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REVIEWS
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The venous system and exercise
Sistemul venos şi exerciţiul fizic

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Abstract
The veins form a collecting system for blood returning from the periphery to the heart. The veins have many special functions: transport, blood reservoir, circulatory homeostasis. The factors controlling venous return are the central heart pump, the pressure at the end of the capillaries, the right atrial pressure, the peripheral venous tone, the peripheral muscle pump of the leg, the respiratory pump, the gravity, the competent venous valves. Venous return from the lower extremity is achieved by expulsion of the blood by the lower extremity muscle pump and valve function that divides the hydrostatic column of blood into segments and prevents retrograde venous flow. During exercise, the central venous pressure may rise slightly due to this effect. Once exercise ends, venous pressure begins to rise once more. When the muscle pump is less active, as in a bedridden subject or during long periods of standing (orthostatic posture), blood tends to accumulate in the veins, causing an increase in the peripheral venous pressure and a fall in the central venous pressure, with a reduced venous return to the heart and diminished cardiac output. The muscular pump is a true pump that results from the mechanical action produced by rhythmical muscular contractions. In exercise, an efficient calf muscle pump may compensate for some degree of reflux and obstruction and prevent the chronic venous insufficiency.
Key words: venous system, chronic venous insufficiency, muscular pump, lower extremity, exercise.

Rezumat
Venele formează un sistem de colectare pentru sângele care se reîntoarce de la periferie spre inimă. Venele au multe funcţii speciale: de transport, rezervor de sânge, homeostazie a circulaţiei. Factorii care controlează reîntoarcerea venoasă sunt pompa centrală cardiacă, presiunea terminală capilară, presiunea atrială dreaptă, tonusul venos periferic, pompa musculară periferică a piciorului, pompa respiratorie, gravitatea, valvele venoase competente. Întoarcerea venoasă din extremitatea inferioară este realizată prin expulzarea de sânge de către pompa musculară din extremitatea inferioară şi funcţia valvulară, care împarte coloana hidrostatică de sânge în segmente şi previne fluxul venos retrograd. Exerciţiul fizic are ca şi efect creşterea presiunii în sistemul venos central. După terminarea exerciţiului fizic presiunea venoasă creşte din nou. Când pompa musculară este mai puţin activă (clinostatism sau ortostatism prelungit), sângele se acumulează în vene, cauzând creşterea presiunii venoase periferice şi scăderea presiunii în sistemul venos central, cu scăderea întoarcerii venoase şi scăderea debitului cardiac. În efort, o pompă musculară eficientă gambieră poate compensa pentru un anumit grad de reflux şi obstrucţie şi preveni insuficienţa venoasă cronică.
Cuvinte cheie: sistemul venos, insuficienţa venoasă cronică, pompa musculară, extremitatea inferioară, efort.

Introduction

The veins form a collecting system for blood returning from the periphery to the heart. The final destination of venous blood from the systemic circulation is the right atrium of the heart and that of venous blood from the pulmonary circuit is the left atrium.

Veins have three coats or tunics in their walls: tunica intima is the inner endothelial lining, in contact with the blood stream. One structure, which is present in veins, is that of venous valves, particularly in lower limbs. The valves allow unidirectional flow only towards the heart; the tunica media is a middle layer composed of smooth muscle and elastic fibres; the tunica adventitia is the outer layer, of fibrous collagenous tissue.

From the microcirculatory bed, the blood enters the venous system. Veins from the head and neck, the jugular veins, join on each side the subclavian veins from the upper limbs to form the brachiocefalic veins, which unite into the superior vena cava. This main vein from the upper half of

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the body is joined by the vena azygos and vena hemiazygos from the chest wall, and ends in the right atrium.

The inferior vena cava, which drains the lower half of the body (leg and pelvic veins) and ends in the right atrium, is formed by the junction of the two common iliac veins, is joined by gonadal, renal and hepatic veins, and ends in the right atrium.

The pulmonary veins drain the lungs and pass directly into the left atrium.

The veins have three properties: distensibility (extensibility), elasticity, contractility.

