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PROSPECTS OF INTERMITTENT PNEUMATIC COMPRESSION AS A NEUROTROPIC THERAPY

Zaitsev D. V.

Shupyk National Healthcare University of Ukraine, Kyiv

Introduction. Intermittent pneumatic compression (IPC) is known as a vascular therapy. At the same time, it is obvious that the mechanical action of IPC is tropic for receptors; in addition, stimulation of blood circulation leads to increased transport of immune and regulatory substances, which directly affects the functional state of the autonomic nervous system. The study of the IPC effect on the nervous system will enrich the set of non-drug means of prevention, treatment and rehabilitation in neuropsychiatric diseases.

The aim of the study is to characterise the effect of IPC on the functional state of the nervous system according to scientific literature.

Materials and methods of research. The search was limited to 1992–2022 and was done on the GoogleScholar search engine. The search in English was carried out using the keywords: «intermittent pneumatic compression», «pressotherapy» and «receptor», «nerve», «autonomous», «cerebral», «sensor», «palsy», «stroke». The search in Ukrainian was carried out using the corresponding analogues of the keywords. Additionally, selected publications cited by the found sources were analysed.

Results. The IPC procedure causes activation of proprioception and good muscle relaxation. IPC reduces pain of various origins, accelerates the regeneration of nerve endings and improves neuromyographic parameters. During the IPC procedure, adaptive fluctuations in the balance of the autonomic nervous system are observed with the development of parasympathicotonia and a decrease in the intensity of regulatory processes. IPC may enhance recovery from exercise but does not affect athletic performance. IPC has little effect on desynchronous and meteopathic disorders. IPC has a positive effect on the long-term aftermath of combat stress. The impact of IPC on the adaptive-compensatory reactions of the nervous system requires further study. IPC increases blood flow velocity and blood oxygenation of the cerebral arteries. IPC does not prevent the onset of sensorimotor disorders due to cerebral stroke, but offers benefits in their treatment. The IPC procedure induces a sleep-like state, and the course of therapy improves the overall quality of a night's sleep. IPC may have a beneficial effect on mental activity, which requires further study.

Conclusions. The IPC can be used for secondary vascular manifestations of nerve diseases, for non-vascular nerve pathology with local hyperfunction and for secondary nervous system damage due to the processes of ischaemia, intoxication, chronic inflammation or regulatory disorders. The possible effects on the nervous system and psychological activity require a wider and more systematic basic and clinical study. Although the procedures require special equipment, it is already widespread in Ukraine and available to the patients. Adding the IPC to the complex therapy of patients with occupational diseases of a neurological profile can help reduce the period of disability, prolong remission periods and reduce disability rates.

Key words: intermittent pneumatic compression, nervous diseases, psychoneurological disorders

Introduction

Despite improvements in control, cardiovascular disease and diabetes remain among the four major non-communicable diseases (WHO, 2022), keeping the search for therapeutic interventions focused on the blood supply to nervous tissue relevant. Today, it is possible to look at intermittent pneumatic compression (IPC) from this perspective. According to the concept of evidence-based medicine, the main indications for the use of IPC are

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thromboprophylaxis and edema syndrome. At the same time, there are attempts to use IPC in patients with ischaemic intermittent claudication, diabetes, tendon injuries, and trophic ulcers, which indicates that there are not well-established ideas about the clinical role of IPC and the expansion of the range of indications for it. The above list of nosologies characterises IPC as a vascular therapy. At the same time, it is obvious that the mechanical action of IPC is tropic for a number of receptors (tactile, proprioceptive, temperature), including those localised in reflexogenic zones; in addition, stimulation of blood circulation involves stimulation of the transport of immune cells and peptides, as well as mediators, hormones, ions and other regulatory substances, i.e., it can affect the functioning of regulatory systems (and thus, at least indirectly, the autonomic nervous system). These circumstances make it possible to consider the nervous system as a target organ of IPC. However, studies in this area are mainly experimental in nature, they are few and far between and insufficient for generalisations. In our opinion, a systematic study of the patterns of influence of IPC on the functions of the nervous system in normal and pathological conditions will enrich the arsenal of non-drug means of prevention, treatment and rehabilitation of psychoneurological diseases.

