Meta-analysis of Effectiveness of Intermittent Pneumatic Compression Devices with a Comparison of Thigh-high to Knee-high Sleeves

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This meta-analysis used all original articles from 1966 to June 1996 that fit the preset inclusion criteria to examine the clinical effectiveness of intermittent pneumatic compression (IPC) devices in preventing deep vein thrombosis (DVT) and pulmonary embolism and to compare the results of knee-high sleeves to thigh-high sleeves. IPC devices decreased the relative risk of DVT by 62 per cent when compared with placebo, 47 per cent compared with graduated compression stockings, and 48 per cent compared with mini-dose heparin. IPC devices significantly decreased the relative risk of DVT compared with placebo in high-risk patients such as neurosurgery and major orthopedic surgery patients and in modest risk patients such as general surgery patients. In major orthopedic surgery patients, the incidence of DVT was similar for IPC- and warfarin-treated patients; however, IPC was significantly better than warfarin at decreasing the incidence of calf only DVT, whereas warfarin seemed to be better at decreasing proximal DVT. IPC devices are effective in decreasing the incidence of DVT in patients at moderate to high risk and are probably more efficacious than graduated compression stockings or mini-dose heparin; however, IPC devices are not protective against pulmonary embolism. The data directly comparing the various methods of compression (knee-high *versus* thigh-high sleeves and graded-sequential *versus* uniform compression) are sparse and conflicting.

VENOUS THROMBOEMBOLISM IS a major cause of death and morbidity among hospitalized patients. It is estimated that pulmonary embolism (PE) causes death in over 100,000 patients each year in the United States and contributes to the death of another 100,000 patients. Also, it has been estimated that there are approximately 260,000 clinically recognized cases of venous embolism occurring each year in acute care hospitalized patients in the United States. PE is most often the result of deep vein thrombosis (DVT) of the legs. Many cases of PE and DVT are subclinical and are never diagnosed, making the true incidence much higher than what is clinically recognized. Some authors have concluded that fatal PE may be the most common preventable cause of hospital deaths.[1]

Many different methods for venous thromboembolism prophylaxis have been used. A task force was formed by the Department of Surgery at St. Elizabeth Health Center in 1989 to review the medical literature and make recommendations regarding the indications for venous thromboembolism prophylaxis and the most effective prophylactic treatments. The findings of this task force were subsequently published.[2] The task force recommended that one of the prophylactic treatments that should be available was the Kendall's Sequential Compression Device (SCD). This pneumatic compression device consists of leg sleeves which extend from just above the ankles to the upper thigh. There are multiple compartments in the cuff that are sequentially inflated from the ankle to the upper thigh with decreasing gradations of pressure, "milking" the veins in the leg from distal to proximal.

The hospital bought the SCD pumps and stocked the thigh-high and knee-high sleeves, which were disposable and a direct patient charge item. However, in March 1994, in an attempt to minimize hospital costs, the SCDs were compared with the Flowtron Pneumatic Compression Devices (PCDs). The main difference was that the PCD compartments were uniformly inflated to the same pressure rather than in a graded-sequential fashion. An updated review of the literature did not reveal convincing evidence that the SCD was more effective than the PCD with the thigh-high sleeves. Also, nurses and patients seemed to prefer the PCD over the SCD in a limited hospital trial. So the hospital made the conversion to the PCD.

In 1996, in another effort to reduce hospital costs,

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the idea of converting from the thigh-high to the exclusive use of knee-high sleeves was suggested. Over the previous year, 3160 pairs of thigh-high sleeves had been used compared with only 490 knee-high sleeves. The knee-high sleeves cost about $11 less than the thigh-high sleeves, so this conversion would result in about a $35,000 annual cost savings to the hospital. This review of the medical literature and meta-analysis was performed to examine the clinical effectiveness of intermittent pneumatic compression (IPC) devices, in general, and to specifically compare the effectiveness of knee-high sleeves [calf compression alone with either uniform compression (IPC-C) or graded-sequential compression (IPC-CS)], with that of thigh-high sleeves [calf and thigh compression with either uniform compression (IPC-T) or graded-sequential compression (IPC-TS)].

