



## ARTICLE INFO

Received  
January 13, 2018  
Accepted  
March 04, 2018  
Published  
April 25, 2018

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**Keywords**

Compression stockings  
Multiple treatment  
Pulmonary embolism  
Deep vein thrombosis  
Venous thromboembolism

**How to Cite**

Razi M, Gu JP. Application of Intermittent pneumatic compression devices and graduated compression stocking in venous thromboembolism. *Sci Lett* 2018; 6(1):13-17



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# Application of Intermittent Pneumatic Compression Devices and Graduated Compression Stockings in Venous Thromboembolism

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**Abstract**

Venous thromboembolism is a disease, which is the combination of deep vein thrombosis and pulmonary embolism. Multiple treatments and prophylactic modalities are available, ranging from pharmacology to mechanical options. Intermittent pneumatic compression devices (IPCD) and graduated compression stockings (GCS) come in the mechanical modalities category and are useful options in venous thromboembolism, especially in those patients at risk of bleeding by pharmacological therapies and also to augment the effect of pharmacological therapies in some scenarios. In this review, a clearer understanding of the working and effectiveness of the above two mentioned compression devices is gained after reviewing the available literature with appropriate guidelines and recommendations for their uses in different scenarios, which helps in supporting the theory that their use can be helpful in supplementing the treatment and prophylaxis of venous thromboembolism. IPCD and GCS clearly have a role to play in the prophylaxis of venous thromboembolism. Studies depict and give support to the idea that IPCD's are effective as an individual therapy and also in combination therapy with thrombolytics. GCS like IPCD have also been shown to be effective both individually and in combination therapy with pharmacological modalities. Going forward, more targeted studies are required for both GCS and IPCD working and benefits for gaining a clearer consensus which would help in better incorporation of these modalities in the management of venous thromboembolism.



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## Introduction

Venous thromboembolism is a name given to a group of disorders, which comprises of deep vein thrombosis and pulmonary embolism [1]. Deep vein thrombosis is defined a scenario of the establishment of a blood clot in the deep veins [2]. Though it mostly occurs in the deep veins of the distal limbs, it may also occur in other places as well as in the deep veins of the proximal limbs, the vena cava [2]. Venous thrombosis is explained by the Virchow's triad which postulated three factors for its formation and propagation, including irregular blood flow, blood coagulation disturbances and lastly the vessel wall abnormalities [1]. The symptoms of deep vein thrombosis, which are erythema, pain and edema, occur in the acute phase of deep vein thrombosis [3]. Pulmonary embolism occurs due to the migration of a piece of thrombus from the limb to the lungs, which mostly occur as a sequel to hospitalization post-surgery or trauma [4]. The chronic complication of deep vein thrombosis manifests as pain, swelling and ulcers which in combination are designated as a post-thrombotic syndrome (PTS) presenting in around half of the deep vein thrombosis patients within two years of the onset of deep vein thrombosis [5].

## Treatment options

The treatment modalities in use nowadays are targeted towards alleviating these complications like recurrent deep vein thrombosis, pulmonary embolism, post-thrombotic syndrome and eventually death [3]. Multiple treatment options are available for the treatment of deep vein thrombosis ranging from pharmacological and interventional therapies to compression therapies and mechanical thrombolytic, which are administered according to the needs and requirements of the patients [6]. A number of prophylactic options are also available for venous thromboembolism like the mechanical modalities [graduated compression stockings (GPS) and intermittent pneumatic compression devices (IPCD)]; pharmacological options like low molecular weight heparin and warfarin, these modalities have been proven to be more effective when used in combination [7].

