Systemic and local cryotherapy

Edited by Zdzisław Zagrobelny

Preface

It has been 20 years since cryotherapy was introduced in Poland. Practical wisdom gained during this period has broadened the range of its applications.
We hand to readers this extensive monograph on endemic and systemic cryotherapy which being written by many authors presents A very wide scope of issues. Most of the presented papers were already published in “Acta Biooptica et Informatica Medica” but, according to periodical editors, they have not been sufficiently disseminated. For that reason as an editor of this monograph I have chosen papers by various authors who are engaged in cryotherapy either as doctors or researchers.
I am conscious that construction of the book is not always coherent in terms of presentation methods, content and literature quotation. Nevertheless, it has been for the first time in the country when various medical cryotherapy applications were studied so comprehensively.
I wish to thank professor Halina Podbielska and professor Wiesław Stręk, editors of “Acta Biooptica et Informatica Medica”, for their encouragement and content-related advice, and also doctor Edward Łukowiak and Mrs. Wiesława Jeleńska – Hombek for editorial help and correction of this book.

Zdzisław Zagrobelny

Chapter 1

Zdzisław Zagrobelny

Cryotherapy… what is it?

Cryotherapy is one of therapeutic methods of cold application. However, among these methods cryotherapy (or cryostimulation) seems specific and unique and cannot be compared in physical, physiological or clinical sense with any other physiotherapeutic treatment that incorporates cold for partial or whole body chilling.

The differences between conventional chilling treatment and endemic or systemic cryotherapy are as follows:

1 applied temperatures are extremely low: from –80^{O}C to 196^{O}C (boiling point of liquid nitrogen), so after AN extended period of application they could be dangerous for cells, tissues or whole organism

2 Thus, application of extremely low temperatures must be limited to very short periods – virtually not longer than 3 minutes, regardless of the body area subjected to cold application

3 The body heat loss after 3 minutes of application of air cooled to –140^{O}C could be compared with body heat produced after assimilation of ingredients of a small egg

4 THE Human being is a homeothermal creature and this does not change during cryotherapeutic treatment. The temperature of blood, cranium, chest and abdominal cavity remains unchanged, however, the temperature of skin and limbs changes due to different regulation of microcirculation.

5 The highest loss of heat after treatment does not exceed 3^{O}C in skin and 12^{O}C in limbs but in both cases it is impossible to cool down treated areas to 0^{O}C and cause more extensive thermal damages (in fact such cases are known but their origin is completely different)

6 At the turn of XIX and XX century people developed cryogenics – the ability to produce and maintain extremely low temperatures using special devices. Physicists learned the methods of liquefaction of both natural and synthetic gases, even in industrial volumes. Warsaw University represented by professors: Zygmunt Wróblewski and Karol Olszewski significantly contributed to these achievements.

In general endemic or systemic cryotherapy, excluding few obvious contraindications MAY HELP IF YOU SPELL IT CONTRA-INDICATIONS, remains safe.

What is cryotherapy in the clinical sense? It is a physiotherapeutic treatment which means stimulating a point, surface or whole parts of the body expecting that such stimulation will activate therapeutic or regulative response of central nervous system. Since the stimulation is carried using extremely low temperature the response will be of thermoregulatory character. It is so, because human body has its internal, precise thermostat that controls, by means of physical mechanisms, heat loss and gain.

In Poland cryotherapy was introduced in 1983 at Academy of Physical Education in Wrocław in cooperation with Institute of Low Temperatures and Structural Research of Polish Academy of Sciences in Wrocław, some clinics of Academy of Medicine and other therapeutic institutions. At the beginning many devices producing liquid nitrogen vapours were constructed in order to conduct endemic treatment. In 1989 first Polish low-temperature chamber was built and was tested on healthy volunteers. It has been operating up to now at Rheumatological Ward in hospital in Kamienna Góra. The lack of serious complications as well as evident curative and relieving properties proved on many patients convinced us that cryotherapy can be applied as an ambulant treatment not only endemically but also on the whole organism. AS A result the second cryo-chamber was built in 1996 at the Institute of Rehabilitation in Rzeźbiarska St. 4. It was as a tribute to THE Academy of Physical Education for its 50th foundation anniversary. Patients, also with non-rheumatic diseases, are welcome here to take advantage of the treatment. Over 100 of patients suffering from numerous motive MOTOR?dysfunctions have already been subjected to over 1000 of applications. The second Polish cryo-chamber was built at a relatively small cost, unfortunately, AND there is still not enough money to advance infrastructure (computers, measuring and rehabilitative equipment) of this unique investment which could be named cryorehabilitation.

Accordingly COMA in A clinical sense cryotherapy is a superficial, stimulating application of extremely low temperatures during 2-3 minute periods in order

to induce and utilize physiological reactions against cold and also to support and facilitate basic treatment in motion therapy. Cryotherapeutic treatment prior to exercises enables longer and three times more intense therapeutic gymnastics.

The heat transfer from organism to the surroundings of cooled area or whole body can be described as heat loss through radiation and the volume of such loss can be calculated.

Clinical effects of cryotherapy include: alleviation of pain in the whole organism, mass,NOT SURE WHAT YOU MEAN B MASS impulsive hyperemia of skin or limbs caused by the organic effort to warm up the cooled parts, anti-swelling effect, atony NOT SURE WHAT ATONY IS..MAYBE TONING of muscles and increase of their strength, and also RATHER THAN AND ALSO . OTHER BENEFITSafter systemic treatment: outstanding improvement of mood, enhanced will to move (perform therapeutic exercises), better cooperation with doctors and physiotherapists and distinct improvement of humoral and cellular immunity of the organism. Serial repetition of treatment (10-20) preserves certain flaccidity of spastic muscles, painlessness and improving tolerance of cold – perceived as burning chill and prickling. In result AS A RESULT greater comfort of rehabilitation and its significant shortening are achieved as well as incomparable therapeutic effects.

Chapter 2

Zdzisław Zagrobelny

Therapeutic application of cold

At the beginning of XXI century medicine faces serious and complicated problems including increased number of chronically ill and handicapped people or high direct, indirect and social costs of modern therapy. Thus, health service managers or doctors must adjust their way of thinking. On one hand, individualization of therapy and its optimization by means of conventional methods seem essential, but on the other hand it is necessary to introduce alternative methods, both inexpensive and effective. The main aim should be reduction of costs of therapy and retaining high standards at the same time. Here, great opportunities are offered by physiotherapy and motion. The definition of physiotherapy describes it as a complex treatment, based on assumption that organism will not function properly unless provided motion, training and effort. Therefore this is natural method of therapy which developed purely from empiricism. Actually the physiotherapy incorporates hydrotherapy, heat therapy, cold therapy, thermotherapy assisted electrotherapy, gymnastics, massage and other treatment.

During physical therapeutic treatment THE human body is subjected to operation of various impulses which induce systemic or organic reaction which again activates and regulates THE natural defensive forces of the body.

The impact of physical impulses on THE human body can be explained on BY RATHER THAN ON the example of thermoregulation phenomenon observed in hematohermal HEMATOTHERMAL?creatures. Thermoregulation in its main sense means balanced regulation of human body heat – thermal homeostasis. In humans and warmblooded creatures constant temperature is normally observed in body cavities, chest and cranium. Skin and limbs react in heterothermic way. The heterothermic character of skin and limbs determines hematothermic behaviour of body cavities by affecting THE operation of THE cardiovascular system – mainly through microcirculation and metabolism intensity under the control of thermoregulation centers. Thus, thermoregulation in some way depends on metabolism and THE cardiovascular system. Thermal therapy induces rapid thermoregulatory reactions by means of thermoreceptors which are sensory nerves recording changes of temperature. Subthalamic thermoreceptors are one of the most important as subthalamus itself controls THE majority of hormonal and all vegetative functions of human organism. So these, in other words, thermoentheroreceptors or thermodetectors are sensitive to actual blood temperature and their stimulation may result in active and direct heat production (trembling or thrilling muscles) or only in intensified food ingestion and metabolism which also leads to increased heat production.

Various factors also affect the concentration of Ca^{++} ions vs. Na^{+} ions in subthalamus which may disturb the balance of this biological thermostat. Increased Na^{+} concentration in subthalamus is caused by interleukins 1 and prostaglandins and results in fever. Increased Ca^{++} concentration causes slight lowering of body temperature.

In skin there are thermoexteroreceptors that can be distinguished as sensitive to high and low environmental temperatures (thermoreceptors of cold and heat). Thermoreceptors of excessive heat are also situated here. They enable THE operation of so called “thermal sense” which regulates the feeling of “thermal comfort” – such comfort, in a thermal sense, may be perceived differently depending on environmental conditions. Thermoexteroreceptors

are also associated with the phenomenon of behavioral thermoregulation which makes the overheated body look for shade, wear loose clothes, drink cold liquids whereas on cold days receptors make us wear thick clothes, move, heat our places or drink warm liquids.

Production of endogenous heat is sometimes called chemical thermoregulation. This is the production which exceeds the needs of basic metabolism and THE main sources of that heat are motor muscle activity or their visible and invisible thrills and tremblings.

The loss or gain of exogenous heat by the body takes place by means of physical mechanisms and that is physical thermoregulation. The direction of flow of heat depends on temperature gradient between organism and surrounding atmosphere, objects or items. Depending on gradient, tissues or environment become the source of heat.

The idea of therapeutic application of cold is actually the same as therapeutic application of heat, however, this IT RATHER THAN THIS is the tissue that becomes the source of heat. That heat is absorbed by THE surroundings of the tissue. Intensity of the process increases along with increased gradient of temperature between surroundings and the tissue.

Therefore therapeutic application of cold is based on intensification and acceleration of natural and permanent mechanisms of heat transfer through increasing differences between temperature of tissue and environment. The physic DO YOU MEAN PHYSIC OR PHYSICAL, physiologic and clinical nature of cold treatment consists of various elements and according to archaic documents it was investigated even 5000 years ago. The medicine of ancient Egypt featured considerable rationality and this is where application of cold started.

The loss of body heat through tissues can be based on conductivity, convection, evaporation or radiation depending on THE object or material absorbing the heat.

The sources of therapeutic cold can be ice, snow, icy-cold water, frozen gels, laminar flow of cool air across or along A bare body, evaporation of fluid priorly sprayed on body surface and finally vapors of natural or synthetic gases condensed in extremely low temperatures.

The prime results of cold application in the initial stage are contraction of

blood vessels, reduced blood flow and metabolism of tissues, limited dynamics of liquids and in general reduced perspiration. Cold also reduces neural excitability and conduction which causes endemic anaesthesia and soothes injury induced inflammation.

Some of the potential dangers of cold application are frostbites or tissue necrosis resulting from ischemia which may happen during extensive cold treatment. Clinical cold incorporation is advisable for any kind of tissue suffering from inflammation or intense, endemic pain. Moreover, due to atonic properties of cold it can be locally applied on muscles in case of impulsive or neural spasticity.

Physiological results induced by cold make it the treatment of choice in the therapy of injuries of soft tissues eg. sprained or impaired joints, haematomas, overloaded or bruised tissues (sport medicine towards professional sport). NOT QUITE SURE WHAT THAT MEANSCold prevents further injuries of tissues reducing excessive swelling. Cold application is also the treatment of choice in first aid or early stage therapy of 1st and 2nd degree burn BURNS or extensive skin excoriation. Cold slows down or prevents inflammation after such injuries. Inflammation may cause greater damages than the primary injury. GOOD TO EXPLAIN WHY/HOW

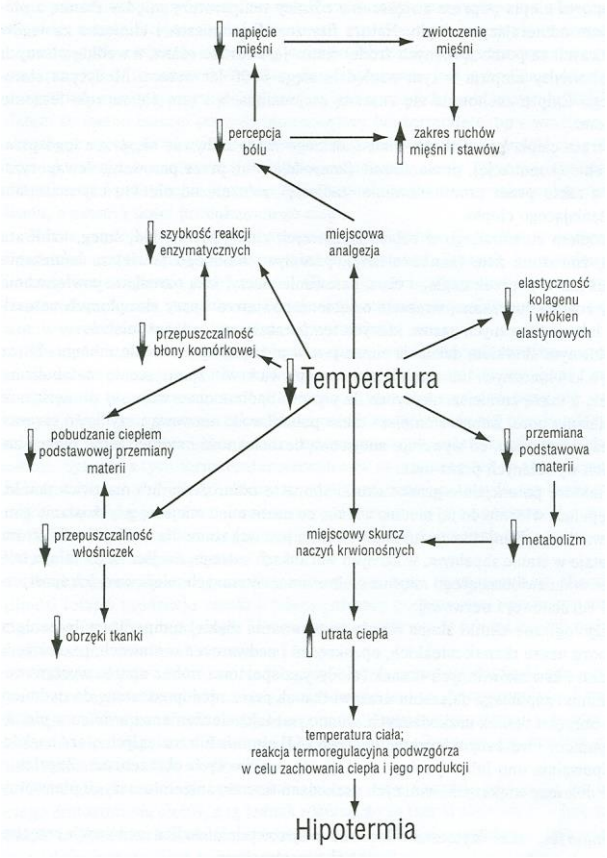
For its antiphlogistic features due to reducing the blood flow cold is also useful in therapy of endemic infections. Penetrating tissues it cools nerves and muscles thus inhibition INHIBITING chemical reactions in the process of neuromuscular conduction. Therefore cold features another advantageous effect which is reducing tensional reaction [THEREFORE ANOTHER ADVANTAGEOUS EFFECT OF COLD IS THE REDUCTION OF TENSIONAL REACTION] of muscles against stretching. In that way cold may be applied before any other treatment targeted on reducing muscular tension or to enlarge the range of articular movements limited by shortening or spasticity of muscles (before therapeutic exercises). Application of cold is contraindicated CONTRA-INDICATEDon anaemic area of tissues, areas without perception and in patients bearing low tolerance of cold.