Methods

A MEDLINE computerized search was conducted for all clinical studies on IPC devices published in the English medical literature between 1966 and June 1996. Also, the bibliographies of all papers obtained as a result of the MEDLINE search were reviewed for other pertinent articles. Also, published articles or manuscripts presented at national society meetings submitted by product company representatives were also reviewed. The following data were abstracted from each article and tabulated: author, year, journal, citation, study groups included, number and type of patients involved, methods used for surveillance and diagnosis of DVT and/or PE, and the results of the study. When possible, DVT was recorded as involving the proximal veins or the calf veins only.

A meta-analysis was performed by combining the data of comparable studies for IPC-C and IPC-T alone and combined. Criteria for inclusion in the meta-analysis was: 1) study must be a prospective randomized controlled trial; 2) study must use routine surveillance for DVT with either nuclear venography, impedence plethysmography, venous duplex and/or doppler ultrasonography, intravenous contrast venograms, or a combination of these; and 3) treatment and control groups of combined studies must use the same prophylactic methods. Data on the incidence of PE was included in the meta-analysis when available, even though most studies performed no routine surveillance for PE. Results of those articles directly comparing knee-high sleeves (IPC-C or IPC-CS) with thigh-high sleeves (IPC-T or IPC-TS) were compared in an attempt to determine whether one type of sleeve is more effective than another in preventing DVT or PE.

Chi square was used to analyze categorical data. Test statistics were considered significant if the probability of a chance finding was less than five per cent.

Results

The first article on IPC devices was published in 1971[3] and all of the early articles used knee-high sleeves with uniform calf compression alone (IPC-C). The first published article on thigh-high sleeves was in 1980,[4] and the majority of articles since 1987 have focused on thigh-high sleeves with graded-sequential compression.

Of the 57 studies used in the meta-analysis, 30 studies[3,5-33] involved knee-high sleeves (2 used IPC-CS, 27 used IPC-C, and 1 used both); 21 studies[4,34-53] involved thigh-high sleeves (all used IPC-TS); and 6 studies[19,54-58] compared knee-high sleeves (IPC-C or IPC-CS) with thigh-high sleeves (IPC-T or IPC-TS). One study[59] was excluded because it was a duplicate report of the same data from another article,[4] and another study using an IPC device on the arms only with knee-high sleeves was also excluded.[60]

More recently, an IPC device with compression only of the planter venous plexus on the sole of the feet (IPC-F) has been commercially available. But, only two studies on its efficacy have been published and both involved hip or knee replacement patients. One study[61] showed a decreased incidence of DVT with IPC-F compared with aspirin therapy (25% *versus* 59%; $P < 0.001$), whereas the other study[62] showed that IPC-F was better than mini-dose heparin (hep) plus aspirin therapy (0% *versus* 20%; $P = 0.05$). However, more studies are needed with larger numbers of patients and with comparison with prophylactic methods, which have been found to be more efficacious including other IPC devices. The results of these studies were not included in the meta-analysis.

Meta-analysis demonstrated that IPC was more effective than placebo, graduated compression stockings (GCS), or mini-dose hep in preventing DVT (Table 1). However, IPC did not seem to be protective against PE (Table 1), although the incidence of PE was small and only two studies[48,50] performed routine ventilation-perfusion scans for surveillance of PE. IPC devices were significantly and equally protective against proximal DVT and calf only DVT compared with placebo (Table 2). IPC devices reduced the relative risk of proximal DVT and calf only DVT compared with both GCS and hep, but because of the small numbers, the difference was not statistically significant (Table 2).

IPC devices significantly decreased the incidence of DVT compared with placebo in general surgery, neurosurgery, and major orthopedic surgery patients (Table 3). It also decreased the incidence of DVT in gynecological cancer surgery patients, but this difference was not statistically significant. Again, there was no protection against PE in any of these groups, although there may have been a trend in the major

TABLE 1. *Meta-analysis for Prospective Randomized Controlled Trials of Effectiveness of IPC in DVT and PE Prophylaxis in all Patient Types*