The purpose of the study is to characterise the peculiarities of the effect of IPC on the functional state of the nervous system, to identify and systematise groups of psychoneurological nosologies that are promising for the therapeutic use of IPC.

Materials and methods of research

In order to cover the largest number of potentially relevant papers, the search was conducted in the Google Scholar search engine. The search was limited to 1992–2022. The search was conducted in English using the keywords: «intermittent pneumatic compression» and «pressotherapy» for intervention and keywords: «receptor», «nerve», «autonomous», «cerebral», «sensor», «palsy», «stroke». A search was also conducted in Ukrainian for relevant analogues of the keywords. An in-depth analysis of selected publications cited by the sources found was carried out. Based on the analysis of the data obtained, a systematic view of the reaction of the nervous system to IPC was formed.

Results of research and their discussion

IPC and peripheral nervous system

IPC can reduce the intensity or shorten the duration of pain of various genesis, namely, those caused by sports training [1], static work [2], sprains, post-traumatic edema, bone fracture [3], and arthroplastic surgery [4]. The analgesic effects of IPC in the treatment of peripheral vascular disease, such as diabetes [5] and intermittent claudication [7], are also well described. In the above examples, the rapid analgesic effect of IPC is secondary to anti-edematous, anti-inflammatory and other vascular effects. At the same time, in the long term, IPC can directly interact with nerve endings, for example, by accelerating their regeneration after injury [7].

Since in recent years the views on the etiopathogenesis of dorsalgia and diagnostic approaches have been significantly modernised, the domestic experience of local application of IPC should be evaluated phenomenologically. In Ukrainian research papers of 1999–2001, there are references to the reduction or disappearance of acute back pain, cessation of paresthesias in the extremities, improvement of electroneuromyographic

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parameters, and reduction of the treatment period for pain syndrome in case of application of IPC.

The study (D. Zaitsev et al., 2018) examined the effect of the head and back IPC procedure on body balance during standing. Since the effect was not on the prorioceptors, but in the segmental projection of the bodies of the corresponding neurons, this study did not clarify which structures responded to the procedure. The obtained stabilographic data indicated that the phenomenon of general relaxation (both directly muscle relaxation and, according to indirect signs, cerebral inhibition) after the procedure is a pronounced leading reaction, against which subtle changes occur. A decrease in the role of visual control and a marked increase in proprioceptive influences on the body balance strategy were also found.

K. S. Zaitsev (2015) showed that a single use of IPC increases the strength and speed of impulse conduction through neuromuscular contacts, and a course of IPC increases impulse conduction through nerve fibres and significantly increases the neuromuscular response to stimulation, possibly due to an increase in the number of synaptic contacts. L. O. Tarshynova et al. (2015) reported that in patients with cerebro-spinal form of multiple sclerosis, oscillatory dynamics of pyramidal and cerebellar syndromes with a tendency to mitigation was observed in the setting of IPC. In the case of peripheral neuropathy due to chemotherapy, the IPC procedure improved foot sensation and balance control during the first day of observation [8].

The large CLOTS 3 trial showed that IPC, even when administered from the first hours after cerebral stroke, does not affect the likely development of long-term outcomes or reduce disability. Although the 6-month mortality rate significantly decreased, this was due to the survival of terminal patients whose quality of life and functional capacity remained low. Nevertheless, the inclusion of IPC in a comprehensive rehabilitation programme for hemiplegia increases the effectiveness of motor [9] and sensory function recovery [10].

It is likely that certain effects of IPC are provided by reflex mechanisms, in particular, a rapid decrease in blood pressure after procedures in the feet, back and head, cessation of spasms and muscle relaxation, development of a meditative state or drowsiness during procedures. This assumption requires experimental confirmation.

