Cryotherapy: Physiological Considerations and Applications to Physical Therapy

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Contemporary cryogenics has been developing from the end of the 19th century since the liquefaction of oxygen, nitrogen, carbon dioxide and hydrogen, and also the industrial production and storage of liquid coolants, enabled the development of cryobiology and the use of extremely low temperatures in medicine. The term "cryotherapy" was first used in 1908 by A.W. Pusey to describe the treatment of skin lesions with very low temperatures [Zagrobelny et al. 1999; Jezierski 2006;]. Currently, cryotherapy refers to various treatments aimed at lowering the body surface temperature without tissue destruction, whereas in cryosurgery diseased tissues are destroyed through freezing. The world's first cryogenic- temperature chamber was set up in Japan, in 1978. Thanks to Yamauchi and his team, cryotherapy began to be widely used in medicine [Zagrobelny 2003; Skrzek 2009].

The clinical application of low temperatures is recommended for inflammatory conditions, such as swelling and acute localised pain. It is essential to clarify the distinction and clear labelling of methods based on low temperature usage and the intended purpose, as the body's response to low temperature depends on the temperature, method of application, exposure time, method and rate of heat loss, humidity of the cooled air, and the characteristics and age of the subjects.

Cryostimulation requires making use of a suitable croyogenic liquid as a coolant source. It is based on the use of very low temperatures (-100oC and lower) in order to induce a physiological reaction to cold.

A different category of treatment in modern medicine and rehabilitation, the cooling of tissues, is based on different methods and rates of tissue heat loss using various temperatures and methods of application achieved by the use of bags of ice, frozen silicone gel, salt solution, wet cold (which is not tolerated well by many people), partial bathing in cold water or whole body bath (temperature below 10oC). Cooling results in heat loss, the treated body area experiences vasoconstriction, a long-duration decrease in the temperature of the exposed tissues, decrease in inflammatory reaction and inhibition of strong symptoms of inflammatory reaction, but without any stimulatory effect [Rawecka & Rokita, 2006].

2. Cryogenic liquids

Cryogens (cryogenic liquids) are those liquids with a boiling point not exceeding 120 K under normal atmospheric pressure. The following are various types of cryogens and respective temperature ranges:

1. wetcold-waterwithice,0°C
2. damp cold - cold air, temperature from -15 o C to -30 o C
3. dry cold– vapours of liquefied gases:
    1. liquid nitrogen vapour: -196 °C
    2. carbon dioxide vapour: -75 oC

The most rapid effect can be achieved with water (wet cold). Subjecting a patient to a cold bath, however, is unpleasant and can cause shock, and therefore is used only in selected cases. Cryostimulation using dry cold (vapours of liquefied gases: nitrogen, air, carbon dioxide) is also quick, convenient and much more patient-friendly [Bojek 2006; Rawecka & Rokita 2006].

Cryogenic liquids, vapours and cold gases used in the wrong way are able to cause serious damage related to frostbite. However, liquid nitrogen in short contact is not harmful, because at the time of contact with warm tissue, it evaporates intensely. It is important to avoid contact with the eyeball as it may cause serious and irreversible damage to the cornea. The danger with these substances is in their low temperature and high density. They are kept in specially insulated containers that are designed to withstand rapid temperature changes.

Local cryotherapy (temperature at the outlet of the nozzle can range from -160° C to -196° C), ventilation : ventilation with nitrogen vapours (gas with a mixture of nitrogen vapours and cooled air (temperature of the gas mixture varies from -100° C to -178° C), and ventilation with cold air (temperature ranges from - 30° C to -34° C).

Cryostimulation procedures

Whole-body cryotherapy is often used as preparation of the patient to physiotherapy. However, cryotherapy is also increasingly often performed for the purposes of biological regeneration and prevention of musculoskeletal overload and injury (athletes), and as a way of increasing immunity. In some cases with symptoms of inflammation (acute and chronic musculoskeletal injuries), the purpose of cryostimulation is to decrease the temperature of the inflamed tissue as cold is known to limit inflammation symptoms. This protects against oedema of periarticular tissues and any further damage caused by pressure and movement of tissues. In such cases very good results are obtained by local cryotherapy.

Local cryostimulation

Local cryotherapy treatment uses usually the following cryogens: liquid nitrogen, carbon dioxide, cooled air [Sieroń & Cieslar 2003]. Prior to cryostimulation, the patient should thoroughly dry the body surface to be subjected to treatment. It is most desirable to keep the patient in a standing position or if not possible, in a sitting or lying position. Procedure duration is defined individually for each patient, depending also on the body structure, muscle mass and fat thickness. Cryotherapy is not used for more than about 5 joints at the same time which should not be longer than 12-15 minutes. The hand, foot and spine are considered as a single set of small joints [Księżopolska - Pietrzak 1998].