## Mechanical prophylaxis methods

The implementation of GCS and IPCD is recommended during the state in which the patients are immobile until they regain mobility and should be avoided in ischemic limbs [8]. These devices

help in reducing pain, skin oedema and require minimal laboratory examinations [8]. The suggestions and protocols for the use of mechanical devices like GCS and IPCD for the prevention of venous thromboembolism are varied and unclear, thus making their implementation a norm is difficult [9]. There is a clear difference in the incorporation of GCS and IPCD from organization to organization and even though a high level of evidence exists but not much endorsement is given to these options [10]. An established protocol is to be devised based on the multiple current clinical practices whose benefits are reinforced by the evidence and proficiency. The protocol needs to take into account the mechanical methods of thromboprophylaxis along with the pharmacological methods of using anticoagulants, both in tandem with anticoagulation and in those patients with contraindication to anticoagulants [11-13].

### Graduated compression stockings (GCS)

The graduated compression stockings exert the desired anti thromboembolic effect on the lower limb veins by applying compression in a graded style on the regional veins [1]. They exert the desired effect by helping to counter the processes involved in pathogenesis of venous thromboembolism which are 1) decreasing the venous stasis by compressing the veins of the lower limbs to decrease the diameter of the veins, and speeds up the blood flow; 2) proximal compression of the ankle thereby increasing the blood flow; 3) decreasing the venous pooling by boosting the calf muscle pump effect which also increases the venous valve performance and 4) alterations in the effects of some of the clotting factors [14]. The stockings are either thigh length or knee length [15]. A detailed meta-analysis comparing which type has the better efficacy in prevention of deep vein thrombosis in post-operative surgical patient was carried out by Wade et al. [15] which depicted that though the final statistics were not that conclusive, there is a clear sign that thigh-length stockings are better than the knee length stockings and that the thigh-length stockings, when combined with the pharmacological drugs, provided a better outcome than individually. As per the directions of the European Society of Anaesthesiology for prophylaxis of venous thromboembolism in perioperative patients by Arash et al. [9], they recommend the independent use of GCS with no pharmacological interventions for preventing venous thromboembolism in patients at intermediate and high risk (Grade 1B), and also in patients with

contraindications to pharmacological therapies (Grade 1B). Another review by Sachdeva et al. [16] which focuses on the use of GCS for prevention of deep vein thrombosis in the Cochrane database of systemic reviews shows a strong evidence in supporting the theory of using GCS, especially in general and orthopaedic surgery whereas their effectiveness is not clear in medical patients. Combination therapy with pharmacological drugs and GCS has yielded better outcomes [7]. A study conducted to find the venous thromboembolism situation in Germany states that patients in hospital settings had been advised to use compression stockings for prophylaxis routinely next only to the administration of heparin [17].

Compression stockings are also useful in preventing post-thrombotic syndrome by reducing the pressure and preventing reflux in the lower limb veins [18]. They also help in diminishing leg symptoms and the risk of post-thrombotic syndrome following acute deep vein thrombosis [18]. A trial of GCS is applicable to those with acute deep vein thrombosis in the proximal part of the lower limb for inhibiting post-thrombotic syndrome [19]. They are also used in the treatment of post-thrombotic syndrome by diminishing their symptoms as the GCS presents a viable option owing to low risk [20]. A GCS of 20-30 mm Hg pressure can be used either knee length or above the knee length. [20]. The knee-length GCS is associated with better compliance and the pressure may be increased to 30-40 mm Hg or even 40-50 mm Hg in severe cases or if the patient remains symptomatic [20]. As per Scottish Intercollegiate Guidelines Network (SIGN) of 2010, using below knee GCS, providing 40 mm Hg compression pressure at the ankle, on the affected lower limb for 2 years' post deep vein thrombosis in order to prevent the occurrence of the post-thrombotic syndrome was recommended [21]. The Korean guidelines also suggest using GCS in patients with lower limb deep vein thrombosis for the reduction in incidences of post-thrombotic syndrome (Class IIa, Level A) [3]. The main reason for noncompliance with GCS is that the patient experience in using the GCS is not great [22]. It is associated with undesired side effects like discomfort, pressure necrosis, rolling down and creating a constrictive band [23]. Abnormal arterial flow can exacerbate ischemia in patients using GCS [24]. Skin discoloration, blistering, contact dermatitis can also occur in patients using GCS owing to an allergy with the material of GCS [24].