As a possible rare complication of the IPC, cases of neuropathy or temporary numbness due to excessive mechanical compression of the nerves have been described. This indicates the potential possibility of external mechanical massage of the nerve trunk by means of IPC. The therapeutic feasibility of this method may be the subject of further research.

IPC and the autonomic nervous system

M. O. Bezpalyi et al. (1999), observing the dynamics of capillary tone and blood pressure, expressed the opinion that IPC stimulates the zones of segmental reflexes and Zakharyin-Head and activates vertebro-visceral connections and vegetative-vascular reactions. I. I. Sukharev et al. (2001) believed that the effect of IPC is due to neuroreflex reactions; the method affects extero-, proprio- and interoceptors, restoring their functions, improving nerve conduction and regeneration, reducing trophic and vasomotor disorders. Clinical observations of the approach of vegetative samples to normotonia, mitigation of balneotherapy reaction, meteorological syndrome, and dysfunctions of internal organs led to the idea (L. M. Bilyak, T. M. Plenova) that IPC restores the balance of autonomic regulation. Subsequently, A. P. Chuprykov (2007) expressed the opinion that IPC can enhance reflex

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and neurotransmitter inhibition of the reticular formation and cerebral cortex, reduce the energy demand of neurons along with an increase in cerebral haemodynamics, which improves the functional state of the cortex, reduces nervous excitability, facilitates the development and enriches the spectrum of autonomic reactions induced by IPC. Although the ideas about the effect of IPC on nervous activity have been formed long ago and in detail, they were mostly speculative and had the nature of assumptions, but nevertheless prompted researchers to pursue further research.

The performance of IPC procedures under the control of heart rate variability (D. Zaitsev et al., 2017) revealed a number of characteristic effects, such as a reflex increase in parasympathetic tone with a decrease in sympathetic effects, an increase in the activity of neurohumoral regulation, an increase in the role of the segmental autonomic system with a decrease in the influence of higher centres, and a decrease in the tension of regulatory systems. It turned out that adaptive fluctuations in the sympathetic-parasympathetic balance lasted for the first 10–15 minutes of the IPC procedure, and after 25–30 minutes of the procedure, the dynamics of parasympathicotonia stabilised in the plateau phase. During the procedure, an increase in the activity of the vasomotor centre was detected, and after it an increase in the total absolute level of activity of regulatory systems, which, in our opinion, requires further research.

Later (D. Zaitsev et al., 2019), in the group of combatants with adaptation disorders, during the course of the IPC, there were signs of active adaptive and compensatory processes with harmonising adaptive changes in the phases of vagotonia and sympathicotonia, which tended to form a compensated, close to normal state of vegetative balance. The maximum of adaptive reactions, the period of the highest reactivity of the organism to the procedure of IPC occurred approximately on the 4th day from the beginning of the rehabilitation course. The greatest number of indicators of heart rate variability, which significantly differed from the pre-rehabilitation state, was achieved around 6–7 days of the course. Thus, it was concluded that the duration of the course of IPC as part of complex rehabilitation in conditions of chronic stress and adaptation disorders is 7–11 days.

The experience of using IPC in sports medicine is controversial. In general, the use of IPC can accelerate the recovery of athletes after physical exertion [1], but at the same time has no significant effect on sports performance [11].

The use of IPC in the conditions of extreme environmental factors during the Antarctic winter in participants of Antarctic expeditions reduced certain symptoms of desynchronous disorders: there was an improvement in systolic blood pressure, pulse rate, electrical activity of the heart, reduced fatigue, and improved emotional state. In general, IPC gave an incomplete correction of desynchronosis syndrome disorders, «Antarctic syndrome», symptoms of chronic stress and maladaptive disorders – but like most of the studied methods and means [12].

V. S. Rozhkov (2009) observed in urological patients in the treatment of asthenic IPC syndrome a significant decrease in the manifestations of general weakness, fatigue, emotional lability, a feeling of internal tension, anxiety, depression, headache and chest pain, improvement of sleep, concentration, memory and performance.