The treatment time takes usually from 30 sec to several minutes (3-4 min), depending on the patient's skin response. The treatment may be repeated twice a day but with a break of at least 6 hours. The recommended duration of the break is determined by the sustained stimulatory effect after a single session. In children, treatment should be used very cautiously and of a shorter duration than adults due to the higher sensitivity of the younger skin and usually lower amount of subcutaneous fat. The distance of a cryoapplicator from the surface of the body depends on the quality of the device, and the temperature obtained at the nozzle exit, usually about 10 cm from the body surface (in older devices, the distance can be up to 15 cm). The treatment area of the body should be progressively swept over to avoid cooling of just one spot. Initially the patients experience a burning sensation. The patient must stay in communication with the physiotherapist and inform him about the pain or the burning sensation. After reported discomfort the applicator should be positioned further from the tissue, or the movement of the nozzle should be sped up. Rapid skin blanching is an indicator for immediate cessation of the treatment [Jezierski 2006].

During cryotherapy, one must remember about the bi-phasic vascular response to extremely low temperatures, and bear in mind the desired effect. Initially, in micro-circulation, a constriction of vessels as a result of closing of pre-capillary sphincter and activation of arteriovenous anastomoses, which takes from a few to a ten or so seconds, after which the vessels dilate and arteriovenous anastomoses close, during which blood flow increases. A lower temperature of the coolant (liquid nitrogen vapour) results in a stronger and faster first stage, i.e. vasoconstriction causing tissue ischemia. In this way one can reduce the effects of trauma, reduce the rate of metabolic processes (which may be helpful for example in the physical therapy of arthritis), while hypoxia reduces perceived pain. In the second phase, local hyperaemia occurs (increase in local blood flow due to the effect of internal and external factors, known as the rebound effect), during which metabolic processes are intensified and muscle tension is reduced.

Treatment duration and temperature are diverse and depend on whether the goal is mainly to generate secondary hyperaemia and reduce muscle tension, e.g. in preparing the patient for physiotherapy or massage, or whether the first phase is the primary goal, slowing metabolism and reducing the effects of trauma. Cryotherapy is often used as an analgesic agent, and this effect can last for several hours. The manner of cryostimulation is also influenced by the patient's age, physical condition, sensitivity to low temperature, or existing disease and its severity [Kasprzak & Markowska 2008].

In some cases, excessive hyperaemia may worsen pain in the long-term (with a strong inflammatory component). In this case cold therapy instead of cryotherapy is recommended.

Fig. 1. Examples of stationary and portable cryotherapy apparatus

Diseases in which local cryotherapy is used

Patients with locomotor disorders are now the largest group of patients eligible for cryotherapy. An efficient muscle-joint and skeletal system is fundamental for the functioning of the human body. The inability to move affects an individual both socially as well as psycho-socially. As musculoskeletal disorders affect people of all ages and from all social groups, researchers worldwide have been looking for the most beneficial methods of treatment. Cryotherapy has gained the greatest recognition as supporting treatment of the motor system [Bieńkowska et al. 2006; Hopkins 2006; Łuczak & Michalik 2006].

Ankylosing spondylitis

In ankylosing spondylitis pain forces patients to reduce their motor activity. The progress of the disease and reduced physical activity leads to a reduction in joint mobility, periarticular ossification and degenerative changes. The spine assumes deep thoracic kyphosis, deep compensatory cervical lordosis, thoracic stiffness and stiffness in the peripheral joints affected by inflammation. The advancing total thoracic rigidity causes a situation where lung ventilation only takes place through diaphragm movement. Kinesitherapy and cryotherapy are currently the preferred treatments for ankylosing spondylitis. Cryostimulation decreases the concentration of acute phase proteins and immunoglobulins in serum and increases the concentration of □-endorphin.

The cryotherapy-induced reduction of inflammation and the higher threshold of pain perception allows the use of physiotherapy to a greater degree. The patient benefits from a reduced need for analgesics and anti-inflammatory drugs. Local cryostimulation should be followed by kinesitherapy based on an individual program, allowing for the period of the disease (acute or remission), the severity of the disease, its extensiveness, the patient's age and the incidence of other diseases. In the acute phase of the disease, cryostimulation plays an important role in reducing pain as well as inflammation, allowing for sufficient activity of the patient during exercises. During remission, the most important aim is to gradually regain motor functionality [Sieroń & Cieslar 2003; Jezierski 2007].

Rheumatoid arthritis (RA)

RA is a chronic immunologically dependent connective tissue disease that is characterised by non-specific, symmetric arthritis, sometimes accompanied by non-joint changes and systemic complications. The course of RA is characterised by alternating periods of joint inflammation and remissions. This disease can occur in three

forms: mild, medium and acute. Diagnosing the disease is synonymous with pharmacological treatment that should be supported by physical therapy. Cryostimulation has beneficial effects in RA - it increases active muscle power and lowers passive muscle power. Pain and increased oedema of joints is reduced, resulting in increased range of motion in the inflamed joints. A single cryostimulation of a specific part of the body takes about 3 minutes and has both analgesic and anti-inflammatory effects. Therefore cryostimulation should be immediately followed by physical exercise [Sieroń & Cieslar 2003; Straburzyńska - Lupa et al. 2005; Krawczyk - Wasilewska et al. 2007; Jezierski 2007].

