paraplegia[5,19,57,114] and poliomyelitis. These diseases reduce either the basal metabolic rate or the capacity to shiver or both. Senescence is accompanied by progressive reduction of metabolic rate. In the older person metabolic rate is affected as well as ability to control heat production[26,28,53,72]. In the case of lowered metabolic rate the subject is less able to withstand a cold environment. The amount by which heat production capacity is reduced determines the gravity of the disease. In moderate cases, behavior compensates for poor tolerance of cool ambient temperatures.
*Increase of heat production.* The etiology of this may also be endocrine or muscular. The most frequent endocrine affection increasing heat production is hyperthyroidism[112]. Excessive production of high thermogenic catecholamines[25] may raise heat production in subjects affected by pheochromocytoma, at least during hypertensive attacks. Tetanus is the best known of diseases with excessive muscular heat production. Malignant hyperthermia is an activation of all neuromuscular synapses by general anesthesia in genetically predisposed subjects[10,32,55]. It results in death from hyperthermia. A comparable syndrome has been described after extensive burns in children[70] and may also be induced by some psychotropic drugs[31,88,95]. The gravity of such affections depends on the amount of the excessive heat produced. Behavior may compensate for slight increases such as increased basal metabolic rate during hyperthyroidism. When heat production overwhelms maximal heat dissipation, the patient may die as a result of irreversible brain lesions due to hyperthermia, as for example, in the case of tetanus or acute malignant hyperthermia.

*Vasodilatation*

*Decrease or suppression.* Raynaud's disease affects local areas with total suppression of vasodilatation. This does not usually affect general temperature regulation since other skin territories should compensate for the deficit in heat loss of the areas affected by Raynaud's disease. Chronic arterial obliteration leads to the same, but in this case permanent decrease of heat exchange. In paraplegia, thermoregulatory vasodilatation may be absent below the spinal section[19,27,33,42,82,117]. Thermoregulatory responses of the non-lesioned territories are preserved and so core temperature is seldom affected.
*Increase.* The most typical case is erythrodermia[41,111]: permanent vasodilatation of a variable surface of skin leads to irreducible heat-loss proportional to the area of the skin affected. This disease may become fatal when metabolic heat production must compensate permanently for heat loss in a subject shivering continuously. Vasodilating drugs[8,92] and hypnosis[87,91] sometimes increase heat dissipation and may lead temporarily to the same symptoms. Localized sympathectomy produces the same results. However, the fact that the affected territory is generally limited explains why the subjects easily compensate for their heat loss in the latter case. Menopausal hot flushes represent typical cases of short term increased vasodilatation. However, they will be considered below under the heading of 'pathology of regulation' since there is evidence that they are the result of a central signal.

Table 3. Classification of diseases resulting from a pathological modification (decrease or increase) of the thermoregulatory centers

| | Heat gain | Heat loss | Set-point |
|---|---|---|---|
| Decrease | General anesthesia<br>intoxications | ? | Anapyrexia<br>(central lesion ?) |
| | Occasional hypothermia after central lesion | | |
| Increase | Lethal hyperthermia after central lesion | Menopausal hot flushes | Fever<br>– phagocytosis<br>– inflammation<br>– tumoral<br>– emotional<br>– hypothalamic<br>– heat stroke<br>– paraplegia |

*Sweating*

*Decrease or suppression.* The most demonstrative case is anhidrosis[90,108] due to congenital absence of sweat glands. In such subjects vasodilatation is the only possible way of heat dissipation. This response is not powerful enough to permit them to live in tropical climates. Furthermore, severe hyperthermia may occur during moderate physical effort.

In the case of paraplegia, the sweating response below the lesion is either absent[86] or inadequate[34,96] owing to the disconnection of nervous control of sweating. Atropine and similar drugs are widely used in surgery, cardiology and anesthesiology for their secretion-inhibiting effects, and so one could expect them to decrease sweating response. Finally, sweat glands do not regenerate in scars. This may compromise heat loss in subjects working, or heat exposed, after recovery from extensive burns[48].