IPC and the central nervous system

A number of studies have demonstrated the ability of IPC, which is performed on the lower extremities for various reasons, to increase cerebral blood flow

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and oxygenation of cerebral tissue [13] without affecting intracranial or cerebral perfusion pressure. In patients with cerebral infarction, IPC can promote bilateral cerebral circulation in the prefrontal, sensorimotor and temporal cortex and have a positive effect on functional rehabilitation in case of their damage [14].

In experiment (D. Zaitsev, 2019), a short, single procedure of IPC was performed on the scalp with the effect assessed by rheography. The obtained observations allowed us to assume that IPC has a reflex effect on the tone of cerebral vessels, leading to rapid changes in haemodynamic balance (correction of asymmetry, harmonisation of blood distribution in arterial basins) and arterial blood filling (fluctuations in vascular volume).

A. I. Konshina et al. (2009) observed a number of changes in the functional state of the visual analyser when introducing IPC into the treatment of ophthalmological patients, which indicates its positive effect on the vascular system of the retina and optic nerve.

Drowsiness is a well-known effect that develops during IPC procedures. In our experience, in at least half of the cases, there is a tendency to fall asleep with varying depths, from inhibition of cortical reactions and napping to signs of advanced sleep (sleep apnoea), which probably depends on situational fatigue or lack of daily sleep in a particular patient. The study of the effect of the IPC course on the quality of night sleep (D. Zaitsev, 2016) showed an improvement in the patients' morning state of health with a decrease in feelings of exhaustion and lack of sleep upon waking up in the morning, an improvement in the subjective assessment of sleep depth, a decrease in daytime drowsiness and fatigue, and a decrease in the incidence of psycho-emotional arousal or taking stimulants before bedtime. There was a reduction in the subjective need for nighttime sleep.

There are some observations of a favourable effect of long-term use of IPCs on the mental component of quality of life, in particular, according to the Lymph-ICF-LL [15] and ShortForm-36 [16] questionnaires. This effect is secondary and depends on the success of specific therapy for the underlying disease.

In 2009–2013, researchers led by A. P. Chuprykov observed clinical cases and small groups of children with psychoneurological spectrum disorders treated with the help of the IPC. There was a decrease in hyperactivity with complications in play activities, improvement in sleep and communication, reduction of nighttime enuresis, reduction of autistic signs in the form of orderly behaviour, improvement in obedience and trust, increase in sleep duration, increase in vocabulary and sentences, increase in sociability, sleep and appetite, disappearance of fear, and stabilisation of mood. The use of IPCs as a support for pharmacotherapy in children with epilepsy has made it possible to reduce the dose of anticonvulsants and, in some cases, achieve a relatively long remission in the course of epilepsy. It has been suggested that IPC has a mild depressant effect on the cerebral cortex. The possibility of a favourable effect of IPC on memory, attention, and thinking both in pathology and especially in clinically healthy individuals, as well as the corrective effect of IPC on anxiety and depression, seems to be quite promising for scientific research.

L. Xiaojing et al. (2022) emphasise the role of meningeal lymphatic drainage in reducing the neuroviral load on brain tissue. If the ability of IPC to activate meningeal lymphatic drainage is proven, this may explain the cases of improvement in the condition of patients with chronic herpesvirus neuroinfections known from our practice.

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Summary and perspectives

A summary of experience and knowledge about the neurotropic effect of IPC is given in the Table. It can be seen that with a single use of IPC, reflex reactions occur mainly in the peripheral and autonomic parts of the nervous system, and their development is characterised by a certain afferent gradualness, while vascular effects are observed in all parts of the nervous system relatively evenly (they have a corresponding local specificity and can develop independently). Among the slow long-term effects during the course of IPC, the effects of vascular-metabolic and mixed origin prevail, while purely reflex reactions are unlikely. The effect on the central nervous system is almost exclusively humoral, except for reflex drowsiness; the effect on the autonomic nervous system is predominantly reflex.

Based on the generalised picture of the neurotropic effect of IPCs, certain classes of pathological conditions can be identified in which IPCs can be used as an additional neurotropic therapy (Figure). Acute cerebrovascular accidents, autoimmune and demyelinating processes, and toxic encephalopathies are left out of the scheme, in which the prognosis of the clinical feasibility of IPCs is currently difficult.