Analysis	Total DVT	Reduction of RR	*P*	PE	Reduction of RR	*P*
IPC *versus* placebo						
IPC-C *versus* placebo*	83/863 (9%) 232/863 (27%)	64%	<0.001	8/298 (2.7%) 5/279 (1.8%)	−50%	0.47
IPC-T *versus* placebo†	38/240 (16%) 96/267 (36%)	56%	<0.001	2/215 (0.9%) 6/222 (2.7%)	66%	0.29
All IPC *versus* placebo	121/1103 (11%) 328/1130 (29%)	62%	<0.001	10/513 (1.9%) 11/501 (2.2%)	11%	0.82
IPC *versus* GCS						
IPC-C *versus* GCS‡	9/99 (9%) 17/114 (15%)	39%	0.16	2/99 (2.0%) 1/114 (0.9%)	−130%	0.60
IPC-T *versus* GCS§	4/62 (6%) 10/64 (16%)	59%	0.10	2/62 (3.2%) 2/64 (3.1%)	−3%	1.00
All IPC *versus* GCS	13/161 (8%) 27/178 (15%)	47%	0.04	4/161 (2.5%) 3/178 (1.7%)	−47%	0.71
IPC *versus* hep						
IPC-C *versus* hep¶	16/204 (8%) 37/218 (17%)	54%	<0.01	4/204 (2.0%) 3/218 (1.4%)	−42%	0.72
IPC-T *versus* hep	3/50 (6%) 3/58 (5%)	−16%	1.00	0/25 (0.0%) 1/20 (5.0%)	100%	0.44
All IPC *versus* hep‖	19/254 (7%) 40/276 (14%)	48%	0.01	4/229 (1.7%) 4/238 (1.7%)	−4%	1.00

RR, relative risk.
* Refs. 5, 7, 12, 13, 15–19, 21–23, and 27–29.
† Refs. 4, 33, 41, and 51.
‡ Refs. 23 and 26.
§ Refs. 34 and 43.
¶ Refs. 16, 23, 24, and 26.
‖ Refs. 36 and 51.

orthopedic surgery patients (Table 3). The only studies comparing IPC to warfarin were performed in major orthopedic patients (mostly hip and knee replacements and hip fractures). IPC compared with warfarin reduced the relative risk of DVT by 28 per cent, but this difference was not statistically significant (Table 3). In neurosurgery and major orthopedic surgery patients, IPC significantly decreased the incidence of both proximal DVT and calf only DVT, but there were not enough general surgery or gynecological cancer surgery patients to make a valid comparison (Table 4). IPC devices were significantly better than warfarin in preventing calf only DVT (Table 4). However, warfarin had a lower, although not statistically significant, incidence of proximal DVT compared with IPC (Table 4).

When studies of IPC devices using knee-high sleeves (13 used IPC-C and 2 used IPC-CS) were compared with those using thigh-high sleeves (all 4 used IPC-TS), the knee-high sleeves had a slightly greater reduction in relative risk of DVT (64% *versus* 56%). However, the placebo group in the studies with thigh-high sleeves had a significantly higher incidence of DVT (36% *versus* 27%), so the patients in these two groups of studies may not be comparable.

Only six studies[19, 54–58] have directly compared knee-high (all used IPC-C) with thigh-high IPC sleeves (all used IPC-TS except for one used IPC-T[19]). Three of these studies reported data on changes in femoral vein blood velocity (FVBV), two studies reported data on venogram contrast clearance time, one study reported data on changes in systemic fibrinolysis, and only two studies reported data on incidence of DVT.

Of the three studies reporting data on changes in FVBV,[54, 56, 58] two studies showed no statistically significant difference and one study revealed an advantage for knee-high sleeves (FVBV augmented by 107% for IPC-C *versus* 77% for IPC-TS; $P < 0.01$). Of the two studies[54, 55] that reported data on venogram contrast clearance times, the decreased clearance times in calf and popliteal veins compared with control were similar for both IPC-TS and IPC-C. IPC-TS did seem to have a greater effect on decreasing clearance time in femoral veins but the statistical significance of this difference was not reported on one of the studies[54] and there seemed to be methodological problems with the other study.[55]

The one study,[19] which examined changes in systemic fibrinolysis, involved multiple phases but revealed that IPC sleeves applied to the arms, lower leg, or entire leg all decreased euglobulin clot lysis time, indicating an increase in systemic fibrinolysis. The results also suggested that IPC-T had a greater effect

TABLE 2. *Metanalysis for Prospective Randomized Controlled Trials of Effectiveness of IPC in Proximal and Calf DVT Prophylaxis in all Patient Types*