*Increase.* The most typical case is hyperhidrosis. Sweating occurs in the affected territories even in the absence of hyperthermia[73,100]. During the clinical evolution of burns, direct water evaporation is proportional to the affected area and may lead to severe dehydration and hypothermia[47,93]. Therapy consists of adequate perfusion and in maintaining the patient in a warm and humid environment.

*Behavior*

*Decrease or suppression.* The importance of thermoregulatory behavior is often underestimated by the physician. It powerfully influences temperature regulation by continuously adapting heat exchange to physiological needs. The main responses are posture, displacement, and the generation of microclimates[16]. When such behavioral accommodation cannot take place, as in cold-exposed or heat-exposed infants, the pathological consequences may be dramatic if the physician or the parents do not adapt the ambient temperature to the child's need[24,54,101,105,109]. Senescence may also impair thermoregulatory adaptive behavior[28,53].

Catatonic or cataleptic attacks during schizophrenia completely inhibit any behavior, including thermoregulatory responses. In the case of congenital indifference to pain the patient presents neither affective response to a painful stimulus nor thermal discomfort in spite of correct temperature perception[20]. The lack of thermoregulatory adaptive behavior may lead to hyper- or hypothermia when the ambient temperature is different from thermal neutrality. Such subjects have to be taught behavioral adaption to thermal challenges, and this teaching may sometimes appear excessive to the non-initiated physician.

*Increase.* Thermophobia and abnormal chill could be classified under the heading 'increase' in behavior since they render patients more aware of environmental temperature. However, they are likely to be normal types of motivation in response to a deficit or excess of heat production, as reviewed above. On the contrary, the case of young psychotic patients attracted by hot radiators to the point of burning themselves is clearly an excessive, abnormal form of thermal behavior[56].

We can conclude that the pathology of thermoregulatory peripheral responses seldom influences deep body temperature for two main reasons: 1) the remaining autonomic responses generally compensate for the pathological excess or deficit; 2) behavioral adaptation also compensates for the deficit in a most efficacious way and limits the need for the more expensive autonomic responses. The cases where the physician is aware of the deficit are therefore rare and are limited to cases of paramount gravity such as malignant hyperthermia.

*3. Pathology of the central command of temperature regulation*

Disturbances of deep body temperature due to hypothalamic lesions have been reported in the literature for more than 50 years[3,7,12,29,107,118]. In such studies, the authors studied first the histological lesions of the brain and generally merely noted the subject's temperature. Even though the nervous centers for temperature regulation are not yet clearly identified, it is likely that they command independently the protection of the body against 1) hypothermia, 2) hyperthermia, and 3) define the set-point of temperature regulation. Any of these functions may be affected by a pathological condition (table 3). Independence of the structures responsible for these 3 functions is consistent with the accepted model of the organization of temperature regulation in the CNS[15,97]. Pathological conditions may depress or suppress the function, or may increase or exacerbate it.

*Pathology of defense against cold*

*Suppression of central command.* When the central command of thermoregulatory responses is suppressed, the subject is left with only basal metabolic heat production and is therefore unable to resist even a light cold exposure. The subsequent hypothermia is different from the hypothermia induced by an insufficient peripheral response; the subject does not shiver and does not seek heat. The pathological consequences for the functioning of the body of such centrally-induced hypothermia are nevertheless the same as those induced by insufficient peripheral responses. Centrally-induced hypothermia may occur under 3 circumstances:

a) During anesthesia the central command of protection against hypothermia is inhibited by the anesthetic drugs. Indeed, hypothermia generally occurs during surgery, when ambient temperature is too low: ambient temperature is usually adapted to the surgeon's rather than the patient's need. The degree of hypothermia is increased by curarization, which abolishes the slightest muscular heat production. Post-operative warming of the patient may lead to a non-surgical shock syndrome when reflex vasodilatation combines with blood loss to decrease blood pressure[94].

b) Alcohol or barbiturates induce toxic coma, but also centrally-induced hypothermia if the patient is exposed to a cold environment[79].

c) Lesions of the CNS may lead permanently to the same syndrome[9,19,21,30,37,39,50,58,67]. In such cases, thermoregulatory heat dissipation is preserved[39], as well as the capacity to respond to infection by fever[37,50,67]. CNS lesions in such

cases are located in the hypothalamus. They may be surgical[58] or granulomatous[9,21,67]. Some cases of episodic hypothermia in otherwise healthy subjects probably result from a resetting of the thermostat's set point and will be examined below under this heading.