Therapeutic application of cold is A very effective and inexpensive method of treatment both at home or in therapeutic facilities, in the latter always under the supervision of A competent therapist or doctor. It is a therapy of choice for

THE majority of therapists in every acute injury of tissues. Such therapy decreases the deadly ratio of pathology limiting it to primary damage under the condition of quick and proper cold factor application.

EachTAKE OUT EACH body heat loss during therapy can be accurately calculated from suitable formulas or equations provided that their easily derivable components are known.

Until recently cooling through conduction was the most widely employed method of treatment (mainly endemic) of skin by utilizing icy-cold water or crumbled ice as cooling factors. Ice can be utilized in the form of ice compress, thermophore filled with crumbled ice or frozen wet towels. In all these examples treatment lasts from 10 to 15 minutes with 5 minutes break and the cycle is repeated until the best possible results are achieved.DIAGRAM NEEDS TRANSLATING



Pic 2.1. Physiological results of endemic cold treatment incorporated in physical therapy.

Immersion in icy-cold water is used to cool the surface of the body but such

treatment is tolerated only by few patients and only during very short period (in cardiosurgery in systemic anaesthesia such treatment is occasionally used to achieve artificial hypothermia to the blood temperature limits of $30^{O}C$, and during some operations even to $11^{O}C$ – $13^{O}C$).

Cold compress can be describes as plastic bag filled with special gel which remains plastic after freezing. They are produced also in Poland and represent good quality. The frozen compress is wrapped in wet towel to obtain more effective heat absorption and placed onto skin for maximum 1 hour. The treatment utilizing cold compresses should be normally continued for 30 minutes, after that time endemic, impulsive increase of blood flow is limited at the highest ratio (Lewis reaction).

Cooling through transferring the heat from the body into surroundings is rarely employed right now. Most profitable application of convective cooling may be incorporation in relieving fever or hyperpyrexia, some of the infectious diseases and central nervous system disorder which may complicate due to excessive heat production and malfunctioned physical thermoregulation. Convective cooling is mainly realized by means of powerful fans or blowers directing the laminar flow of cooled across or along the naked body.

Cooling through evaporation is based on the principle that to evaporate volatile substances from the surface of skin it is essential to provide thermal energy which in result leads to cooling of that surface.

Chloroethane is such fluid that enables endemic cooling of injured surfaces and has been employed in that way for many years (apart from anaesthetic applications). In 1962 Traherne advised the use of inflammable and nontoxic chlorofluoromethane for the same purposes, however, the fluid in Poland is hardly known and is not produced.

To calculate the heat loss from the cooled area it is necessary to standardize the procedures of evaporation of aforementioned fluids. Pressurized container filled with chloroethane is equipped with calibrated nozzle thanks to which a very thin stream of volatile fluid can be obtained. The stream should be released at 0,5m – 1m distance from the skin surface and should be applied at right angle vs. this surface. The stream should flow continuously. The speed of flow should be constant and rate 100 mm/s, application should last few seconds and after few second break it should be repeated.

Therapist has to remember about the possibility of frostbiting caused by too intensive cooling as well as possibility of inflammation or explosion of chloroethane vapors which would cause skin burn. Chloroethane burns producing green flame. It is mostly utilized in sport medicine.

Cooling through radiation. THE Human body may lost significant volumes of heat even up to 55%. In general radiation proceeds very slowly during different periods of the day with different intensity depending eg. on the worn clothes. CLOTHES WORN

Radiation means energy flux emitted by material system in the form of waves or particles and also the process emission itself. Radiation can be distinguished as electromagnetic radiation, nuclear radiation and radiation of energy of elastic waves. One of the types of electromagnetic radiation is thermal radiation, emitted by each body in temperature higher that absolute zero. This radiation becomes visible in the temperature higher than $500^{O}C$. Thermal radiation is more intense when the difference between body temperature and environment grows bigger.

As a result of THE widening of blood vessels THE body surface and respiratory tract become warmer and it increases radiation (or conduction) of heat. A Similar situation can occur when THE body is surrounded by extremely cool air or when body surface is treated with vapors of condensed gases in a turbulent way. In order to cool and stimulate skin to activate the thermoregulatory mechanisms most frequently vapors of liquid nitrogen, cooled air and vapors of nitrogen monoxide are used.

Thermal energy emitted by surface radiation A can be calculated from Stefano-Boltzmann equation (Conte 1970):

$W_R=e*A*T^4$

Where:

W_R – energy of thermal radiation expressed in Watts

e – emissive power of a body

A – Stefano-Boltzmann constant

T – temperature in Kelvins

So, the energy of thermal radiation between two surfaces having different temperatures T_1 and T_2 can be calculated as follows:

$W_R=E*A_1*(T_2^4-T_1^4)$

Where:

A_1 – 1 cm^2 surface emitting thermal energy at the temperature T_1

E – factor that is taken into consideration when estimating emissive power of surfaces e_1 and e_2 at temperatures T_1 and T_2. The emissive surface can be planar or convex and then energy is emitted at all wavelengths perpendicularly to planar surfaces (e_{nor}) or at none specific direction in case of spherical or cylindrical surfaces (e_{hem}). The E value varies from 0,5 to 1.

T_2 – temperature of cooled human body surface – at internal temperature $36,6^{O}C=309,75$ K

T_1 – temperature of surrounding air cooled in the heat exchanger to $-196^{O}C=77K$

In these conditions, during 1 hour extremely cool air by means of rapidly accelerated radiation and conduction (ice dust from expired steam and CO_2) would cool down the human body surface which would loose 1305 kcal. However, the cryogenic treatment can last maximum 3 minutes. During 3 minutes the body would loose 65,2 kcal, during 2 minutes – 43,5 kcal and during 1,5 minutes – 32,6 kcal.

Therefore the body heat loss during 3 minute exposure is relatively low, equal to calorific value of a small egg. Shorter exposures cause even lower loss. Those conditions and time cannot cause hypothermia COMA only some minute thermal skin damage of 1st degree may occur. However, that stimulation is intense enough to activate mechanisms of thermoregulation and induces heat production, conservation and redistribution to cooled areas. The lower are temperatures of cryogen THE LOWER THE TEMPERATURE OF CRYOGEN ? and the shorter are THE INSTEAD OF ARE periods of application the safer is the treatment itself SAFER THE TREATMENT IS AS as it does not affect the temperature of body cavities. The main organs can function in the optimal temperature.

Following above considerations one should QUESTION WHETHER RATHER THAN THINK IFthink if each therapeutic application of cold can be named cryotherapy or is the cryotherapy anything specific? In other words, what is the essence and definition of cryotherapy?

Cryotherapy is a noninvasive application of extremely low temperatures of cooled air or vapors of condensed gases. Application induces radiational,

endemic or systemic cooling of human body surfaces and must not last longer that 3 minutes. Rapid cooling, almost sucking out the relatively small portions of heat from the tissues stimulates endemic or systemic thermoregulatory centers to conserve, redistribute and when it is necessary to produce heat.

After endemic or systemic cryotherapeutic treatment THE following results may be observed: subjective local, remote or systemic anaesthesis (among others: large volumes of endorphin ENDORPHINS are secreted), hyperemia of cooled areas (warm blood is instinctively directed to vessels where blood was cooled), atony?? TONING? of healthy muscles and increase of their power, WOULD BE GOOD TO KNOW HOW/WHYreduction of spasticity of muscles – when present (inhibition neural conduction and neuromuscular stimulation). As a late effect, anti-swelling action and stimulation of immunologic system are observed.

Clinical symptoms, especially after systemic cryotherapy, are accompanied by increased plasmatic concentrations of important hormones and modulators which normally are considered as emergency reactions. This also proves IMPROVES? the therapeutic character of the treatment.

Physical mechanism of cooling tissues, utilizing extremely low temperatures for quick cooling of body surfaces or respiratory tract, clinical and laboratorial, immediate and late symptoms or results, the possibility of numerous repetition of the treatment during the day and in long series – these all factors contribute to conclusionTHESE ARE ALL FACTORS THAT CONTRIBUTE TO THE CONCLUSION that cryotherapy features significant differences from conventional therapeutic cooling.

In the papers written in German or English one may encounter distinct expressions: eg. *Kaltherapie* and *Kriotherapie* or *coldtherapy (cryo/kryo/therapy).*

Cryostimulation can be a synonym of cryotherapy. There is some loss of heat after treatment but it is so small that neural stimulation using “burning cold” has, with no doubt, its importance in initiating clinical and laboratorial changes.

In Poland, cryotherapy application to healthy persons (scientific research) and patients (scientific research and therapy) was initiated in 1983 by the author of this chapter. Shortly after, this method of therapeutic application of cold,

especially in endemic version, was so widely used that it has become the most frequently conducted physiotherapeutic treatment and it is still being developed. If it had not been for low temperature physicists and cryogenists and their input it would not have been possible to construct cryogenic equipment: from the simplest applicator to complex cryogenic chambers and cabins. Especially THE Institute of Low Temperatures and Structural Research of Polish Academy of Sciences in Wrocław with its researchers, technicians and constructors and above all Mr. Zbigniew Raczkowski greatly contributed to these achievements.

It seems that it is necessary to distinguish the cooling treatment and cryotherapy as there are many clinical, physical, therapeutic differences justifying such distinction in the literature on that subject.

Cryotherapy and also cryosurgery has HAVE numerous applications in medicine and veterinary medicine. Endemic or systemic cryotherapy can be employed in:

1. complex therapy of rheumatic or degenerative diseases or rheumatism of soft tissues
2. in DONT NEED IN primary or secondary degenerative diseases of kinetic system,
3. acute and chronic injuries, both of sport or surgical origin, contributing to accelerated healing of those
4. therapy of rare autoimmunologic diseases or collagenose
5. therapy of bone diseases, especially in case of primary or secondary ostheoporosis
6. alleviation of chronic pathological pain in patients subject to conservative treatment
7. in DONT NEED IN fighting impulsive and systemic spasticity in the process of neurological rehabilitation
8. in DONT NEED IN immediate therapy and early stage therapy of children and adults suffering form FROM burns
9. inducing homeostasis in internal bleeding from digestive tract or in external bleeding eg. extensive skin excoriation
10. biological restoration of professional atheletes or mentally or physically exhausted adult persons

Each investment in this branch of knowledge: cryobiology, cryogenics and cryotherapy is well oriented in modern medicine. The cryogenic devices and facilities are not expensive as well as their exploitation.ARE NOT RELATIVELY EXPENSIVE GIVEN THEIR POSSIBLE EXPLOITATION

Literature:

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Chapter 3

Halina Gregorowicz, Zdzisław Zagrobelny

Systemic cryotherapy. Indications and contraindications,

process of treatment and its physiological and clinical results.

The story of therapeutic application of cold is probably as old as mankind and medicine. Such treatment was performed by ancient Egyptians ca. 2500 years B.C. Hippocrates advised hypothermia as the remedy against swelling, bleeding or pain and also observed that cold shows analgesic properties. These facts were later confirmed by surgeons, among others, Napoleonic surgeon baron D.J. Lorrey during Russian campaign observed that limbs of wounded soldiers could be amputated with minimum pain and bleeding as long as they were earlier covered with ice or snow.

Superficial analgesic properties of chloroethane, which had been known since XVII century, were discovered in France in 1847 by P. Flourens. However first clinical application of chloroethane in the form of aerosol took place only in 1866 in Switzerland and was carried by P. Redard. Redard was also the first to incorporate chloroethane in systemic analgesia. Until today endemic, analgesic properties of choroethane are utilized by sport medicine mainly in treatment of injuries. Chloroethane evaporation from the area of application causes local temperature change even by $-20^{O}C$.

Modern cryogenics was introduced when physicists learned how to condensate CONDENSE? gases, ie. since the end of XIX century. Contemporary physicists, also with Polish researchers among them, achieved more than condensation of oxygen, carbon dioxide, air or hydrogen. They also enabled production of these cooling agents in industrial volumes and invented methods of storing them in special tanks that are used up to now.

In the first half of XX century cryobiology was developed. Cryobiology investigates changes in cells and tissues under the operation of subzero temperatures. Liquid cooling agents were incorporated in therapy of dermatological illnesses and superficial benign or malignant tumors.