Analysis	Proximal DVT	Reduction of RR	*P*	Calf Only DVT	Reduction of RR	*P*
IPC *versus* placebo						
IPC-C *versus* placebo*	26/536 (5%) 59/530 (11%)	56%	<0.001	34/536 (6%) 82/530 (15%)	59%	<0.001
IPC-T *versus* placebo†	23/215 (11%) 54/222 (24%)	56%	<0.001	15/215 (7%) 42/222 (19%)	63%	<0.001
All IPC *versus* placebo	49/751 (7%) 113/752 (15%)	57%	<0.001	49/751 (7%) 124/752 (16%)	60%	<0.001
IPC *versus* GCS						
IPC-C vs GCS‡	6/79 (8%) 8/91 (9%)	14%	0.78	3/79 (4%) 6/91 (7%)	42%	0.51
IPC-T *versus* GCS§	0/38 (0%) 1/39 (3%)	100%	1.00	1/38 (3%) 4/39 (10%)	74%	0.36
All IPC *versus* GCS	6/117 (5%) 9/130 (7%)	26%	0.56	4/117 (3%) 10/130 (8%)	56%	0.15
IPC *versus* hep						
IPC-C *versus* hep‡	6/79 (8%) 15/86 (17%)	56%	0.06	3/79 (4%) 8/86 (9%)	59%	0.16
IPC-T *versus* hep	—	—	—	—	—	—
All IPC *versus* hep	6/79 (6%) 15/86 (17%)	57%	0.06	3/79 (4%) 8/86 (9%)	59%	0.16

RR, relative risk.
* Refs. 13, 17, 18, 21, 23, and 27–29.
† Refs. 4, 33, and 41.
‡ Ref. 23.
§ Ref. 34.

TABLE 3. *Metanalysis for Prospective Randomized Controlled Trials of Effectiveness of IPC in DVT and PE Prophylaxis by Patient Groups*

Analysis	Total DVT	Reduction of RR	*P*	PE	Reduction of RR	*P*
General surgery						
All IPC *versus* placebo*	13/157 (8%) 27/172 (16%)	47%	0.04	1/62 (1.6%) 1/57 (1.7%)	8%	1.00
Gynecological cancer surgery						
All IPC *versus* placebo†	19/152 (13%) 28/149 (19%)	33%	0.13	6/152 (3.9%) 2/149 (1.3%)	−194%	0.28
Neurosurgery						
All IPC *versus* placebo‡	53/436 (12%) 142/433 (33%)	63%	<0.001	1/175 (0.6%) 2/178 (1.1%)	49%	1.00
Major orthopedic surgery						
All IPC *versus* placebo§	19/138 (14%) 63/140 (45%)	69%	<0.001	1/95 (1.1%) 5/93 (5.4%)	80%	0.12
All IPC *versus* warfarin¶	26/164 (16%) 37/169 (22%)	28%	0.16	0/180 (0.0%) 0/196 (0.0%)	N/A	N/A

RR, relative risk; N/A, not applicable.
* Refs. 5, 21, and 51.
† Refs. 28 and 29.
‡ Refs. 12, 13, 15, 18, 22, and 41.
§ Refs. 4, 17, 27, and 33.
¶ Refs. 39, 42, and 45 (all IPC-TS devices).

on systemic fibrinolysis than IPC-C; however, this study also had serious methodological problems.

Of the two studies[54,57] comparing knee-high to thigh-high sleeves that reported incidence of DVT, one showed a slight advantage to thigh-high sleeves[54] whereas the other showed no significant difference.[57] The first study[54] randomized abdominal surgery patients to one of three treatment groups—IPC-TS (83 patients), IPC-C (83 patients), or hep (85 patients). The incidence of proximal DVT was lower for IPC-TS compared with IPC-C (2.4% *versus* 7.2%; $P < 0.05$). There were no significant differences in incidence of calf only DVT between IPC-TS and IPC-C (14.5% IPC-TS *versus* 10.2% IPC-C; $P = 0.48$). However,

TABLE 4. *Metanalysis for Prospective Randomized Controlled Trials of Effectiveness of IPC in Proximal and Calf DVT Prophylaxis by Patient Groups*