*Excessive central cold response.* This dramatic situation has been reported in two subjects after surgical lesions of the hypothalamus[3]. Such a syndrom exposes the patient to death from hyperthermia. If this syndrome is permanent the prognosis is grave, since the only way to prevent hyperthermia would be general anesthesia or curarization. One may speculate in addition that its logical therapy would be heat exposure in order to inhibit the activity of cold receptors.

*Pathology of defense against heat*

*Suppression of central command.* This syndrome in humans has not as far been reported in the literature. Lack of protection against heat exposure should normally head to fatal hyperthermia even during light muscular work or medium heat exposure. It is not known whether general anesthesia affects the thermoregulatory command of heat dissipation since the patients being operated on are generally hypothermic. In the dog, tachypnea resists general anesthesia better than shivering does.

*Excessive central warm response.* The common form of this in humans is the menopausal hot flush. The flushes last only some minutes while the subject experiences a sudden, almost explosive, activation of all autonomic responses to heat. As a result, deep body temperature falls[74,75,77,110]. The flush can be induced by injection of TRH[76]. The menopausal flush has been compared to an autonomic seizure. It can be preceded by a feeling of warmth, which would indicate that the flush is a response to a sudden anapyrexia (see below).

*Pathology of the thermoregulatory set-point*

In temperature regulation thermoregulatory responses tend to equalize the actual core temperature with its hypothalamic set-point. In a healthy subject the set point is 37 °C; but a pathological condition may change it. Whatever the absolute value of set-point temperature, the patient will tend to defend it by using autonomic and behavioral responses in the same way as the healthy subject.

*Lowered set-point: Anapyrexia.* If the set-point for temperature regulation is lowered to below 37 °C, autonomic and behavioral heat dissipating responses should occur even at a core temperature around or below 37 °C, and should lower body temperature. Such situations are not merely theoretical since some rare cases have been reported in the literature[19,37,44,49,51,98]. The syndrome generally appears during childhood in the form of episodic attacks which may last from 30 min to several days. After initial vasodilatation and intense sweating, deep body temperature decreases well below 37 °C. During this phase of low $T_b$, therapeutic warming of the patient immediately induces vasodilatation and sweating, and core temperature does not increase. Nevertheless, the capacity to produce fever is preserved. Temperature regulation is therefore unimpaired except for the low set-point. At the end of the attack shivering and vasoconstriction normalize body temperature. In some of such patients, agenesia of the corpus callosum has been reported. In some patients the low $T_b$ set-point is permanent[19,50]. In this case, heat-dissipating responses are preserved above the set-point. This indicates that thermogenic capacity is intact and that only the set-point of temperature regulation is lowered. Whether periodic or permanent, this syndrome deserves to have a name, and may be called *anapyrexia* (reversed-fever) since it is comparable to fever. Fever is a resetting of the thermostat to a high $T_b$ and anapyrexia is a resetting of the thermostat to a low $T_b$.

*Raised set point: Fever.* In the familiar case of fever, the patient uses all thermoregulatory means in order to increase $T_b$, and defends this higher temperature[35,40,85]. It may be concluded that during fever the set-point of body temperature is raised. This situation is different from passive hyperthermia[106] and is conceivably the result of selective pressure during the phylogenic evolution of species[36,62]. It is likely that fever is beneficial to the body's defense against aggression, in particular infectious disease. The physician should therefore not oppose fever but rather facilitate it. During fever, endogenous vasopressin is produced by the CNS. This substance produces antipyretic effects[115]. However, excessive production of vasopressin may induce convulsions[14,59,115], and this may explain the phenomenon of fever convulsions during the first years of childhood. These convulsions may occur up to the age of 3 or 4 years, then the resistance to fever seizures increases with the maturation of the CNS[52].
The etiology of fever may be infection, tumor, or inflammation[4]. Emotion[89] and hypothalamic lesion[69,71] should also be considered as potential etiologies of fever since in such cases the set point of temperature regulation is also raised. Fever has also been reported in paraplegia[5].