In 1907 Whitehouse constructed a device releasing vapors of liquid nitrogen which was employed to remove superficial tumors and therapy of some dermatological changes. On the base of construction of Whitehouse's device all modern cryoapplicators were built. Cryoapplicator is a common name for all portable sources of liquid nitrogen or other cooling agents. Therefore

Whitehouse’s device was a milestone in the development of therapy based on destruction of diseased tissues – it was called “cryosurgery” or “cryodestruction”. In various diseases and in many clinical disciplines cryosurgery became the treatment of choice.

In the 70’s of our century IN THE 1970'S a new conception of cryotherapy was invented. It included stimulating, superficial operation of cryogenic temperatures (below –100^{O}C) during very short periods of time (2-3 minutes) in order to induce and utilize physiological, systemic reactions against cold, assist basic treatment and ease motion therapy.

Cryogenic temperatures can be applied endemically in THE case of skin and joint diseases or systemically in THE case of many other diseases – in cryochambers or cryocabins.

Cryotherapy was introduced into clinical practice by Toshiro Yamauchi and his team working in Reiken Rheumatis Village Institute in Oita (Japan). It was there where world-first portable cryoapplicators and cryochamber were built (1978). In 1981 during European Congress on Rheumatology Yamauchi presented systemic therapy and its influences on both diseased tissues and the whole body.

The Japanese results inspired Reinhardt Fricke, head of St. Joseph Clinic of Rheumatology in Senenhorst (Germany), who established cooperation with THE Oita center and also started to investigate all kinds of cryotherapy. Initially Fricke followed Japanese methods but after some time introduced new procedures, eased the therapeutic regime and shortened duration of therapy to 6-8 weeks.

In Poland, cryotherapy was introduced in 1983 in Wrocław in the Department of Physiotherapy headed by professor Zdzisław Zagrobelny. It was here, where the first cryoapplicator was installed and used to apply cryotherapeytic treatment assisted by kinesitherapy to volunteers with rheumatism and posttraumatic diseases. Before that, Dr Szeffer-Marcinkowska incorporated vapors of liquid nitrogen to dry-cooling of scalding wounds of test-animals which significantly accelerated healing of those. This method has already been incorporated into clinical practice and showed similar therapeutic results.

In 1989 Poland-first IN 1989 POLAND'S FIRST cryochamber was built (2nd in Europe and 3rd in the world).

The first Polish cryochamber was tested on healthy volunteers, students of THE Academy of Physical Education in Wrocław, and it was installed in Rheumatological Ward in THE hospital in Kamienna Góra where it has been successfully operating since 8 Oct 1990. The chamber utilizes air cooled to –110^{O}C : –160^{O}C as cooling agent.

THE Human body maintains constant internal temperature with daily fluctuation of 0,5^{O}C – 0,7^{O}C and is more sensitive to external cold than to heat. Apart from physiological regulation THE human body features also behavioral regulation.

Physiological defensive mechanisms against cold include: conservation of cold (contraction of superficial blood vessels) and production of heat (muscular trembling, visible or invisible thrills – the latter inducing only increased plasmatic concentration of K^{+} ions). Such thermogenesis is activated by thermoregulation centers at the body temperature of 36^{O}C. the heat .THE HEAT [CAPITAL T IN THE] produced in that way 2-3 times exceeds the volume of heat produced during basic metabolism.

In adult human HUMANS only long lasting exposure to cold or short but very intensive operation of extremely low temperatures launches additional, hormonal reaction accelerating tissue metabolism and increasing the temperature of tissues. There ARE also other reactions aimed to maintaining the heat homeostasis.

The very well known analgesic effect of low temperatures is caused by cold induced shutdown of receptors and their connections with proprioceptors and braked conduction in sensory neurons. Pain alleviation is also reasoned by the Melzack-Wall theory of “control gates” (1965) on pain conduction in central nervous system. Moreover, there are biochemical bases of low-temperature analgesia which include increased secretion of beta-endomorphin – a highly analgesic neuropeptide – and its increased concentration in blood serum. Such effect – apart from cold – is also due to other factors such as stress.

The impact of low temperature on loosening of skeletal muscles can be explained by decreased number of pain stimuli reaching THE spinal cord and segmental inhibition of gamma-motoneurons stimulation. Moreover, an additional mechanism of loosening muscular tension was found – it is CAUSED BY inhibition of conduction in motion nerves.

The changes in circumferential blood circulation are crucial for patients subjected to low temperature therapy. Within THE limbs, their blood supply regulation depends entirely on sympathetic system and as a consequence under operation of low temperatures the loss of heat in limbs is higher than within THE thorax (Levis' reaction) which results in narrowing of blood vessels and decreased perfusion. On the other side, cold reduces sensitivity of organic muscles against sympathetic stimuli and operation of catecholamine which enables better blood supply in limbs, however, this mechanism is not very efficient.

Extended application of cold is, similarly as stroke (shock), followed by centralization of circulation which enables possibly easiest flow of warm blood to life supporting organs. Systemic results of cooling of areas of skin or whole body depend on: patient's age and their record of diseases, state of nutrition, efficiency of blood vessels, period of cold application and its intensity, action of prescribed pharmaceuticals, alcohol consumption, individual tolerance against cold.

Systemic cryotherapy applied to healthy persons or suffering from rheumatic or degenerative diseases for 2-3 minutes in the temperature of –140^{O}C (+/- 10^{O}C) induces numerous clinical, hormonal and biochemical effects. These effect EFFECTS are extraordinary both from scientific or therapeutic point of view. The operation is a specific opposition of finnish sauna. Clinical consequences of systemic cryotherapy include(after endemic therapy not each of them is observed):

1. outstanding, positive impact on psyche – betterment of mood
2. subjective analgesia against articular, superficial and also internal pain, overcoming of weariness
3. loosening of muscles tightened around diseases joints, significant increase of muscular strength despite excessive, disease-characteristic decay of muscles, braked sensory and motoric conduction in nerves
4. massive blood flow through body diaphragm and organs which causes pinkening and sensation of hot

All these facts which can be observed at least 3 hours after treatment contribute to improved rehabilitation enabling 3-times greater intensification and extension in time. Also it is possible to increase the

number of applications up to 3 per day. Heat conservation in thorax is fully maintained, its superficial temperature can be lowered by 0,5 to 3,2^{O}C, and at the kneecap level by 9,5 – 11,5^{O}C with unchanged temperature of body cavities which is proved by normal temperature of oral cavity.

All patients who were qualified for treatment in cryogenic chamber were subjected to regular, thorough medical examination. Actual and past physical state of each patient was surveyed to eliminate possible contraindications against cryotherapy (recent and past diseases, prescribed medicines). Patients were also questioned about individual tolerance towards cold. All patients were subjected to auscultation of lungs and heart, palpation of abdomen cavity, measurement of blood pressure and pulse frequency, electrocardiographic examination and neurological examination. The 5-year experience of Polish and Western researchers in systemic cryotherapy helped to indicate contraindications against this kind of treatment.

The absolute contraindications are as follows:

1 sensitivity against cold,
2 cryoglobulinemia,
3 cryofibrinogemia,
4 Raynaud disease,
5 Cold urticaria
6 Purulent or gangrenous skin diseases,
7 Agammaglobulinemia,
8 Diseases of central nervous system,
9 Neuropathy of sympathetic system,
10 Hypofunction of thyroid,
11 Endemic disturbance of blood supply,
12 Significant deficiency of blood,
13 Action of some medicines especially neuroleptics and alcohol,
14 General cachexia and hypothermia,
15 Claustrophobia,
16 Little experience of persons applying the treatment,
17 Any technical defect of the device

After thorough examination, marking hemodynamic indicators and

spirometric examination of patients before and after therapy in cryochamber it was possible to indicate absolute contraindications concerning cardiovascular and respiratory system. These are as follows:

1 defects of aortic valves,
2 diseases of cardiac muscles or valves during cardiac failure
3 acute effort angina pectoris or spontaneous angina pectoris,
4 disturbance of heart operation at the pulse rate higher than 100/min
5 arteriovenous leakage in lungs
6 acute diseases of respiratory tract of various origin

It is assumed that patients who are qualified for cryogenic treatment show normal gas exchange, regular breathing and can show inefficient EFFICIENT??ventilation of lungs.

Relative contraindications:

1 age over 65 years,
2 overcome venous blood clots, embolism of circumferential arteries
3 excessive emotional lability resulting in eg. excessive perspiration

Each patient before entering the chamber was instructed to wipe the body with a towel in order to remove sweat. This is important because of possibility of formation of ice crystals on the surface of the body which could induce momentary sensation of prickling cold.

Each patient was also asked to avoid deep breaths while breathing through surgical mask and follow the rule: inspiration must be 2 times shorter than expiration. If lungs are rapidly filled with extremely cooled air which after warming doubles its volume it may induce respiratory oppression. Staying in operating chamber without aforementioned safety mask is inadmissible.

Additional safety clothes for patients include: woolen socks, wooden boots, woolen gloves, special ear cover, not to mention shorts or swimsuits. Eyeballs do not require any safety equipment.

In this way secured patients are asked by chamber servicemen to enter the antechamber where they accommodate to low temperature. Then patients in groups of 5 enter the chamber and walk round and round during 120 seconds. Often they are accompanied by serviceman wearing special suit.

Patient while staying in the chamber retains visual and vocal contact with servicemen outside the chamber and the doctor who qualified them for the treatment. The doctor is also on stand-by in case any incidental reaction occurOCCURS. Breathed steam is immediately turned into ice dust similar to mist. Actually, this dust slowly descends on the bottom of the chamber which brings the necessity to ventilate it from time to time to avoid difficulties in watching the patients. Breathed carbon dioxide also may be frozen into tiny crystals.

After treatment patients stay in room temperature. In general, everyone while staying in the chamber didn't feel cold in the common sense but rather burning of bare parts of the body similar to piercing with blunt needle. It may be described as "chilly burning".

It is worth mentioning that patients were in terrific mood after treatment. They informed about feeling totally calmed down and being full of vigor and physically relaxed. All pain and exhaustion were taken away even if before the treatment they were quite intensive. Described good mood was maintained for several hours and even longer. Next important thing was sensation of heat common for all patients after leaving the chamber. It seems natural because patients were rapidly moved to the room where temperature was 150^{O}C higher that inside the chamber. This sensation might also originate from rapid widening of blood vessels which was indicated by pinkening of skin. No blueing of protruding parts of the body was observed. The sensation of heat was maintained until 4-5 hours after the treatment and with patients who were immediately subjected to intense rehabilitation it lasted even longer.

Systemic cooling did not cause any undesirable effects in the cardiovascular system. Neither in measurements of arterial blood pressure and pulse rate nor in electrocardiographic records were noticed any changes in hemodynamic indicators measured by ultrasonograph. Therefore it may be stated that systemic cryotherapy does not affect the operation of healthy heart as well as heart showing some minor disturbances of its functions.

Preventing extremely cold air from being inspired into respiratory tract helps to avoid, apart from minor individual cases, respiratory oppression.

Occasionally, among those entering the chamber, there were also people who suffered form bronchial asthma. They claimed that breathing inside the chamber is exceptionally easy and natural. It may be due to normal or even increased values of oxygen concentration inside the chamber indicated by oxygen concentration sensor or the fact that in such conditions muscular lining of the bronchi is flaccid.

Taking into consideration all contraindications against cryotherapy it should be underlined that all patients subjected to that treatment were volunteers who signed agreement to participate in the experiment.

“Cold shows soothing properties as it affects brain and nervous system” – this was written in XIX century by Napoleonic surgeon D. Lorrey. However, he observed soldiers during russian campaign when it was extremely cold and his descriptions rather refer to hypothermia. In the chamber, 2-3 minute treatment cannot induce hypothermia which is proved by recorded superficial heat values right after the therapy, temperature of oral cavity and lack of laboratorial signs of hyperactivity of hormonal axis TSH-T_4-T_3. It may result from accumulated pharmacological action of increased plasmatic concentrations of beta-endorphines, catecholamines and cortisol against central nervous system as it was observed after the treatment.

Despite no research was madeBEING CARRIED OUT to investigate that issue, it may be assumed that similar action towards psyche may be induced by ionization of air cooled to –160^{O}C in the cryochamber.

Probably similar observations inspired experiments with cryogenic treatment of patients suffering from various types of depression. Such experiments are carried in Japan but their results have not been finally released. The described psychosomatic effect of extremely low temperatures makes them useful for the purposes of biological restoration – also in sport. Unfortunately application of cryogenic temperatures to organism of an athlete may increase concentration of testosterone to such a level that it would be qualified as doping.

It should be underlined that people who sweat because of emotional reasons show very low tolerance towards low temperatures. As well as inside or outside the chamber they feel severe cold however without trembling and increased body heat. Therefore excessive sweating must be

considered as absolute contraindication against cryotherapy.