Analysis	Proximal DVT	Reduction of RR	*P*	Calf Only DVT	Reduction of RR	*P*
General surgery						
All IPC *versus* placebo*	1/62 (2%) 0/57 (0%)	N/A	1.00	5/62 (8%) 4/57 (7%)	−14%	1.00
Gynecological cancer surgery						
All IPC *versus* placebo†	6/152 (4%) 5/149 (3%)	−18%	0.78	13/152 (9%) 23/149 (15%)	45%	0.07
Neurosurgery						
All IPC *versus* placebo‡	25/320 (8%) 53/317 (17%)	53%	<0.001	20/320 (6%) 56/317 (18%)	65%	<0.001
Major orthopedic surgery						
All IPC *versus* placebo§	11/138 (8%) 31/140 (22%)	64%	<0.001	8/138 (6%) 32/140 (23%)	75%	<0.001
All IPC *versus* warfarin¶	20/164 (12%) 11/169 (7%)	−87%	0.07	6/164 (4%) 26/169 (15%)	76%	<0.001

RR, relative risk.
* Ref. 21.
† Refs. 28 and 29.
‡ Refs. 13, 18, 22, and 41.
§ Refs. 4, 17, 27, and 33.
¶ Refs. 39, 42, and 45 (all IPC-TS devices).

hep had the lowest incidence of proximal or calf only DVT of all three treatment groups (proximal DVT 0.6% and calf only DVT 2.4%; $P < 0.01$ for both analysis), which is inconsistent with other studies comparing IPC devices to hep.

Maybe this is because the IPC devices were only used intraoperatively and for 16 to 24 hours postoperatively, whereas hep was given preoperatively and for 7 days postoperatively. All cases of proximal DVT were detected between the 3rd and 6th postoperative day (2–5 days after the IPC devices were discontinued). The authors concluded that the thigh-high sleeves with graded-sequential compression is more effective then knee-high sleeves with uniform compression of the calf only but admitted that the IPC devices may be more effective if used for a longer period of time postoperatively. However, this is one small study with methodological problems as outlined above and it has not be corroborated by any subsequent studies.

The other study[57] comparing knee-high to thigh-high sleeves in regard to the incidence of DVT was presented at the annual meeting of the American Thoracic Society (Boston, MA; May 1994), but it has not yet been published. It was a prospective, randomized, clinical trial involving major trauma patients (closed head or spinal cord injury; pelvic or lower extremity fractures; or penetrating abdominal or thoracic injuries) who would be anticipated to require confinement in bed for at least 72 hours. The patients were randomized to receive either IPC-TS or IPC-C. The patients had IPC and Duplex ultrasonography of both legs three times the 1st week, twice a week for the next 2 weeks, then once the 4th week. The study was terminated at 4 weeks or when the patients were ambulatory or out of bed for over 2 hours/day.

Fifty-one patients were randomized to each treatment arm of this study, and there was no significant difference in the incidence of DVT (2.0% IPC-TS *versus* 3.9% IPC-C; $P = 1.00$). At the discretion of the treating physician, 12 patients (8 IPC-TS and 4 IPC-C) considered to be at "high-risk" for DVT were also given hep (5000–7500 units subcutaneously every 12 hours). The authors concluded that IPC was effective in decreasing the incidence of DVT compared with the historical incidence of DVT of 40 to 65 per cent in this patient population and that there was not a significant difference between IPC-TS and IPC-C. This study is also small and has methodological problems in that a greater proportion of the IPC-TS patients were perceived to be at high risk for DVT and received concomitant hep therapy.

Another problem with the comparison of knee-high to thigh-high sleeves is that 92 per cent (33 of 36) of the studies reviewed using knee-high sleeves used uniform compression, whereas 96 per cent (26 of 27) of the studies reviewed using thigh-high sleeves used graded-sequential compression. No study compared uniform compression with graded-sequential compression for thigh-high sleeves (IPC-T *versus* IPC-TS) and only one study[32] compared uniform compression with graded-sequential compression for knee-high sleeves (IPC-C *versus* IPC-CS). This study showed there was no difference in incidence of DVT between the uniform and graded-sequential compression groups (7% IPC-CS *versus* 7% IPC-C).