To date, scattered data have been accumulated that allow us to cautiously and in general terms formulate the concept of the neurotropic effect of IPC. IPC procedures have a rich reflexogenic potential, which requires a separate special study from the point of view of reflexology. In general practice, among the clinically noticeable reflex effects of IPC, one should include muscle relaxation, drowsiness, and lowering of blood pressure, which are typical reactions and depend more on the fact of the procedure than on its specific settings. In most cases, the effect of IPC on the nervous system is indirect, due to the activation of blood flow, which serves the needs of nervous tissue or compensates for its functional failure. There is a lack of reliable clinical trials in this area, as the vast majority of studies are either physiologically focused or have a pilot, exploratory nature and design. In-depth clinical trials will help clarify indications and contraindications, and most importantly, optimise the methodology for using IPCs for disorders and diseases of the nervous system and mental health.

Table

Clinical effects of intermittent pneumatic compression in the functional state of the nervous system

Effect of intermittent pneumatic compression	Compartments of the nervous system		
	peripheral	autonomous	central
Disposable (procedure)	▲ *proprioception* ▲ *muscle relaxation* ▲ **neuromyographic parameters**	▲ *adaptation of the functional balance* ▲ *parasympathicotonia* ▼ *the intensity of regulatory processes* ▲ **recovery after physical activity**	▲ **cerebral blood flow** ▲ **blood oxygenation of the cerebral arteries** ▲ *drowsiness*
Repeated (course)	▼ **pain** ▲ **regeneration of nerve endings**	▼ ***Desynchronosis and meteorology*** ▼ *long-term effects of stress*	▼ **sensorimotor consequences of cerebral stroke** ▲ ***quality of night's sleep***

Note. ▲ – *increase in manifestation,* ▼ – *decrease in manifestation, italics – predominantly reflex effects,* ***bold italics*** *– mixed effects,* **bold** *– predominantly humoral and metabolic effects.*

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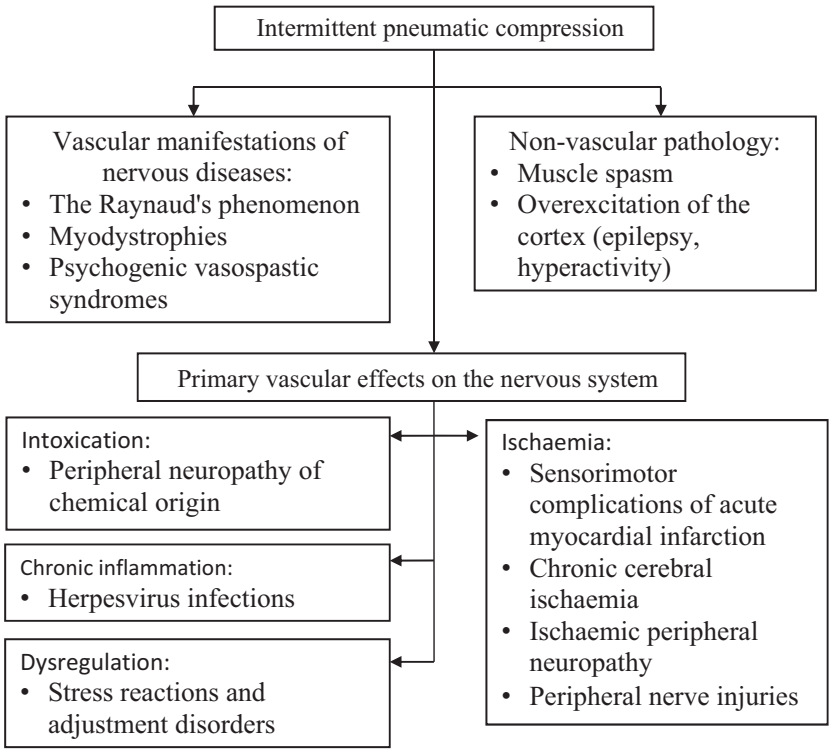

Figure. Potential applications for intermittent pneumatic compression in neuropsychiatric conditions

Among the issues that remain unresolved are the ability of IPCs to influence the duration and cost of treatment, and the comparison of efficacy with neurovascular drugs. In the future, IPC may be included in the second line of therapy as an adjuvant complementary agent.