Just after leaving the chamber patients felt very hot. It is very interesting how production and loss of heat remain balanced despite changing temperatures of environment. The average normal temperature of oral cavity of a healthy, young adult is 36,0 –37,2^{O}C

This isothermal property of an organism is controlled by following factors:

a) skin – normally the loss of heat is due to perspiration but in low temperatures of environment speed of blood flowing through skin becomes a dominant factor.
b) Subthalamus is a set of neural structures placed at the bottom of cranium. These structures work as a thermostat. When the body is cooled, especially using extremely low temperatures, skin blood vessels contract and skin becomes blue or pale which is not observed during cryotherapeutic treatment. Also muscular tension increases, sometimes inducing shivers, however, it was not observed after systemic or endemic cryotherapy either.
c) Inhalalation:INHALATION if the inhaled air is colder than internal body the heat loss occurs as a result of heating that air in lungs and respiratory tract. In cryogenic conditions this factor is essential.
d) Outerwear – during cryotherapeutic treatment outerwear is very specific and ENABLES THE LOSS RATHER THAN PRESERVATION OF HEAT rather enables loss of heat that its preservation.
e) Low-calorie diet with reduced fat does not activate exogenous biochemical reactions in intestinal metabolism. Excessive consumption of cold drinks dissolves blood and urine which is also connected with loss of heat. All these facilitate cryotherapeutic treatment making it more effective.

Therefore, from theoretic point of view, the systemic cryotherapy including few-second stay in adaptational antechamber (–50^{O}C) and 2-minute exposure in the chamber (from –110^{O}C to –160^{O}C, average –140^{O}C) when extensive areas of the body and respiratory tract are subjected to operation of extremely low temperatures cannot induce any superficial damages. Such treatment may only cause decrease of skin temperature within thorax area by 0,5–3,2^{O}C and legs by 9,5–11,5^{O}C. Internal body

heat remains the same which is proved by unchanged temperature of oral cavity. The impact of the treatment on ventilation of lungs is a separate problem.

Cryotherapy cannot induce hypothermia because its syndromes have never been observed. Also, no increased concentration of thyroid hormones was observed which may imply their redundancy in the process of preserving internal temperature.

It is essential that systemic cryotherapy immediately launches thermoregulation which is aimed on heat preservation to maintain the body temperature. Apart from activated thermoregulation, some of the hormonal axes intensify their operation, thus, increased concentrations of catecholic amines, endorphins and other substances are observed. In other words, thermoregulatory effects induced by cryotherapy are symptomatically and therapeutically advantageous for complex treatment of certain diseases.

Heat conservation is better within thorax than limbs. Thus, specific centralization of warm blood circulation occurs which improves the safety of treatment. It is so because normal temperature of blood in main circulatory system is maintained. Within limbs, their blood supply is entirely regulated by sympathetic nervous system. Cold restrains reaction of smooth muscles of blood vessels against sympathetic stimuli which enables transport of warm blood to limbs. However, that mechanism is not very effective. It does not cause any negative results during short-period application of cryogenic temperatures.

The phenomenon of more extensive cooling of limbs than thorax seems to be enhanced by certain technical detail. The cooled air flows into the chamber from the bottom and ascends gradually absorbing the heat from patients staying in the chamber (4 or 5 at a time).

The temperature of skin and thorax restores very quickly after the treatment. In some individual cases the temperature of breastbone skin was higher right after the treatment which proves of early activation of very intense skin perfusion. It may be also due to lack of reaction of microcirculatory system against sympathetic stimulus or increased concentrations of endogenous catecholamines. Thus, most of patients felt cold at first and later only burning and prickling.

It was observed that all patients subjected to 120-second systemic therapy in the temperature of –130^{O}C after 30 minutes from the treatment showed considerable increase of serumal concentration of adrenaline, noradrenaline, ACTH (adrenocorticotropic hormone), beta-endorphin and in case of men – also testosterone. Observed lack of significant increase of plasmatic cortisol concentration despite increased ACTH is hardly believable and may be due to slow secretion of that hormone. Instead, no increased concentration of growth hormone, thyroxine, triiodothyronine, luteinizing hormone, follicle stimulating hormone and 6-keto-PGF1 alfa.

Analgesic effect is very strong and is common for all patients suffering from pain. Such effect lasts 3-4 hours after treatment. However it is not superficial anaesthesia which could enable any surgical operation within cooled area. Thus, this is only subjective analgesia.

Patients suffering from superficial pain receive alleviation, however, even those suffering from severe and intense pain report considerable relief. Therefore the results of cryotherapy are so interesting and contributed to widespread acceptation of the treatment – not only among doctors but, above all, patients.

The mechanism of analgesic operation of extremely low temperatures is complex and is based upon biochemical and functional features. All patients after 2-minute exposure in the chamber showed considerable increase of beta-endorphins and during the therapy these concentrations were systematically higher. It was also observed that serumal increase of endorphins in patients or healthy persons is associated with extreme cold and does not depend on performed exercises. This occurs despite the fact that physical exercise is believed to release secretion of beta-endorphins. Therefore it is clear that cryogenic analgesia has its biochemical basis. Pain is such a feeling that can be sensed by various receptors spread over whole body. There are opinions that there are no specific pain sensitive receptors. Severe and chronic pain, called pathological pain, originates from damage of tissues and leads to physical and mental exhaustion of patient who cannot live normally. The phenomenon of pain has never been properly defined nor understood. It used to be described as a negative feeling which could only be characterized by the person suffering from it.

Therefore pain and reaction against it will be different for each person. Concerning individual reaction against pain – it will be also different depending on situation and timing.

The mechanism of releasing beta-endorphins can be described as follows: cold stimulates various receptors (perhaps before their cold-induced functional shutdown through unknown reflex arcs) which activates subthalamus to secrete factor releasing precursor of beta-endorphin i.e.: propiomelanocortin and beta-endorphins and also ACTH. Increased secretion of beta-endorphin from subthalamus and its higher concentration in serum was observed after operation of various stressful factors and as a consequence of physical effort. In this application of cryotherapy it is a matter of great importance.

Also, beta-endorphins are probably secreted by adrenal glands. It is assumed that endogenous catecholamines, concentration of which is high after cryogenic treatment, contribute in some part to releasing beta-endorphins. It is very important in case of rheumatic or degenerative diseases or injuries when rehabilitation plays a key role in preserving and restoring physical performance of patients.

Cryotherapy induces release of beta-endorphins, however, such release may be also due to physical exercises during intense rehabilitation – but this has not been confirmed yet. The analgesic effect of cryotherapy due to operation of endogenous beta-endorphins lasts about 3 hours. Therefore it would be advisable to repeat the treatment 2-3 times a day and follow it with intense rehabilitation which is also favored by physical comfort and painlessness. Such treatment lasting during a long period may preserve the analgesic effect for some time.

The analgesic effect is also caused by cold induced functional shutdown of various cold-receptors and their connections with propioreceptors. This may be the second mechanism, apart from beta-endorpnis operation, that provides deep analgesia and enables rehabilitation. Obviously, inhibition of conduction in sensory neurons has an analgesic effect too.

The next functional phenomenon which causes analgesia is due to existence of so called “control gates” in the central nervous system (according to Mellzack-Wall theory). Pain-stimulated receptor conducts

impulses to higher levels of central nervous system by means of two types of neurons:

1) quickly conducing, thick, showing low excitability threshold
2) slowly conducing, thin and naked, showing high excitability threshold

This theory assumes the existence of cells, situated in spinal cord, which control and select pain impulses conducted by those neurons.

But only those impulses that reach “control gate” as first, which means those conducted by thick neurons, are quickly passed through and stimulate transmitting cells. Those cells transmit the impulse to cerebral cortex where it is received as sense of moderate pain. After that the gate is “closed” for slowly conducted impulses because thin neurons require more intense stimulation. If the slowly moving impulse was passed through the control gate and reached the cerebral cortex it would be received as sense of severe pain.

The second control gate is placed within thalamus and controls pain-induced impulses conducted by cranial nerves and their fibres. Probably the same mechanism applies to impulses conducted by “non-pain” and other specific fibres. Therefore rapid application of extremely low temperatures, initially causing minor pain or burning, seems to disable both control gates to conduct intensive pain impulses, for example pathological pain.

The “control gate theory” itself would clearly explain the analgesic properties of cryotherapeutic treatment even if the fact of increased secretion of beta-endorphins in low temperatures was not known. Such property of systemic cryotherapy, when it is incorporated in complex treatment, enables reduction of doses of common analgesic or non-steroid anti-inflammatory medicines.

Jonderko (1987) explained that reduced flow of pain impulses to spinal cord could account for segmental inhibition of stimulation of gamma-motoneurons, and at the same time, relaxation of muscles which facilitates the motion therapy.

Brzecki et all. (1990) observed another mechanism causing inhibition of conduction of motor impulses under operation of endemic cryotherapy. Before cooling (2-minute treatment using air cooled to –180^{O}C),

immediately after and also 1 hour after the maximum muscular effort of left-wrist cubital flexor was measured using two pin electrodes and electromyograph. The electrodes were placed on two nerves: … and left cubital.

The analysis of the record revealed that strength of the muscle (represented by frequency of the record) considerably increased after one hour from the treatment.

It implies that cryotherapy not only features analgesic action through disabling receptors and slowing down conduction in sensory neurons, not to mention increased secretion of beta-endorphins, but also shows an advantageous effect on motor discharge which may lead to strengthening of muscles. Reduction of speed of conduction of motor impulses in the nerves has no impact on muscular strength after cryotherapy. If such change apply APPLIED to one cooled muscle and two nerves it may BE assumed that in systemic cryotherapy A similar effect will be observed in all dynamic parts of the body. The analgesic effect and inhibition of neural conduction (especially of motor impulses) induce, AND to some extent, atony ??of muscles. Increased muscular strength can be explained by larger number of activated motor units.

Therefore, atony NOT SURE WHAT ATONY IS of muscles along with their strengthening are the next, apart from analgesia, results of cryotherapy which considerably contribute to improved rehabilitation of patients by means of motion therapy. As it was observed the cryotherapy itself does not improve fitness of patients. Application of only cryotherapy even deteriorates the ability to perform exercises. Patients themselves pointed out that they felt worse after only cryogenic treatment, however, the objective evaluation of their state was rather impossible. As a conclusion, it may be stated that to achieve improvement or restoration of fitness it is necessary to perform intensive exercises taking advantages of comfortable condition of patients after systemic cryotherapy. Therefore the definition of cryorehabilitation was introduced to underline the absolute necessity to support rehabilitation with cryotherapy and achieve the best possible therapeutic effect.

The circulatory effect of systemic application of low temperatures impacts

both micro- and macrocirculation of blood. Changes in microcirculation confirm the therapeutic effects of cryotherapy, however changes in macrocirculation may play a key role in general safety of cryogenic treatment. The primary effect induced by application of extremely low temperatures in microcirculation is, at least in skin, deep contraction of blood vessels causing paleness but without blueing of covered parts of the body, lips and nails. As it seems, capillary constrictors are contracted or tightened which causes limiting and inhibition, in some areas of skin even complete standstill, of capillary blood flow. This results in stimulation of sympathetic system and increasing of concentration of catecholamine. Blood with oxygen that was not transported to tissues flows back, by means of open arteriovenous fistulae, to large veins and right part of heart being only minimally or not at all cooled.

Such A situation takes place for several seconds. Vasodilatation of microcirculation and increased capillary blood flow quickly reinstate the temperature or even increase its value immediately after treatment. Intensified perfusion of skin lasts for many hours and that can be displayed by means of thermographic or isotopic methods. Perfusion of skin and tissues may be escalated when right after the treatment patients are subjected to exercises. The increased plasmatic concentration of prostacyclin, which is responsible for vasodilatation of blood vessels, was not observed.

Atony ?? of capillary constrictors and closing of arteriovenous fistulae is probably due to lack of effective consequences of sympathetic stimuli and increased endogenous concentrations of catechole amines. It concerns also muscles of veins.DONT UNDERSTAND THAT SENTENCE

In general, disturbances of local blood supply may contraindicate CONTRA-INDICATE EASIER TO UNDERSTAND local or systemic cryotherapeutic treatment. This is logical, however, AND must be clinically verified. Cryotherapeuitc treatment is always connected with extended and intensive rehabilitation of patients. So, if cryogenic temperatures disturb the microcirculation only for a short period and after the treatment it is enhanced even for a long time, thus, for example atherosclerosis of vessels of hindlimbs is a doubtful contraindication. An obvious

contraindication may be Buerger disease or diabetes. Therefore that problem remains open.

When it comes to venous microcirculation, especially in hindlimbs, several effects induced by deep cooling of skin veins may cause evolution of inflammations and clots. These effects are: increased number of thrombocytes – highly above standard values, contraction of veins stimulated by hormonal or neural impulses, increased concentration of cortisol. In AS A RESULT result patients who overcame blood clots or congestion of circumferential arteries must be excluded from cryogenic treatment.

Cryosurgery, which utilizes subzero temperatures to destroy diseased tissues, also shows that one of the first effects of freezing temperatures is contraction of veins in microcirculatory system and subsequent formation of clots.

One of the underestimated effects of cryotherapy is anti-swelling action. Swelling and effusion around diseased joint have various reasonsCAUSES. Anti-swelling action of cryotherapy seems to be induced by: a few hours' extensive blood supply of arteries around swelling, increased capillary filtration, improved patency of lymphatic vessels in surrounding intercellular space and finally rehabilitation of joints.