Individualized designing of the therapy with GCS may lead to increased compliance [25].

### **Intermittent pneumatic compression devices (IPCD)**

The IPCD's work by directing a sequential compression on the lower limbs which in turn helps in increasing the venous flow. This phenomenon helps in decreasing the venous pressure in the lower limb by increasing the venous emptying, which results in an increasing arteriovenous pressure gradient and arterial flow [7]. These devices also increase the shear and strain forces on the endothelial cells, which help in enhancing the profibrinolytic, antithrombotic and vasodilatory effects, including the release of tissue plasminogen activator (tPA) [26]. Several venographic studies have shown substantial evidence to prove the efficacy of IPCD over the past 25 years [27].

Single chamber, multiple chamber, foot only, thigh-length, calf-length, and foot and calf are some of the types of IPCD's which supply air to legs and/or foot chambers that are intermittently inflated with air to a 35 to 55 mm Hg pressure in a uniform or progressive manner (10s to 35s) [28]. This process ensues with a deflationary period of 1 minute, which allows the leg or foot to fill up with blood again [28]. The majority of studies in surgical patients indicate that IPCD reduces the risk of postoperative deep vein thrombosis [29, 30]. The CLOTS (Clots in legs or stockings after stroke) 3 trial states that IPCD look a feasible option in preventing deep vein thrombosis in immobile patients with stroke [31]. Due to this reason, IPCD's are considered an alternative option to pharmacological method for thromboprophylaxis, especially in surgical patients [12, 13]. The Caprini scoring system devised in the United States divides the patient groups into low, moderate, higher and highest risk groups. It recommends using pharmacological thromboprophylaxis with or without IPCD in higher risk group patients and pharmacological thromboprophylaxis along with IPCD in the high-risk group patients [32]. The American College of Chest Physicians (ACCP) also postulates using pharmacological thromboprophylaxis (Grade 2B) or mechanical thromboprophylaxis, preferably IPC, (Grade 2C) for moderate risk patients. They also recommend using pharmacological and mechanical thromboprophylaxis collectively in high-risk surgical patients (Grade 2C recommendation for the addition of mechanical thromboprophylaxis) [33].

Using IPCD for prophylaxis in patients undertaking surgery and having a contraindication to heparin is also suggested by the American College of Physicians, but not endorsed as a standalone option [34]. A trial of combining fondaparinux with IPCD showed better outcomes in decreasing the occurrence of venous thromboembolism in patients having abdominal surgery when compared to IPCD alone [35]. One more study conducted by Wan et al. [36] concluded that the combination of IPCD with low molecular weight heparin (LMWH) produced better outcomes in the prophylaxis of deep vein thrombosis and pulmonary embolism. The IPCD's can also be an inconvenience for patients to use as they are needed to sit in one place for a prolonged period of time apart from being expensive [19]. But even after that the IPCD's are reasonable to use in immobile patients who have severe post-thrombotic syndrome and oedema in whom the interventional therapies are not feasible [19].

## Conclusions

The graduated compression stockings (GPS) and intermittent pneumatic compression devices (IPCD) are useful options for prophylaxis of venous thromboembolism but are underused at this moment of time. The studies that have been done so far do shed light on their efficacy in preventing venous thromboembolism. The IPCD's have been shown to be more effective than GCS and the combination therapy of mechanical thromboprophylaxis with pharmacological drugs have yielded better outcomes. The guidelines do exist recommending their use but differ from each other. Incorporating these devices in daily hospital scenario needs work too, and their usage differs from hospital to hospital. Though the results of present studies show significant evidence of their efficacy, further studies should be conducted to obtain a clearer insight into their prophylactic efficiency and a model needs to be formulated to ensure their implementation.

## Conflict of Interest

The authors have no conflict of interest.

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