The veins provide low resistance conduits for afferent transport of the blood to the heart, having many special functions:

a) Transport: the primary function of the venous circulation is to return blood to the heart.

b) Blood reservoir: the veins perform a storage and reservoir function for the circulating blood volume. The bulk of the blood volume is contained in veins and venules, which thus represent the capacity vessels of the circulation.

c) Circulatory homeostasis: the compliance of the venous system plays a part in circulatory homeostasis. The capacity of the venous reservoir facilitates cardiovascular homeostasis through volume shifts.

Venous circulation

The factors controlling venous return are:

- the central heart pump (the inotropic state of the he art);
- the pressure at the end of the capillaries, right atrial pressure (pressure gradient);
- peripheral venous tone;
- the peripheral muscle pump of the leg;
- the respiratory pump;
- gravity;
- the competent venous valves (Rhodes & Tanner, 1995; Pocock & Richards, 1999; Guyton & Hall, 1996; Fox, 2011)

The total blood volume of a normal adult is about 5 liters. The bulk of the blood (about 3-3.5 liters) is found in the veins: 20% in large systemic veins, 42% in small veins and venules.

The veins thus act as a reservoir for blood and are called capacitance vessels.

Under normal conditions, the pressure is 1.6-2.4 kPa (12-18 mmHg) at the venous end of the capillary and falls steadily toward atrial pressures, up to 0.5-0.9 kPa (4-7 mmHg).

The average venous pressure in the heart is around 0.3 kPa (2 mmHg), 1.3 kPa (10 mmHg) in the venules and falls to around zero in the right atrium (Barrett et al., 2010).

Veins are capacitance vessels, which contain around two thirds of the total blood volume.

The effect of the skeletal muscle pump on veins

The muscular pump of the lower limb includes the pumps of the foot, calf and thigh. The calf muscle pump is the most important, has the largest capacitance and generates the highest pressure (26.6 kPa=200 mmHg) during muscular contraction (Burnand, 2001).

Alternate muscular contractions and relaxations are important for the blood flow. When muscle contracts, thick-walled veins are compressed and the blood flows toward the heart. Relaxation of the skeletal muscles moves the blood from the arterial system into the veins. This action of the muscles is known as the muscle pump. It assists the action of the main pump, the heart.

During contraction of the calf muscle pump (gastrocnemius and soleus muscles), blood is driven into the large capacity popliteal and femoral veins. The valves prevent retrograde flow during relaxation of the muscles, generating negative pressure and draining blood from the superficial to the deep venous system through perforating vessels. When exercise ceases, the veins slowly fill from the capillary bed, and blood returns to resting venous pressure.

The venous blood flow is facilitated during walking, when the muscle pump of the lower limbs is rhythmically activated. The muscle pump increases venous return and decreases venous volume.

The venous system and venous disease

Venous return from the lower extremity is achieved by expulsion of blood by the lower extremity muscle pumps and valves that divide the hydrostatic column of blood into segments and prevent retrograde venous flow (Goldman & Fronek, 1989).

Chronic venous insufficiency consists of manifestations of venous hypertension, defined as a failure to reduce venous pressure with exercise.

In normal conditions, the venous valves and the calf muscle pump limit the accumulation of blood in veins. Failure of the lower extremity muscle pump due to outflow obstruction, muscular weakness, loss of joint motion or valvular failure is associated with peripheral venous insufficiency (Araki et al., 1994).

In acute situations, stasis within these valved conduits and failure of peripheral muscle pumps to return blood against gravity are a factor in the formation of deep venous thrombosis.

Chronically, venous insufficiency may result from superficial or perforating deep venous obstruction or valvular incompetence (Meissner et al., 2007).

Valvular incompetence is associated with a rapid recovery time after muscular contraction. If the deep vein valves are incompetent, blood oscillates within the deep veins and there is no reduction in pressure. Deep venous obstruction is associated with little reduction in resting pressure, which is elevated during calf contraction. The result is venous hypertension, edema, pigmentation, fibrosis and ulceration in the skin.