In macrocirculation under THE operation of systemic cooling several effects are observed. These effects concern changes in values of diastolic and systolic pressure of arterial blood and also minimal, maximal and average values of heartbeat rate. In examined groups of healthy COMA as well as ill persons with rheumatic diseases no particular changes of these parameters were observed – but the practice shows something different.

The daily observations of hundreds of patients and thousands of single treatments proved that cryogenic treatment may significant increase of DONT NEED OF blood pressure, however momentary and imperceptible. This concerns patients with labile arterial hypertension or fixed hypertension either cured or not. There ARE also less frequent cases of sinusal tachy- and bradycardia, however these cases retreat very quickly.

THE Above facts may remain unnoticed because normally there are 4-5 persons in the chamber at the same time and after the treatment they are

examined only one after another. So patients who were last in the queue may show no signs of sinusal tachy- or bradycardia. It should BE underlined that such circulatory effects of cryotherapy are observed very rarely FULL STOP THEY SHOULD HOWEVER however they should be taken into consideration. It must be soIT IS LIKELY BECAUSE because systemic cryotherapy stimulates secretion of catechole amines and cortisol hydrocortisone enhances ENHANCING sensitivity of vascular muscles toward these hormones – with observed normal or slightly more alkalic pH of arterial blood.

Therefore patients with hypotonia and tachycardia or bradycardia should be qualified for cryogenic treatment only after careful examination or pharmacological preparation due to the fact that increased blood pressure could severely endanger their health.

Following all aforementioned absolute and relative contraindications it may be concluded that systemic cryotherapy:

1. does not affect heartbeat rate and the value of arterial blood pressure,
2. does not launch untimely stimulation of heart,
3. does not induce or worsen blood supply of TO heart, so that there are no signs of stenocardia
4. does not reduce contractibility of left ventricle

Thus, excluding all possible contraindications originating from circulatory disturbances induced by cryotherapy, the cryogenic treatment is a safe therapy and does not affect the functionality of circulatory system.

It conditions widespread incorporation of the method which assisted by rehabilitation facilitates long term remissions, brings longterm analgesic effects and improves muscular strength to such extent that has not yet been observed after conventional treatment.

The lack of severe disturbances in THE functioning of circulatory system as a whole implies that during low temperature application there are no negative changes in gas exchange and ventilation of lungs.

In a common sense IT IS COMMON SEMSE THAT respiration includes gas exchange between lungs and blood and blood and tissues as well as ventilation of lungs. In that way, suitable volumes of oxygen are evenly transported to all alveoli showing partial oxygen pressure lower than that of

deoxidized blood. Thus, THE gradient between partial oxygen pressure of alveoli and blood enables oxygen diffusion from alveoli toward blood. The same mechanism applies to oxygen transfer from hemoglobin and its diffusion into tissues.

Therefore respiration is a process that is based on passive diffusion of oxygen through respiratory membrane to capillary vessels entwining the alveoli. After that efficient mechanisms are necessary to transport oxidized blood to tissues where oxygen is released from hemoglobin. The effectiveness of respiration in the sense of tissue oxidation and elimination of CO_2 can be evaluated by means of gasometers or by measuring acido-alkalic equilibrium. It is reported that these indicators remain proper as long as patient showed no contraindications against cryotherapy.

From first-aid practice it is known that respiration is possible even without ventilation. In case of crushing or blocking the chest or any other accident when ventilation is simply impossible the victim can be kept alive by application of pure oxygen straightly into mouth or trachea even for 45 minutes. Such type of respiration is called diffusive respiration.

Another function of ventilation is elimination of CO_2 from tissues and organism. CO_2 by means of diffusion is transferred from tissues into blood and then in THE lungs from capillary vessels into alveolar air. The lack of CO_2 ventilation even during direct application of oxygen (as in the example above) causes quick accumulation of that gas in the organism to a level that threatens functionality of respiratory centers, cephalic arteries and vasomotor centers as well. The quickly increasing hypoxia and hypercapnia occur in every case of suffocation – this is called ASPHYXIATION… (asfiksja)

Even most effective ventilation will not maintain proper gas exchange in case of major deficiency of blood or CO induced hemoglobin blockage as it happens in nicotinism, intoxication, oxygen transport disturbances or impaired oxygen release from hemoglobin to tissues. The same applies to severe pathological changes in respiratory membrane, presence of arteriovenous leakage in lungs or other changes in perfusion of some areas of lungs.

The optimal conditions for releasing the oxygen from blood into tissues are

achieved when values of hematocrit indicator are lowered to 30^{O} (blood acidosis). In these conditions hemodilution is observed. Hemodilution is employed in cases of severe and extended operations in order to maintain optimal oxidation of tissues and improve rheology of blood. Reducing pH of arterial blood shifts the hemoglobin dissociation curve to the left, thus, larger volumes of oxygen are supplied to tissues. Normally, such defensive mechanisms are not launched because gas exchange is adequate with demands of ill or healthy persons. This is why severe deficiency of blood, arteriovenous leakage in lungs and various severe disease of respiratory tract are included among contraindications against cryotherapy. In other words it is assumed and confirmed by gasometric measurement that patient shows normal gas exchange and respiration. Inefficient ventilation of lungs is not a contraindication.

The statistical analysis of records of spirometric measurements proves that systemic cryotherapy does not affect values of the most important indicators of proper ventilation: VC, MVV, FVC, FEV-1. However clinical analysis of individual cases indicates that considering the quality of ventilation patients can be divided into 4 groups. One of these groups consisted of 50% of patients who showed the same, normal values of indicators before and after the treatment.

There is also a group in which patients showed various disturbances in ventilation and various diseases of respiratory system. The disturbances are maintained after the treatment and may be even more severe vs. initial state. In particular types of diseases the disturbances after the treatment may deteriorate. Mostly, mixed abnormalities in ventilation were observed. That group consisted of 20% of patients.

About 10% of patients showed normal values of indicators of ventilation before the treatment and after the cryogenic operation they showed various disorders. In most cases disorders were of psychogenic or iatrogenic origin (however individual hypersensitivity of respiratory system against extremely cooled air must be also taken into consideration). It seems that at least disturbances of iatrogenic origin can be overcome and thus number of complications during the treatment can be limited.

About 20% of patients showed various, mixed types of respiratory

disorders before the treatment and after the therapy showed normal values of ventilation indicators. In these patients the initial malfunctions of ventilation were undoubtedly of psychogenic origin. Systemic therapy induces outstandingly advantageous results in psychical sphere of a patient: perfect mood, feeling of soothing and deep psychosomatic relaxation. The majority of patients were addicted to nicotine and that might be a root cause of psychogenic disorder in ventilation.

This state may be due to hormonal and metabolic changes which are caused by systemic cryotherapy. It was observed that in both healthy and ill patients suffering from rheumatic inflammation of joints extremely cooled air operating on the whole body and respiratory tract induces secretion of endogenous catecholamines, ACTH, cortisol and beta-endorphins. These hormones and biological substances in higher concentrations cause considerable improvement of cerebral performance. They have also positive impact on respiratory system preventing major complications of ventilation and respiration or soothing any possible diseases.

The cryochamber in Wroclaw consists of two rooms. One is adaptational antechamber where the air is cooled to $-50^{O}C$ and the main chamber where the temperature can reach $-140^{O}C$ or even $-160^{O}C$. In the first room patients stay only for few seconds and then 2 minutes in the chamber maintaining verbal and visual contact with servicemen. Patients are often accompanied by one of the servicemen inside the chamber. The oxygen indicator installed inside the chamber always shows 21-22% of oxygen content. Such oxygen volume prevents hypoxemic hypoxia also in patients with psychogenic disturbances of ventilation before or after the treatment.

Patients wearing swimsuits, socks, boots and with covered parts of the body enter the chamber through the antechamber. Oral cavity and nose are covered with surgical mask cushioned with several layers of gauze. At this stage it is important to avoid mistakes such as leakiness of the mask or putting too small pieces of gauze. These shortcomings could enable entering of cold air directly from the chamber into respiratory tract. Next factor that may induce changes in ventilation before or after treatment is abandoning the rule of slow and shallow inspiration. The inspiration versus

expiration ratio must be like 1:2.

Cold air entering nares NOSE and respiratory tract becomes warmer and increases its initial volume which may cause suffocation or respiratory oppression. Such mistakes may be called “iatrogenic reasons of ventilation disorders”, however, this definition could be expanded also on cases of disorders originating from hypersensitivity of respiratory system against antigen, allergen or cold air. The feeling of suffocation may also induce psychogenic disorder of ventilation of lungs.

In the cryogenic chamber steam and CO_2 from expiratory air immediately turn into icy dust. It is filtered by the surgical mask and gauze covering mouth and nose so that it does not irritate respiratory tract – of course when MAKES MORE SENSE IF YOU TAKE OUT WHEN the mask and gauze are properly applied and the rule of slow inspiration is followed. Therefore cooled air in the chamber consists solely of oxygen and nitrogen. Such A mixture, having passed THE surgical mask, becomes heated very quickly in nasal passages, throat and respiratory tract. It seems that the temperature of that air is considerably higher than the temperature of the air filling the chamber. The safety of application of cryogenic treatment to patients with disorders of ventilation is evidenced by lack of vestigial symptoms of hipoxia and hypercapnia, deterioration of cardiac blood supply or heartbeat disturbances.

Systemic cooling of the whole body in the cryochamber applied in cases of articular inflammatory diseases or metabolism-based diseases is intended to: induce comfortable psychical conditions of patients during rehabilitation, achieve complete analgesia, cause extensive blood supply of cooled areas, loosen the muscles around diseased joints (inhibition of motoneural conduction and increasing muscular strength at the same time).

Aforementioned effects of cryotherapy are maintained even 3 hours after the treatment so rehabilitation exercises can be extended in time and also more general and intensive versus conventional treatment. Cryotherapy ALSO enables also[TAKE OUT] reduction of doses of non-steroid, anti-inflammatory and analgesic medicines or even resignation TOTAL WITHDRAWL OF THOSE DRUGS from those.

Systemic cryotherapy itself proved to be a therapeutic treatment – not only symptomatic one. The excitation of hormonal axis, especially, CRF-ACTH-cortisol, and increased plasmatic and endogenous concentrations of those hormones showed anti-inflammatory and healing properties similar to increased GH concentration observed in some clinical cases. Increased concentration of testosterone in man (sometimes in women) showed anabolic properties contributing to improved healing of diseased joints.

After cryogenic therapy some of fixed disorders of ventilation connected with, above all, chronic diseases of respiratory system were cured rather than intensified. This effect concerns also psychogenic disorders of ventilation which become normalized after the treatment. During application of several-week therapy to patients with fixed disorders of ventilation it seems advisable to incorporate also physiotherapy of chest. Especially, it applies to cases of coexisting syndromes of *bronchitis-emphysema* and *asthma-bronchitis-emphysema* and may contribute to healing of these disorders during or after therapy.

Continuously developing research on aspects of operation of systemic cryotherapy, in particular, its safety and positive impact on numerous preventive and defensive mechanisms of the organism prove that the treatment assisted by kinetic therapy is strongly recommended in following cases:

1. inflammatory diseases of kinetic system: rheumatic inflammation of joints, spastic inflammation of spinal joints, rheumatic fever and other,
2. metabolism-based inflammatory changes in nerves – uratic gout
3. some of THE skin diseases affecting joints – psoriatic skin inflammation
4. degenerative diseases and secondary degenerative changes in joints and spine
5. rheumatic diseases of soft tissues (*myosistis* and *fibromyositis*) or connective tissue
6. autoimmune diseases
7. chronic inflammation of cervical vertebreae
8. biological restoration of exhausted muscles.

This method does not only feature symptomatic operation on mentioned cases but it shows true therapeutic effect in these diseases and moreover

facilitates rehabilitation.

Chapter 4

Krystyna Księżopolska-Pietrzak

The role of cryotherapy in treatment of diseases of kinetic organs.
Mechanisms of operation, indications and contraindications.

Cryotherapy means application of air cooled to less than –100^{O}C on surface of the body during 2-3 minutes in order to induce and utilize physiological responses against cold. The positive reaction of the organism on that stimulus supports basic treatment of a disease and also facilitates kinetic rehabilitation.

So far cold was applied in the form of ice-compresses or icy gel compresses. Only incorporation of liquid nitrogen for the purposes of local or general cooling of the body initiated the modern cryotherapy. For the first time cryotherapy using liquid nitrogen was described by Japanese researchers [1]. Several years later German professor R. Fricke informed about outstanding effects of cryotherapy in patients with rheumatic diseases [2].

In Poland, the first device for local applications was constructed in 1983 by engineer Z. Raczkowski. In 1989 the first cryochamber in Poland was built. Local cryogenic treatment has been performed for 8 years in the department of rehabilitation of Rheumatological Institute in Warsaw. Systemic treatment in cryosauna has been applied PRACTISED for 3 years.

The methods of application of cryotherapy.

Cryotherapy can be applied locally of OR systematically. InWITH the local method the stream of mixture consisting of nitrogen and oxygen cooled to less than –100^{O}C is directed onto THE treated organ. The treatment cannot be applied to more than 5 joint JOINTS at a time (hand and foot represent one large aggregation of smaller joints).