The use of IPC in neurotrophic disorders in the periphery (pressure ulcers, chronic wounds and trophic ulcers, spastic angiopathy such as Raynaud's phenomenon, etc) has already become commonplace. It is believed that IPC can have a corrective effect on the effects of physical inactivity and chronic fatigue. Positive experience with the use of IPC in inflammation and injury of peripheral nerves, and especially in neurodegenerative processes, remains extremely limited and uncertain. With regard to the peripheral consequences of cerebral stroke, the effectiveness of IPCs is likely to be inversely related to the duration of the defect; the fact that IPCs are safe to use from the first hours after the event is now practically the most important.

Observations and studies unanimously show that IPC has a positive impact on adaptation processes. In most cases, this effect is described as small, but comparable to other means used in these cases. The IPC stimulates endocrine and immune regulatory processes for a short time, which can compensate for the load on the nervous system; this feature deserves further study of the properties of IPC as a nonspecific restorative agent.

Data on the effect of IPC on anxiety and depression are controversial and need to be clarified. It would also be interesting to determine whether regular or long-term use of IPCs can reduce the risk of acute cerebrovascular accidents. It can be expected that the use of IPCs may be useful in some encephalopathies (discirculatory, possibly

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toxic), disorders with increased excitability of the nervous system (in particular, epilepsy, attention deficit disorder; possibly bipolar disorder). Regarding the impact of IPC on the quality of mental activity, so far, based on individual clinical cases, in the absence of detailed and large-scale studies, we should limit ourselves to the statement that this impact is individual.

In Ukraine, on average, about 3,000 people are diagnosed with a disability for the first time every year. Prior to the full-scale aggression of the Russian Federation, the causes of primary disability per 10 thousand able-bodied people in Ukraine were: cerebrovascular pathology 4.4 cases; mental and behavioural disorders 2.7; spinal osteochondrosis 2.3; pathology of the organ of vision 1.8; diabetes mellitus 1.6; diseases of the peripheral nervous system 0.3 (A.V.Ipatov, 2018) – so, in general, the disabling pathology in which additional involvement of IPCs in complex therapy can be potentially useful was 13.1 cases per 10 thousand working-age population. Significant disadvantages of IPC are the duration of therapy (both the procedure and the course), the need to organise outpatient visits or self-care for device users at home. The principal advantage of IPC is its non-drug nature, which allows it to be freely combined with pharmacotherapy programmes, reducing the drug burden. Other advantages are the complexity of the effect and the comfort of the treatment. Although the procedures require special equipment, such equipment is already widespread in Ukraine and available to the public.

Conclusions

IPC can be used in secondary vascular manifestations of nervous diseases, disorders with increased excitability of the nervous system and in case of secondary damage to the nervous system due to ischaemia, intoxication, chronic inflammation or regulatory disorders. The introduction of IPCs into the complex therapy of patients with occupational neurological diseases can help reduce the duration of disability, prolong remission periods and reduce disability rates.

The possible effects of IPC on the state and functioning of the nervous system and mental health require wider and more systematic basic and clinical research. It should be taken into account that the benefits of IPC in some nervous diseases may be difficult to predict and not obvious. One of the tasks of clinical trials should be to formulate criteria for the optimal use of IPC equipment for the treatment of nervous diseases.

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ORCID ID of the author:
Zaitsev D. V. (ORCID ID 0000000208411504).

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Contact person: Dmytro Valeriiovych Zaitsev, Senior Lecturer, Occupational Health Department, Psychophysiology and Medical Ecology, Shupyk National Healthcare University of Ukraine, Dorohozhytska Str., 9, Kyiv, 04112.