Discussion

Comparison of studies on venous thromboembolism prophylaxis is difficult for several reasons: 1) the studies vary in their method of diagnosing venous thromboembolism; 2) there is marked variability in the types of patients studied; and 3) the numbers of patients in these studies are often small, making it difficult to perform any reliable statistical analysis on their results. However, meta-analysis from a review of the literature clearly reveals that IPC devices are effective in reducing the incidence of DVT. Unfortunately, IPC devices do not seem to significantly decrease the incidence of PE, although it might take a much larger number of patients than could be obtained in the present meta-analysis study to demonstrate a positive effect.

IPC devices have local effects (decrease venous stasis by increasing venous blood flow) and systemic effects (increasing systemic fibrinolysis). During general or spinal anesthesia and in patients with paralysis of the lower extremities or prolonged bedrest, the normal "pumping mechanism" of the calf muscles is lost or impaired, leading to venous stasis. Numerous studies have shown that IPC increases venous blood flow as evidenced by increased mean and peak FVBV[37, 54, 56, 58] and by decreased time to clear venogram contrast.[54, 55]

Two early studies[3, 8] applied IPC-C to only one leg in a group of mixed surgical patients and compared the incidence of DVT between the two legs of the patient, making each patient their own control. In the 75 patients included in these two studies, the IPC-C leg had a three per cent incidence of DVT, whereas the control leg had a 24 per cent incidence of DVT. So, both of these studies concluded that IPC-C on one leg was not protective of DVT on the other leg.

However, a similar subsequent study[19] also included a control group with no prophylaxis. Of the 18 patients in the treatment group, there were no DVTs in either the IPC-C leg or non-IPC-C leg compared with DVT in 3 of 19 (16%) control patients. So, this study concluded that IPC on one leg is protective of DVT in the other leg, suggesting a systemic effect from the IPC device. This was supported by a 1976 article[60] that found application of IPC devices with knee-high sleeves to the arms of surgical patients decreased the incidence of DVT in the legs compared with controls without any prophylaxis (14% *versus* 32%; $P < 0.05$).

Usually, surgery results in a decrease in fibrinolysis postoperatively, which places patients at risk of venous thromboembolism. However, several studies[6, 19, 32, 60] have demonstrated that venous compression secondary to IPC results in release of substances that increased fibrinolysis in normal individuals and prevents decreased fibrinolysis in postoperative patients, which may account for the systemic effects seen with IPC devices.

Based on the present meta-analysis, IPC devices decreased the relative risk of DVT by 62 per cent when compared with placebo, 47 per cent compared with GCS, and 48 per cent compared with hep (Table 1). One study[39] of general surgery patients applied IPC-TS to both legs and GCS randomly on only one leg. The IPC-C+GCS leg had a significantly lower incidence of DVT than the IPC-C alone leg (1% *versus* 9%; $P < 0.05$) so the authors recommended simultaneous use of IPC and GCS. Another study[9] randomized surgical patients to IPC-C or IPC-C+hep and found that adding hep did not seem to improve effectiveness (18% *versus* 26%; $P = 0.38$). However, the IPC-C devices were applied only while the patient was in the operating room, whereas the hep was given for 7 days.

The present meta-analysis also showed that IPC devices significantly decreased the relative risk of DVT by 63 to 69 per cent compared with placebo in high-risk patients, such as neurosurgery and major orthopedic surgery patients, and by 47 per cent in modest-risk patients, such as general surgery patients (Table 3). In major orthopedic surgery patients, the incidence of DVT was similar for IPC- and warfarin-treated patients; however, IPC was significantly better than warfarin at decreasing the incidence of calf only DVT whereas warfarin seemed to be better at decreasing proximal DVT (Table 4).

The effectiveness of IPC devices in prevention of venous thromboembolism can be effected by improper application or usage and by the duration of usage of IPC devices. Three studies[35, 38, 50] reported that 5 to 10 per cent of eligible patients were excluded from their study groups (all IPC-TS devices) because the patient could not be fitted for IPC devices or refused to continue to wear the sleeves. This may have biased their results because the proper way to analyze the data would have been by intent-to-treat. Another study[27] reported that 35 per cent of their IPC-C patients either were not started on IPC-C devices until postoperatively, took off the IPC-C devices in <72 hours postoperatively, or both. This group had a 40 per cent incidence of DVT compared with 32 per cent in those patients who complied with the IPC-C protocol and 53 per cent in the placebo group.