The duration of the treatment is conditioned by THE individual reaction of a patient and normally rates LASTS1-3 minutes. Frequency of treatments: 2 times a day with minimum 6-hour interval. The series of applications depends on type of a DELETE A disease and also THE individual reaction of a patient. Cryotherapy normally lasts from 2 to 6 weeks. In general – cryotherapy can be applied in cryochamber or cryosauna.

Cryosauna is a one-person room inlaid with pieces of wood, having A swinging door that can be easily opened at any time. At the top there is special cover with a hood to protect the patient's head. Patient PATIENTS who stays inside must be moving all the timeTIMES. The average duration of such treatment is 2 minutes. Temperature: from –100^{O}C to –160^{O}C.

A Cryochamber consists of two parts: antechamber with temperature of –50^{O}C and main chamber with temperature between –100^{O}C and –160^{O}C. Maximum load of a chamber is 5 persons at a time. The persons must move for the whole time in the chamber. To protect respiratory system patient must wear safety surgical mask on their nose and mouth. Patients are also instructed how to breathe inside the chamber: inspiration must be 2 times shorter than expiration.

Patients must wear socks, gloves, wooden boots, shorts or swimsuits. Also, special ear protection must be worn. Duration of the treatment: 2 minutes – once a day. The series of systemic treatments depends on type of a disease and can last from 2 up to 6 weeks. Intensification of symptoms of an illness can be observed between 7th and 10th day of therapy. However, it is not an indication to withdraw the therapy.

Once proper verification revealing any contraindications has been done any possible complications occur very rarely. These complications are

mainly superficial frostbites due to improper technique of a treatment or, in case of a local application, contamination of nitrogen.

The effects of cryotherapy observed in human body

During endemic or systemic application of low temperatures on THE surface of the body several effects can be observed:

1. alleviation of pain,
2. reduction of swelling,
3. loosening of skeletal muscles and increasing of their strength,
4. extended range of movement within treated joints

All mentioned effects confirm anti-inflammatory properties of this form of therapy [1,2,5-12].

Effects of cryotherapy are maintained for 2-4 hours after the treatment, so that time can be utilized for intensive rehabilitation.

Numerous reports concerning low-temperature treatment and describing the methods of its application evidence that kinetic therapy must be an inseparable part of such form of treatment [1,3,6,8,13,14].

Cryotherapy can result in:

1. Alleviation of pain: severe and chronic pain results from damage of tissues and leads to mental and physical exhaustion of a patient. Partially or totally analgesic effect of cryotherapy is due to increased secretion of beta-endorphins, cold-induced functional shutdown of sensory receptors and their connections with proprioreceptors, braked conduction in sensory fibres and disabled conduction of pain stimuli through “control gates” (acc. to Melzack-Wall theory) [11,15-17]
2. Reduction of swelling: several-hour long extensive blood supply of areas surrounding the treated tissues contributes to improved metabolism and elimination of its accumulated products. Improved circulation within lymphatic vessels as well as rehabilitation also enhance the anti-swelling operation of cryotherapy [7-9,11].
3. Loosening of muscular tension and increase of their strength: this is due to reduced number of stimuli reaching the spinal cord and segmental inhibition of conduction in motoneurons. Analysis of

electromyographic records of muscular effort evaluation after low temperature application shows that muscular strength is considerably increased. Such mechanism has been confirmed by many clinical observations [9,15,18,19].

Systemic cryotherapy induces:

1. increased plasmatic concentration of adrenaline, noradrenaline, ACTH, cortisol and testosterone (in men). No such increase of concentration of growth hormone, luteinizing hormone, follicle stimulating hormone an 6-keto-PGF-1 alfa [11,14,20].
2. Morphological and biochemical examination of blood after 2 weeks of therapy indicated increased level of hemoglobin, leukocytes and thrombocytes in comparison with values observed before the therapy. The same was observed with creatin and glikemia. They never exceeded the upper level of the norm. Erythrocyte sedimentation rate and Waaler-Rose reaction did not show considerable statistical decrease. In all patients after 2 weeks of systemic therapy lower values of seromucoid concentration were observed. Recently many researchers underlined the destructive role of oxidative stress occurring within connective tissue. Free oxygen radicals created during hypoxia and subsequent reperfusion cause irreversible changes. Inflammatory process as well as articular movement or simple muscular tension contribute to occurrence of that phenomenon. For that reason, an evaluation of influence of cryotherapy and kinetic therapy on the level of active metabolites was attempted. An oxidative response of neutrocytes against stimulation in patients suffering from rheumatic inflammation of joints was measured before and after treatment. The results indicated that cryotherapy normalized the response of neutrocytes against stimulation, thus, showed its anti-inflammatory properties [12].
3. In patients with bronchial asthma there were no impulsive reactions during the treatment. After leaving the chamber respiration was easier and unconstrained [19,22].

Patients whose body was subjected to low temperatures operation observed soothing or complete withdrawal of pain, felt hot, relaxed, calmed

down and rejuvenated. These effects induced by systemic therapy enable to limit the doses or even completely resign from anti-inflammatory and analgesic medicines. It is a matter of great importance especially in cases of chronic and progressing diseases of kinetic system such as rheumatic inflammation of joints. However, administration of the basic medicine must be continued.

Many researchers trying to explain the mechanisms of cryotherapy evaluated its impact on circulatory system. Considering macrocirculation, even after systemic therapy, there were no changes in electrocardiograms, heartbeat rate or arterial blood pressure. Holter records as well as cardiac hemodynamic indicators measured by means of ultrasonography did not show any changes even after 2 weeks of application of low temperatures [5,9,19,23,24].

In microcirculation, cold induces contraction of blood vessels and opening of arteriovenous fistulae for a few seconds. This is followed by widening of blood vessels and closing of fistulae which lasts for a few hours. Blood flow is accelerated. Such effects were observed in capillaroscopy employing a contact method of liquid-crystal thermography and infrared mapping. The above phenomenon proves therapeutic properties oflocal OF LOCAL cryotherapy [9,14,25,26].

It has to be remembered that cryotherapy is one of physical methods of treatment. Local treatment can induce only local reactions. Only after application of systemic treatment the aforementioned general effects may be expected. In case of diseases of kinetic organs cryotherapy must be assisted with rehabilitation performed twice a day.

Cryotherapy indications:

1 rheumatic inflammation of joints,
2 spastic inflammation of spinal joints,
3 psoriatic inflammation of joints,
4 degenerative disease of circumferential joints and spine,
5 uratic gout,

6 discopathy,
7 circumarticular inflammation of tendons, muscles and articular capsule
8 fibromyalgia,
9 injuries of joints and soft tissues,
10 Sudeck symptom,
11 spastic paresis,
12 biological restoration of exhausted muscles

Cryotherapy is not contraindicated in the following diseases:

1 systemic erythematic lupus (in the early stage),
2 systemic morphea,
3 diabetes,
4 subfemoral varicosity,
5 paroxysmal tachycardia
6 metals in internal tissues
7 Reynaud disease

Absolute contraindications:

1 cryoglobulinemia,
2 cryofibrinogemia,
3 agammaglobulinemia,
4 hemoglobulinuria,
5 purulent and gangrenous skin,
6 neuropathy of sympathetic system,
7 diseases of central nervous system (cryosauna, cryochamber),
8 hypofunction of thyroid (cryosauna, cryochamber),
9 severe deficiency of blood (cryosauna, cryochamber),
10 administration of some medicines (neuroleptics, alcohol),
11 cachexia and hypothermia,
12 oversensitivity toward cold,
13 advanced atherosclerosis,
14 tumour disease
15 Prinzmetal syndrom,
16 local frostbistes,
17 skin perforation,
18 claustrophobia (cryochamber)

Relative contraindications:

1. age over 65,
2. any valvular disorders,
3. angina pectoris,
4. disorders of heartbeat rate at frequency higher than 100/min,
5. overcome venous blood clots and congestion of circumferential arteries,
6. emotional lability causing eg. extensive perspiration

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Chapter 5

Possibilities of incorporation of cryotherapy in treatment of patients with diseases of central nervous system.

Introduction

The literature of cryotherapy is vast, however, the indications concern mainly rheumatic diseases, degenerative articular diseases, injuries and their complications, swelling and local pain. In these cases, among others, cold compresses and wrappings are utilized as well as rubbing with ice chunks, chloroethane, Freons or cold natrium chloride solutions [11,21,26,28,31]. There are few papers reporting about ON THE INSTEAD OF ABOUTapplication of cryostimulation in patients with neurological diseases and above all with defects of THE central nervous system. It is worth mentioning that THE definition “cryostimulaton” was used earlier than “cryotherapy” and is more accurate especially when describing actions toward nervous system [32], and thus, it will be used further in this paper.

Grochmal [11] in order to reduce pathological tension of muscles advised cold compresses, massages with ice chunks or chemical agents, but did not mention vapors of liquid nitrogen and extremely low temperatures. Weiss and Duma-Drzewińska [31] used specially constructed cooling blanket to treat spastic limbs and observed considerable improvements. In electromyographic examinations they observed improved bioelectric functionality of muscles manifested by shorter time necessary to loosen the muscles after a maximum contraction and EMG-recorded, improved synchronization of movement. Such effects were maintained up to 2 weeks from the therapy. However, the research were not continued. Szawłowski [27], in children with spastic paresis, utilized only thermal treatment. THE Author of this chapter COMA in order the reduce spasticity of forelimbs in patients after brain stroke COMA utilized

cooling of the limbs for 10-15 minutes in the temperature of –8^{O}C in the specially adapted freezer with a wristband. The author observed loosening of pathological tension which facilitated rehabilitation. The number of experiments was too small to draw some more general conclusions.

Tepperman [30], to achieve reduction of spasticity, advised such application of cold that considerably lowers the temperature of muscles. He observed not only local but also general effects of cooling such as slowed down blood flow in tissues. In practice, he utilized compresses of towels filled with ice and plastic bags with frozen vegetables for 30 minutes, including patients with chronic inflammation of joints, muscles, fasciae or even with bedsores of 1st and 2nd degree. Stillwell [29] describes cold as a factor reducing excessive excitation of muscles caused by even minor change of length of muscles in the spastic limb. During 6-minute treatment he utilized water cooled to +8^{O}C. During that time patient was asked to perform specific exercises. That method of cooling was utilized in patients with spasticity, blood effusions into joints, posttraumatic swelling and pain. To evaluate the effects of cryostimulation Bell [1] examined Hoffman reflex of calf triceps in 16 patients. After cooling temperature of the muscle was lowered to +12^{O}C and electromyographic examination showed positive impact of cryostimulation on extensive excitation of muscles and reducing pathological tension. Dimitrijevic [7] also reported that spasticity is A major obstacle in rehabilitation of patients with defects of THE central nervous system. Among many methods described as effective in reducing pathological pain he also included cryotherapy for its long lasting loosening effects. However, he pointed out that indications must be strictly individualized and the real possibilities of such individualization must be evaluated. The positive effects of cryotherapy depend also on patients' expectation and motivation and their extended rehabilitation [7,8]. Frischknecht [10] to achieve reduction of spasticity advises cold or heat which, however, must be adjusted to individual tolerance of patient. Pharmacotherapy is also acceptable, but it reduces tension of spastic muscles along with tension of healthy ones. Some of patients prefer suffering from spastic muscles to side-effects of some medicines, however rehabilitation cannot always be performed at home. Frischknecht reported that cold successfully reduces clonuses, relaxes muscular tension and removes the

“expanding” effect – all these were confirmed by electromyographic examination. Cooling effect can be achived by means of ice chunks, chloroethane, short immersion in mixture of water and ice and gas vapors cooled from –130^{O}C to –180^{O}C. Pedersen [23] during treatment of spastic muscles utilized cooled to –7^{O}C mixture of water and ethyl alcohol. He mentioned blockage of skin receptors as the first effect of application of cold, which is an impulsive action, and afterwards reduced neuromuscular discharge and blocking of efferent gamma system.

In neuorophysiological examination of patients with rheumatic inflammation of joints, after single application of nitrogen vapors (cooled to –180^{O}C) on wrist and forearm Bilinska et all. [2] observed improved strength of examined muscle which was displayed by increased record density of EMG. Moon and Gragnani [21] subjected diseased hand to 30-minute treatment in a specially constructed dish filled with running water, cooled to +9,4^{O}C. In 9 examined patients, who overcame brain stroke, they observed considerable reduction of swelling and pain.

Author’s experience

At THE Department of Rehabilitation in Rzeszów Hospital, since 1988 we have been applying cryostimulation to patients with defects of central nervous system of various etiopathology. For the purposes of local applications we used “Kriosan” device and in 1993 we have installed Cry-Air Cadena device which enables blowing of air cooled to –35^{O}C with regulated speed. This apparatus is less defective and independent from liquid nitrogen supplies. Basing BASED on literature and earlier author’s experience COMA application of extremely low temperatures were introduced into complex therapy of patients with spastic paresis caused by brain stroke, patients after surgeries of brain aneurism, cranio-cerebral injuries and operated brain tumours. Following very good results in this difficult group of patients and lack of complications cryostimulation was also introduced into rehabilitation of patients with sclerosis multiplex and spinal cord damages.