During *heat-stroke,* the physiological means of heat dissipation are overwhelmed and deep body temperature rises. Above a critical value of deep body temperature patients are in the state of vasoconstriction, stop sweating and may shiver in spite of a deep body temperature of between 40.5 and 40.6 °C. It has been hypothesized that this results from an upward shift of the set point of $T_b$. Paradoxically, muscular heat production may oppose the necessary therapeutic cooling[6].

*Suppression of set point.* Total suppression of the thermoregulatory set point is difficult to distinguish from simultaneous pathological suppression of heat- and cold-responses. Such a situation therefore remains hypothetical. A valid argument for the existence of this syndrome is perhaps the situation presented by some patients: thresholds were suppressed, but the capacity to shiver and sweat remained intact[19,68].

Usually the physician knows fairly little about temperature regulation, since it is an efficacious system. From this nosographic review it appears that the pathology of

temperature regulation is rich enough to deserve our perhaps somewhat humorous title. However it should be pointed out that in most cases the diseases of temperature regulation are benign, and can be ignored – from the point of view of temperature – or so severe that the prognosis is almost hopeless. The reason for this apparent paradox lies in the extreme importance of temperature regulation for humans. Because of this, evolution has produced several redundant regulatory loops. When a deficit hits one loop the others take over and the disease is almost imperceptible. When all loops are suppressed the matter is extremely serious.

Finally, when the pathological condition ends in either hyper- or hypothermia, it is essential to identify the etiology since the therapy adopted will be based to begin with on the etiology. As a result, a given symptom may be treated by opposite but symmetrical therapies.


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# Weather and acute cardiovascular attacks: statistical analysis and results

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*Key words.* Biometeorology; cerebrovascular accident; meteorology; myocardial infarction; predictor; weather type.

## *1. Introduction*

This study deals with the onset of cardiovascular critical phenomena among a human population. A review of published biometeorological studies in this field shows that a great many have been carried out, but most of the results are not supported by precise criteria of statistical significance. Therefore we shall first introduce in this article a synthesis of the results of French studies conducted in the Paris area, which will lead us to develop the methodology which has been used. Next we shall compare these results with those from three other selected studies. The French studies have been conducted within specific spatio-temporal limits, i.e. in a town where critical data have been compiled constituting the statistical population of the study. Indeed, the elaboration of these medical files permits us to ascertain once more a seasonal distribution of the crises with a maximum in the colder period, a fact already well known for a temperate climate[13]. However, our purpose is different; our specific goal is to answer the following question: To what extent could the onset of myocardial infarctions or cerebrovascular attacks be accounted for by short-term meteorological or environmental changes?

## *2. Biometeorological methodology*

### *2.1 Spatio-temporal aspect*

It is necessary in order to study the comparative evolution of the atmospheric situation and the daily number of cardiovascular attacks compiled by a medical service to ensure a certain spatio-temporal unity:
– the clinical cases observed at the emergency medical unit originate from a limited zone (e.g. a city, circa 100 $km^2$) and the study must reject from the files external cases resulting from long distance transportation;
– the meteorological synoptical station taken as a reference station for the calculation of biometeorological predictors is representative of the local atmospheric variations induced by the evolution of the weather.
The basic time unit used for the elaboration of the medical files on the one hand and the meteorological files on the other hand is the day (0–24-h period). The basic spatial unit is the topoclimate[4].

### *2.2 The medical files*

They must collect a large number of cases on the basis of strict clinical criteria. In that respect records of deaths