One study[20] involving open urological surgery patients compared short-term (intraoperatively and in recovery area) with long-term (intraoperatively and postoperatively until ambulatory) use of IPC-C devices and found no significant difference in incidence of DVT (6% short-term *versus* 10% long-term; $P = 0.46$). Reanalyzing the present meta-analysis of IPC

versus placebo according to those studies that started IPC intraoperatively with those that started postoperatively likewise showed no significant difference in reduction of relative risk of DVT (61% intraoperatively *versus* 64% postoperatively).

Another study[37] examined the effects of increasing the maximum compression limit of IPC-TS from 35 mm Hg to 65 mm Hg to 90 mm Hg in patients undergoing abdominal, vascular, or thoracic surgery. There was an increase in the augmentation of mean FVBV compared with baseline precompression with increasing maximum compression limit (175% for 35 mm Hg, 304% for 65 mm Hg, and 366% for 90 mm Hg). The high-pressure group (90 mm Hg) had a lower incidence of DVT (4% *versus* 12%) compared with the low-pressure group (35 mm Hg), but because of the small number of patients in the study, this difference was not statistically significant ($P = 0.61$).

Another meta-analysis on venous thromboembolism prophylaxis was published in 1992 by Clagett et al.[1] comparing control patients with patients treated with various methods for prophylaxis. The paper analyzed patient groups separately, *i.e.*, general surgery patients, hip fracture patients, elective hip replacement patients, elective neurosurgical patients, acute spinal cord injury patients, multiple trauma patients, and myocardial infarction/ischemic stroke patients.

For many of these groups, there were few if any adequate studies to compare methods of venous thromboembolism prophylaxis. There were a significant number of IPC studies in the areas of general surgery, elective hip replacement, and neurosurgical patients with a reduction in the relative risk of DVT of 61 per cent, 60 per cent, and 73 per cent, respectively. No distinction was made in that meta-analysis between the types of IPC devices. However, on reviewing the 14 IPC articles cited, 9 used IPC-C, 2 used IPC-CS, 2 used IPC-TS, and 1 used IPC-TS+GCS.

Also in the 1992 metaanalysis, IPC devices compared favorably with the other prophylactic methods and was equivalent or better than mini-dose unfractionated hep. Low molecular weight (LMW) hep had a greater reduction of relative risk than IPC (all IPC-C) or mini-dose unfractionated hep in the general surgery patients (86% *versus* 61% *versus* 68%, respectively). However, each of the treatment groups were compared with historical control groups, which may or may not have been generated from that individual treatment group's studies, and none of the LMW hep studies cited had untreated control groups. So, it is possible that the LMW hep patients may have been at lower risk for DVT than patients in some of the other treatment groups.

In elective hip replacement patients, the relative risk for DVT was reduced by 77 per cent for adjusted dose hep, 68 per cent for LMW hep, 63 per cent for warfarin, and 60 per cent for IPC (two IPC-TS studies and one IPC-C study). In neurosurgery patients, the relative risk for DVT was reduced by 75 per cent by low-dose hep, 73 per cent by IPC (three IPC-C studies, two IPC-CS studies, and one IPC-TS+GCS study), and 64 per cent for GCS.

Another more recent meta-analysis in 1994 by Imperiale and Speroff[63] focused on venous thromboembolism prophylaxis in patients undergoing total hip replacement. "Stockings" and LMW hep were the most effective forms of prophylaxis with a decrease in the relative risk for DVT of 62 per cent and 64 per cent, respectively, which is similar to Clagett's meta-analysis. However, the treatment group in the six studies included in Imperiale's stockings categorization was IPC-TS in four studies and GCS in two studies.

So, IPC devices are effective in decreasing the incidence of DVT in patients who are at moderate to high risk and are probably more efficacious than GCS or mini-dose hep. IPC devices are not protective against PE. The data directly comparing the various methods of compression (knee-high *versus* thigh-high sleeves and graded-sequential *versus* uniform compression) is sparse and conflicting. More studies are needed to delineate whether any of these methods are better than another. But at present, there is not compelling scientific evidence to unequivocally conclude that any one method of IPC is superior over another so, it would be reasonable to base this decision on cost.

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