In total, cryostimulation has been applied since 1996 to over 800 patients, most of them were rehabilitated clinically, and the number of applications exceeded 12,000. In this group of patients, over 40% of them suffered from

defects of central nervous system. Among them there were 140 patients with spastic paresis of various etiopathology.

First encouraging applications of extremely low temperatures were carried with cooled air current directed on spastic limbs in patients after brain stroke. That experiment was reported in 1988 during symposium of Polish Academy of Sciences. Cryoapplication of vapours of nitrogen was introduced as a routine treatment in the complex rehabilitation of patients with spastic paresis. Nitrogen vapours of temperature –180^{O}C (measured at the nozzle – at skin surface temperature balances between –170^{O}C and –159^{O}C) are applied onto paretic limbs of qualified patients, two times a day during 3 minutes. Application is followed by planned rehabilitation. On average basis, cryostimulation is applied for 3 weeks (5 days in a week) which gives 30 treatments per one patient. Conducted comparison of 15 patients in 2nd and 3rd stage of brain stroke and then larger group of 40 patients with brain-stroke induced paresis with control group of 22 persons with a similar profile of neurological deficiency showed beneficial results of cryostimulation. Considerable reduction of pathological tension of muscles in paretic fore and hind limbs and improvement of kinetic state of examined limbs (measured in Brunnstrom scale) was observed. In the examined group also significant improvement of walking speed was noticed. In none of patients complications were observed and planned program of rehabilitation was entirely realized [18,24,25].

The evaluation of efficiency of cryostimulation with cold air current (-35^{O}C) were carried on the group of 10 patients after brain stroke. Cooled air was blown onto paretic limbs at regulated ratio of 100 – 1500 litres per minute during 5-8 minutes twice a day. After that patients perormed rehabilitative exercises. Each patient was subjected to 30 applications. All patients showed reduced spasticity (the average rated 1 degree in Ashworth scale) which lasted about 3 hours from the treatment and improved movability of the limb. The achieved results were similar to those after application of extremely low temperatures and there were no observed complications either [18].

Positive results of application of extremely low temperatures in the rehabilitation of patients with brain-stroke induced paresis, cranio-cerebral injuries and operated brain tumours encouraged us to incorporate that method

of treatment also in therapy of patients with spinal cord spasticicty, disregarding the pathomechanism of the disease. Therefore treated group included patients with sclerosis multiplex, cervical myelopathy, operated spinal cord tumour and spinal cord abscess. 16 out 18 examined patients showed significant, positive result of cryostimulation against muscular tension and also improved locomotion. Only 2 patients reported feeling of cold which lasted few hours after cryoapplication. In that cases the treatment was withdrawn. Remaining patients reported that the treatment itself was rather enjoyable, caused relaxation of muscles, alleviated pain and induced feeling of warmth in the limbs. The achieved effects are even more valuable due to the fact that cryostimulation was applied to patients in whom physical and pharmacological methods did not bring any reduction of spasticity. In most of the patients pathological tension of muscles disabled any rehabilitation and training of walking [17].

Discussion

The problems with rehabilitation of patients with defects of central nervous system are the challenge to modern medicine all over the world [4,16]. It results from current achievements in preventive treatment, therapy and rehabilitation of defects of central nervous system which contributed to expanding the expected period of life and evidenced that restoration of kinetic functions after defect is possible [8,9]. The frequency of circulatory system diseases in Poland causes 60,000 cases of brain stroke each year. Apart from brain stroke, also brain and spinal cord injuries, tumour and inflammatory diseases, sclerosis multiplex and paralysis in children continuously expand the group of patients subject to neurological rehabilitation.

Table 5.1. Spasticity vs. structure and function (according to Lakke)

Hierarchy	Symptoms	Localization
Intention	Lack of movement	frontal lobe
Emotional state	Impulse	Limbic system
Movement programming	Loss of dexterity	Brain hemisphere
Posture control	Incontrolled	Brain stem

Automatisms	Spinal mechanisms	Spinal level
Reflexes	Reflexes	Segmental level

The basic problems in rehabilitation of patients with defects of central nervous system are disorders in tension of muscles showing the character of cerebral or spinal spasticity [3,5,12-14]. The clinical view of disorders may be diversified depending on localization and severity of defect. Therefore it will be different in cortical focus, subcortical core, cerebral core or spinal core. In clinical examination some of abnormalities are observed: encircling with limbs during walking, penknife-like walking manner, involuntary muscle spasms, exhaustion, painfulness, atheotic movements, dystonic posture and other spastic symptoms like: increased tension of muscles and tendinous reflexes. However, paralysis or paresis of muscles are not spastic symptoms *per se.* Very frequently excessive spasticity disables free movements and walking, despite withdrawing paralysis, and even impedes passive exercises [19].

It is believed that spasticity is due to excessive activity of gamma system which makes greater number of impulses reach long, neural fibres, prompt circo-spiral endings and alfa motoneurons. Spasticity may be also due to lack of connection between cerebral and spinal centers which upsets control over inhibition and enhancing conduction of impulses [11-14]. Dimitrijevic reports that spasticity in fact is a manifestation of residual kinetic control which can be expanded to create functionally useful free movements [9].

To reduce the pathological tension of muscles several methods and factors are used. These are: biochemical factors – active and passive exercises, chemical factors – medicines of local and systemic action and finally even drastic surgical treatment. Chemical and surgical methods are always dangerous for their numerous complications and side effects some of which still remain undiscovered [3,6]. The group of physical factor seem to be free from these negative features. That group includes: electrostimulation, numerous thermal operations and cryostimulation. For several years many authors have called cold more effective in reduction of spasticity than heat [26,28,30] and that was also confirmed by author’s experience. Excessive spasticity can be reduced by manipulating input at the segmental level using factors mentioned above or by means of modeling brain influence on

segmental, interneuronal network. Such procedures result in withdrawal of impulses from spinal cord by reducing excessive proprioceptive and exteroceptive reflexes [6,7].

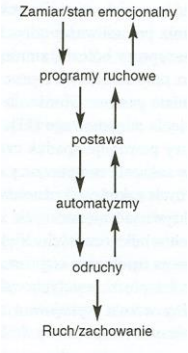
Human HUMANScan distinguish heat from cold owing to two types of thermoreceptors placed in THE skin and able to sense its different values. Cold receptors have maximum discharge frequency between 25^{O} and 35^{O}C, and below 10^{O}C the discharge frequency equals zero. The maximum discharge frequency of cold receptors is twice as high as of heat receptors and the total number of heat receptors equals only 10% of overall number of cold receptors. The total number of afferent impulses generated in cold receptors is 30 times greater than total number of impulses generated in heat receptors [26]. Both biomechanical and physical methods or factors share crucial stimulating aspect, thus, are closer to causal treatment and are recommended in restorative neurology [8,9,13,15,16].

The positive results of local cryostimulation have different explanations depending on authors evaluating this problem. Straburzyński reported that short operation of cold stimulus induced muscular tension whereas loosening of muscular tension was achieved when the impulse lasted longer. The greatest increase of activity induced by cold impulses was observed in reticular system and its stimulation causes inhibition of alfa motoneurons and excitation of gamma motoneurons. Thus, sensitivity of muscles increases which leads to tension and greater reflexive sensitivity [26]. Grochmal claims that treatment with cold inhibits cold receptors, thus, reducing afferent discharge ratio and neural conduction. This partially switches off the Granit loop in the gamma system. Limiting the reaction against cold and inhibiting of conduction results in decreased tension of muscles [11]. Weiss, following other researchers, stated that lower temperature decreases the frequency of discharge in receptors and is most clearly noticeable between 27^{O}C and 30^{O}C. It concerns both primary and secondary of sensory endings and also tendinous organs, however, activity of primary endings is inhibited more than that of secondary endings. Some of middle-thick fibres show the same reactions against cooling and heating [29]. Lippold's observations reported in late 50s indicated that lowering the temperature by 2-3 degrees causes paradoxical intensification of discharge in sensory endings, only further drop

of temperature down to 28^{O}C causes their reduction. He also claimed that reaction against cold is observed only in endings of primary fibres [19].

As it was mentioned before, in neurological rehabilitation biomechanical and physical methods are incorporated. The ability of THE central nervous system to adapt and transform and create functionally correct changes in the matrix of anatomical connection is right now beyond the shadow of a doubt [7,8]. Neural flexibility is related with the variability and accommodational ability of THE brain which founds???FORMS? a base of all structural and functional changes. These changes are the response against passing of time and continuous environmental alterations [9]. Evaluating the influence of various factors on phenomenon of spasticity, one cannot forget about essential fact: the impact of neural motion control on tension of muscles. Recently many clinical neurophysiologists claimed that spasticity is a syndrom of many symptoms of lack of such control [13]. If, following Brodal [5,19], we assume that neuron is an extensive part of central nervous system (including all numerous structures and functions of cerebral cortex, subcortical areas, cerebral core and spinal cord as well as all complex connections between them: cortical and subcortical paths, corticobulbar paths, subcorticobulbar paths, corticospinal paths and bulbospinal paths) then the possibilities of controlling the motion and tension of muscles both in initial and effective stage are simply vast. In the initial stage, which includes initiation, planning and programming of the movement, selection of continuously delivered information and impulses from both internal and external environment is performed. These are visual, aural, atrial, proprioceptive, exteroceptive, psychical or other impulses. The control system must choose only the most important ones in order to complete the initiated task which is motion. These impulses stimulate also the limbic system and through subcortical centers may have positive impact on modification of cerebral control over motion [16,19]. This may also account for variable intensity of spastic syndromes depending on daily hour, position of the body or specific limbs, actual physical state, stress, fill-in rate of urinary bladder or intestines and biochemical parameters of the organism [10,19]. Cerebral defects of selection of impulses incoming from many different sources may disturb the planning and programming of the motion. The factors that also affect the quality of performed movements are patient’s

consciousness and the level of their activity. It is known that severe mental aberration (coma, action of medicines), reduced activity or depression considerably deteriorate the ability of THE brain to control the movements [16,19]. TRANSLATE DIAGRAM



Picture 5.1 Hierarchic system of organization of movement with feedback loops (according to Lakke):

Stimuli generated in cold receptors give 30 times greater number of afferent, exteroceptive impulses than those generated in heat receptors. On the other side, it is known that cold has significant impact on muscles directing a wide array of proprioceptive impulses to spinal cord and superior centers. Therefore it may be assumed that despite the defect of central neuron (in its extended sense) most of the impulses reach the control centers (cortex, cerebellum, cerebral core). This is where the selection and utilization of all incoming impulses (including those connected with cryostimulation) in the process of planning and programming the free movement and also during that movement is performed. Continuously activated (on various levels) feedback loops and feedforward loops enable the control of performed motion and its realization accordingly to original intention. After sufficiently long, controlled

stimulation of THE central nervous system some positive and permanent, corrective actions may be expected [7,15,16,22].

From many authors' as well as self-experience FROM THE EXPERIENCE OF THIS AUTHOR AND MANY OTHERS it is clear that application of cold stimuli show positive impact on performance of free movements in patients with defective central nervous system and also enable, by means of reducing the tension of muscles, passive and assisted exercises [7,11,25,31,32]. Most of researchers associate advantageous operation of cryostimulation with local influence on neuromuscular system without mentioning its impact on superior levels of nervous system. In author's understanding, however, that extensive (both in number and intensity) central stimulation cannot be put aside while interpreting mechanisms of positive operation of cryostimulation, including its impact on cerebral control over motion.

It can be assumed that applied stimuli loosen the pathological tension of muscles through penetration inside the body, cooling of nerves and muscles, inhibition of skin receptors and inhibition of neuromuscular conduction in sensory and vegetative nerves and finally changing the rate of chemical reactions. This induces obtuse perception of pain supported by increased concentration of beta-endorphins and disturbed operation of pain control gates at the spinal cord level and cerebral core level [11,31]. At the same time, however, it should be underlined that all applied stimuli which reach the superior level of central nervous system show impact on highest levels of nervous system and that may induce nervous control of motion and muscular tension.

It is worth mentioning that when basic security rules are followed there are no complications observed in patients with defects of central nervous system regardless of any coexisting disorders of circulatory system and other [11,16,24,25,28]. Therefore it is essential to enable patients with spasticity to apply long-term cryostimulation at home which is possible due to availability of various, safe cooling agents, substances and containers. It will support them in maintaining the positive effects of clinical cryostimulation and may contribute to permanent improvement by means of continuous influence on cerebral control and launching the mechanisms of compensative spasticity in central nervous system [15,22]. From the other side there should occur some

actions of earlier incorporation of this safe and inexpensive method in patients with brain stroke and defects of central nervous system but with other etiology. It will extend the influence on acceleration of autonomous compensation and guide it into correct direction.

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Chapter 6

Jonna Bauer, Anna Skrzek, Tadeusz Bolanowski

Physiological principles of cryotherapy.

Introduction.