Osteoarthritis (OA)

Symptoms of osteoarthritis include morphological, biochemical, molecular and biochemical changes in cells of the cartilage, which lead to softening, fibromatosis, ulcers and weight loss of articular cartilage, sclerosis and thickening of bone, osteophytes and subchondral cysts. Patients with hip degeneration experience destruction of cartilage and subchondral bone, and pain in the hip. Local cryostimulation aims at maximum cooling of the hip. Cold should be applied from the front and medially to the groin and the space between the pubic symphysis and thigh adductor and from the back to the gluteal fold and ischial tuberosity. In addition, cryostimulation should involve the entire thigh, gluteus maximus and iliopsoas. The duration of treatment ranges from 3 to 6 minutes. In degeneration of the knee, cryostimulation is performed on the knee joint and thigh muscles. Cooling of the joint is done best in a sitting position with a bent knee (cold should be first applied on sides, then around the knee cap). Osteoarthritis may involve the joints of the spine or vertebral stem. Cryostimulation is performed on a relevant segment of the spine area and muscles situated in the area. The procedure is followed by exercises intended to strengthen back muscles and abdominal muscles, stretching and increasing the mobility of the spine exercises, and correction exercises [Sieroń & Cieslar 2003; Jezierski 2008; Pasek et al. 2009].

Shoulder impingement syndrome

Treatment of shoulder impingement syndrome is not straightforward. Pharmacological methods are often accompanied by physiotherapy and anti-inflammatory analgesic electrotherapy, ultrasound, massage, kinetic therapy and increasingly popular cryotherapy. The aim of physiotherapy treatment is improvement in the functional efficiency of the limb through the elimination or reduction of pain. Literature reports describe both cold therapy, resulting in a slowdown of inflammatory reactions and reduced metabolism in cooled tissues, and cryostimulation which aims at improving conditions in blood circulation in a given area and to exert a strong analgesic effect. Cryostimulation for patients with shoulder impingement syndrome increases the range of motion in the transverse plane, bending and movement of external rotation, and a slight effect on straightening and bending in the sagittal plane, abduction and internal rotation [Sieroń & Cieslar 2003; Lisinski et al. 2005; Boerner et al. 2007].

Gouty diathesis

This inflammation of joints is caused by crystallisation of sodium urate in synovial fluid and crystal deposition in tissues. Another form of this disease is chondrocalcinosis caused by calcium pyrophosphate dihydrate crystallisation in synovial fluid and crystal deposition in articular cartilage. In patients with acute gout, cryostimulation can be applied only after the attacks. Local cryotherapy causes a short-term reduction in the intensity of local inflammation, but does not stop an attack of gout. Kinesitherapy is introduced gradually and with caution, due to the persistent deposits of sharp crystals in cartilage and other connective tissues [Sieroń & Cieslar 2003; Jezierski 2008].

Osteoporosis

This is a bone disease with a gradual decrease in bone mass with muscles and ligaments losing elasticity, and resistance to physical effort. The decline in mechanical bone strength is accompanied by degenerative changes. The disease affects the neuromuscular system and motor pattern, and results in the painful overload of muscles, ligaments, bones and joints. Treatment with cold, as in previous cases, leads to a reduction in pain, relaxes skeletal muscles and improves their strength, and increases range of motion within the treated joints [Księżopolska – Pietrzak 1998].

Spinal pain syndromes

These syndromes represent a serious medical problem as they affect between 60% to 90% of the European population. The lumbosacral spine is most affected, due to the sedentary lifestyle. Chronic pain leads to lower

psychophysical performance. Cryotherapy decreases muscle tension and reduces the speed of nerve conduction, which are beneficial in relieving pain and allows further treatment with physiotherapy [Woźny et al. 2006].

The mask is necessary for the protection of the lungs – if the extremely cold air reaches lung tissues in greater amounts, then after heating in the lungs its volume may even double which may result in respiratory oppression [Zagrobelny 2003].

The distribution of temperatures in the cryochamber results in the coldest air being located in the lowest area of the device, therefore clogs are the most suitable shoes during cryostimulation. A thick sole is good isolation of the feet from the ground. Socks should be short and protect only the area of the ankles and feet. The popliteal pit is very vulnerable to surface frostbite, as it has a tendency for intense sweating which may be prevented by instructing the patient to avoid sitting or putting a leg on a leg. It is best to wait for the treatment in the standing position, and wipe the area of the popliteal pit and put a knee pad on immediately before entering the chamber [Brojek & Warzocha 2006].

Clothes used during cryostimulation should be made solely from natural components, such as wool or cotton, and should ensure full psychological comfort. It is best if pants are short and tight. Loose pants, such as boxers results in unpleasant rubbing of the frozen material against the body. Wearing any type of shirt is pointless as it inhibits the process of heat exchange during cryostimulation [Raczkowski & 2007].

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