Chronic venous insufficiency, mainly due to venous reflux or venous outflow obstruction, produces a microcirculatory overload.

Physical exercise and chronic venous disease

It is clear that muscle pump causes an increase in venous outflow, but there are other phenomena related to its function which remain controversial (Lurie, 2011). Locomotion in an upright position ensures the highest possible perfusion by a muscle pump, which became the basis for the theoretical model that explains exercise-induced muscle hyperaemia by the combination of vasodilation and an increased cardiac output caused by mobilization of peripheral blood volume (Laughlin, 1987). Some authors report that in patients with venous insufficiency, who should be lacking an optimally functioning muscle pump, the muscle pump effect in exercise hyperaemia seems to be reduced or lacking (Nådland et al., 2011a). The reflux in the great saphenous vein negatively impacts the contribution of muscle pump to exercise-induced hyperaemia, and surgical elimination of reflux reverses this impairment (Nådland et al., 2011b). Another author sustains that no decrease in arterial flow was actually observed in both the tilted and supine positions, regardless of the presence of reflux, and that arterial flow significantly increased during exercise. However, in the absence of reflux, this increase in arterial flow was higher in the tilted than in the supine position, but the difference was not statistically significant in the presence of reflux (Lurie, 2011). Other authors also sustain that the increase in arterial blood flow during muscle exercise does not correlate with changes in venous pressure, or venous outflow (Valic et al., 2005), partially due to a vascular waterfall effect (Naamani et al., 1995).

During exercise, an efficient calf muscle pump function may compensate for some degree of reflux and obstruction and prevent chronic venous insufficiency (Padberg et al., 2004). However, there are observations supporting that after a certain level, the decrease in venous pressure no longer affects arterial flow, also because the rapid filling of the deep veins after muscle contraction is predominantly from the superficial veins, even in the absence of reflux (Almen & Nylander, 1962). Therefore, the pressure-based model of muscle pump seems to be a major simplification. Simultaneous measurements of compartment and venous pressures in healthy volunteers demonstrated that dramatic increases in intracompartment pressures translated into a negligible change in venous pressures (Alimi et al., 1994).

The influence of physical exercise on venous circulation has been relatively little studied (Klyscz et al., 1995; Yang et al.,1999; Padberg et al., 2004; Eiffel et al., 2006; Kahn et al., 2008). The decrease in venous pressure during exercise represents the functional reserve of the venous system of the lower limbs and closely correlates with the clinical class of chronic venous insufficiency (Eklof et al., 2004; Eiffel et al., 2006). However, there are studies of patients with venous disease who showed a prolonged increase in deep vein pressure caused by exercise in 20% of the limbs; none of the limbs with an exercise-induced increase in deep venous pressure had great saphenous vein reflux, and all limbs with great saphenous vein reflux showed a decrease in deep venous pressure with exercise (Neglen & Raju, 2000). Superficial vein pressure does not reflect pressure changes in the deep system during exercise, and the great saphenous vein reflux does not necessarily affect venous pressure in deep veins (Lurie, 2011).

The musculoskeletal dysfunction of the leg is associated with poor function of the calf muscle pump. Poor calf muscle pump function in patients with chronic venous insufficiency can be improved by a physical exercise program: a 6 months daily walking program reduces acute symptoms; 6 months of exercise training prevent or improve the postthrombotic syndrome (Kahn et al., 2008); 6 months of physical therapy strengthen the calf musculature (Padberg et al., 2004).

Another therapeutical value of exercise consists in the fact that exercise is improving outcomes in venous leg ulcers, due to its capacity to promote venous return and reduce the risk of secondary conditions in this population (O'Brien et al., 2014). Despite motivation and interest in being exercise active, people with venous leg ulcers report many obstacles. Further exploration of mechanisms that assist this patient population and promote understanding about the management of barriers, coupled with the promotion of enabling factors, is vital for improving their exercise participation.

Conclusions

1. Deterioration of calf muscle pump function is associated with chronic venous insufficiency.
2. Calf muscle pump function in patients with chronic venous insufficiency can be improved by physical exercise.

Conflicts of interest

Nothing to declare.

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