Stimulation of organism with various impulses, and thus generation of

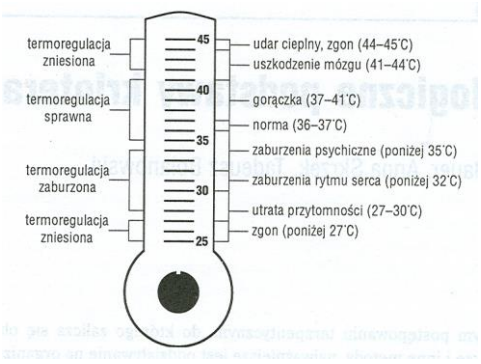
systemic and organic responses or reflexes that activate natural defensive forces of the body are the most important features of physical therapeutic treatment, including application of cold and other methods. The operation of these impulses can be easily explained on the example of the phenomenon of thermoregulation which is common in warmblooded creatures. The main purpose of this mechanism is to balance thermoregulatory functions of human body – in other words: to maintain thermal homeostasis. In humans and other warmblooded creatures, in normal conditions, constatnt temperature is maintained only in body cavities and cranium. Skin and limbs show coldblooded properties. In practice, the coldbloodedness of skin and limbs plays a key role, because it conditions the warmbloodedness of body cavities mainly through changes in operation of circulatory system (especially microcirculatory system) and intensity of metabolism which is controlled by thermoregulatory centers [33].

In normal conditions THE temperature of THE human body fluctuates by AN average OF 0,5-0,7^{O}C during the day regardless of surrounding temperature [14. (It concerns internal organs, the temperature of skin may show greater fluctuations). These changes are completely harmless and even are the symptoms of proper thermoregulation. However, any greater change, especially exceeding maximum or minimum threshold values, can be very dangerous. The range of tolerance of the changes by human body and limits of properly operating thermoregulatory mechanisms are shown in the picture 6.1.

The activation of thermoregulatory reactions in human body takes place by means of thermoreceptors – neural structures which record changes of temperature in time. These receptors can be divided into two groups: thermoexteroreceptors and thermoenteroreceptors. The first ones, as external receptors are located at the circumference of the body ie. in skin and receive thermal stimuli from the environment. The latter control the temperature inside the body [28].

Among thermoexteroreceptors located in skin some of them sense cold, some warmth and the other heat. These receptors are located unevenly and the largest groups are placed in facial skin, abdominal skin and also front side of forearms, arms and fingertips [17,20]. There are more cold receptors than

warmth receptors. There are about 250,000 of cold receptors while warmth receptors consist a group of only 30,000. They are the foundation of thermal sense that enables humans to feel the thermal comfort (or discomfort) which may be related with different value of temperature depending on environmental conditions [25].

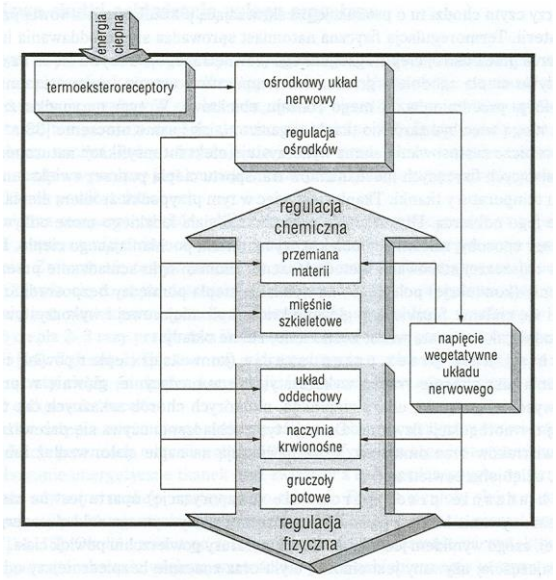


Picture 6.1. The tolerance of fluctuations of temperature by human body versus the ability of thermoregulation.

Main function of thermoexteroreceptors is to transfer neural impulses via afferent paths to subthalamus which is one of the most important parts of brain controlling all vegetative and majority of hormonal functions of human body. In subthalamus these impulses are integrated with impulses conducted by thermoenteroreceptors sensing the actual temperature of blood. In AS A RESULT result specific mechanismS are activated which causes production or loss of heat from the body.

Production or loss are launched by two centers located in subthalamus. First of them protects the organism against overheating and control the loss of heat – its stimulation causes widening of network of skin blood vessels and perspiration. The latter prevents the body from excessive loss of heat by means of narrowing the blood vessels and activating thermogenesis [25,33]. Operation of this specific biological thermostat in a way depends on concentration ratio of calcium versus natrium ions. Increased concentration of natrium ion induces feverish reaction, on the other wayON THE OTHER HAND, increased calcium ion concentration shifts the body temperature to slightly lower value [33].

As an effect of operation of subthalamus several thermoregulatory mechanisms are activated. These mechanisms can be conventionally divided into two groups: chemical and physical. The reciprocal influence between chemical and physical thermoregulation is shown in picture 6.2.



Picture 6.2. The schematic of thermal regulation in the body.

Chemical thermoregulation is based on production of exogenous heat which mainly comes from motor activity of muscles or their visible or invisible trembling, however, only THE production of heat exceeding the demands of basic metabolism is considered here. Physical thermoregulation boils down to gathering or dissipating exogenous heat from the body. It takes place by means of heat transfer accordingly with the gradient of temperature of the body and environment (eg. atmosphere, objects, items). In this sense the source of heat can be located within or outside the body [33].

Therapeutic application of cold utilizes the effect of intensification of natural, permanent physical mechanisms of heat transfer by means of increased gradient of temperature of tissue. In this case the tissue is the source of heat and environment is the heatsink. The loss of heat from human body through tissues can occur in four different ways depending on object or material

absorbing the heat. Until recently, the most widely applied therapeutic method was cooling through conduction based on heat exchange between adjoining objects. It was utilized mainly for the purposes of local cryotherapy and cooling was achieved by means of application of icy cold water, ice chunks or cold compressions.

Cooling through convection of heat from skin into surroundings is right now rarely utilized in medicine and mostly in high fever, heat stroke, some of infectious diseases or defected thermoregulation. In that method, fans and blowers are used which direct the current of cooled air across or along naked body.

Cooling through evaporation is based on the principle that evaporation of volatile liquids from the surface of a body requires thermal energy which results in lowering of skin temperature. To achieve this, normally chloroethane or considerably safer fluoromethane are used.

Cooling through radiation is growing more and more popular nowadays. It utilizes the fact that human body can loss even up to 55% of heat by means of radiation. In general, radiation proceeds very slowly, with various intensity, in different periods of the day and depending on outerwear. It is more feasible the more is the difference between body temperature and environment. To force the differences in temperature mostly vapors of liquid nitrogen are used as well as cooled air which being blown over surface of the body stimulate the activation of thermoregulatory mechanisms. Every loss of heat resulting form application of cold can be precisely calculated from specific formulas or equations as long as elements of these are known. Obviously it is more complicated when it comes to living organisms. That fact may seem more important when we take into consideration that incompetent application of cold can induce severe complications such as frostbites, cardiovascular disorders or respiratory system disorders.

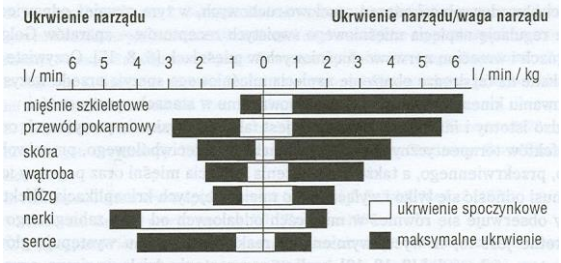
Organic results of systemic application of cold.

The main result of application of cold during cryo-treatment is lowering the skin temperature even by few Celsius degrees. At the beginning of application rapid drop of temperature of skin and subdermal tissues is observed. The

temperature of muscles is also lowered however the process is slower [28]. It is due to contraction of blood vessels which is maintained for about 1 minute after application [7]. Such contraction is induced by reduced blood flow and heat conductivity of superficial tissues. Lower skin temperature is getting closer to the value of environmental temperature which, at the same time, causes decrease of loss of heat through conduction, convection and radiation. The rate of metabolism and action of endocrine glands is changed. It is manifested by muscular trembling, which from energetic point of view can be an effective method of heat production. The volume of heat obtained in that way 2-3 times exceed the volume produced during basic metabolism [14]. On the other side, during muscular trembling increased loss of heat through convection is observed. In result, all heat produced by means of muscular trembling is almost completely lost.

Apart from muscular trembling, the next essential effect that can be observed during treatment is reduction of basic metabolism by even 50% [23]. This decreases the energetic demand of tissues and in result causes drop of oxygen demand [28].

In practice, completely reversed reactions are observed after the treatment. The reinstatement of skin temperature is observed after about 14 minutes and the *plateau* (35^{O}C) is maintained for over 90 minutes [14,15]. About 4 minutes after treatment the width of blood vessels is expanded and may exceed 4 times the initial diameter [9,19]. Such effect can last for a few hours after application.



Picture 6.3 The change of blood supply in organs as the result of application of cold (the blood supply was expressed in litres per minute, and ratio of blood

supply versus weight of the organ was expressed in litres per minute per kilogram) [28]

It brings considerable increase of blood supply of internal organs. Several-hour long excessive blood supply within organs ?? DOESNT REALLY MAKE SENSE..RE-PHRASE contributes to improved metabolism and elimination of harmful products of metabolism. All these, assisted by kinetic therapy accelerates healing of swelling.

Another important result of excessive blood supply is increased concentration of oxygen in muscles which reduces volumes of lactates and histamine, increases concentration of bradykinin and angiotensin and – in resultAS A RESULT – significantly alleviates the pain [9,36]. Additional analgesic factor is due to cold-induced inhibition of neural conduction in some unmyelinated fibres [8,15]. Hypothermia reduces the speed of neural impulses down to 1,2-2 m/s/^{O}C after cooling to 18^{O}C [1]. In resultAS A RESULT, the reflexive responses are deteriorated and the pain threshold is raised [3]. For example pain threshold in A healthy shoulder joint after 15-minute application of plastic bag filled with ice was raised to the same level as that after 20-minute short-wave diathermy. However, in case of diathermy the effect is maintained for considerably shorter period [24].

Another noticeable effects of long lasting application of cold are enhanced secretion in adrenal glands and thyroid, and also accelerated cellular metabolism [17]. The morphological and biochemical examination performed after 2 weeks from treatment indicated increased level of hemoglobin, leukocytes and thrombocytes in comparison with initial values [29,32,3435]. However, the highest acceptable level was never reached [21].

The next effect of application of low temperatures is manifested by relaxed tension of muscles [2,18]. Physiological mechanism responsible for such relaxation has not been fully investigated. Probably it is connected with inhibited neural conduction and reduced reactivity of circumferential sensorimotor endings, including specific receptors – Golgi apparatuses in tendons and neuromuscular spimdle??SPELLING? in muscles – responsible for regulation of muscular tension [6,8,15]. Obviously, the relaxation of muscles mainly contributes to improved rehabilitation of patients with

spasticicty.

The fact that achievement of reactions and therapeutic effects such as analgesia, anti-swelling action, exceeded blood supply, relaxation of muscular tension and increasing their strength does not have to be limited to areas directly subjected to cryostimulation. The systemic effects are as well observed even in remote areas [18,36]. It is worth mentioning that above organic reactions occur during “rebound” time [2,18,19], which means after withdrawing of cold factor, and when operating collectively contribute to anti-inflammatory properties of that form of therapy[4,5,11-13,16,21,22,27-30].

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Chapter 7

Dariusz Biały , Zbigniew raczkowski, Wiesław Stręk, Zdzisław Zagrobelny

The cryogenic chamber in Wrocław

The therapeutic application of cold has great traditions and high effectiveness. In order to obtain maximum advantages of systemic cryotherapy it was necessary to construct devices that would ensure effectiveness, safety and easy assembling. In Poland the first cryochamber was built in 1989 in Wrocław in the Institute of Low Temperatures and Structural Research of Polish Academy of Science. It begunBEGAN the whole series of devices that were installed in many clinical and sport centers all over the country. In 1996 the second cryochamber was built and installed at Academy of Physical Education in Wroclaw.

The construction of the chamber, methods of insulation and preparation the atmosphere in special cryo-purifiers are patented. The specific technical innovations and presented therapeutic parameters, when compared with foreign constructions, show that Wroclaw cryochamber is one of the most advanced devices currently available in the world.

The cryochamber consist of two compartments: antechamber where the temperature reaches –60^{O}C and main chamber where temperature can drop to –110^{O}C or even –160^{O}C. The schematic construction of the chamber is shown in the picture 7.2.

The walls of the chamber are made of materials bearing unique insulative properties which enable maintaining of room temperature in the outer part of the chamber despite extremely low temperature inside.

In the cryochamber liquid nitrogen is utilized as the cooling agent. The

construction features very quick cooling down to preset temperature and also very stable operation during many hours. Due to that fact groups of 4-5 persons can enter the chamber every 3-5 minutes which gives average capacity of 50-80 persons per hour. All parameters concerning operation of the chamber are independently controlled by two electronic systems and supervised by cryogenic engineer.

Picture 7.1 The cryochamber in Academy of Physical Education in Wroclaw.