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Compression therapy in lymphedema: Between past and recent scientific data

Giovanni Mosti[1] and Attilio Cavezzi[2]

Abstract

Aim: To extrapolate and discuss the scientific data on compression in lymphedema treatment, so to review old and innovative concepts about pressure, stiffness and other interplaying factors related to its efficacy and comfort.
Material and methods: Narrative review based on search in Medline/Google Scholar through key-words related to compression in lymphedema.
Results: Currently available literature lacks relevant details about data on protocol, devices, techniques, interface pressure, stiffness, as well as biases are represented by the different descriptions to present the outcomes. More recent evidence from adjustable wrap devices and elastic garments question the need for high pressure (especially for the upper limb) and stiffness in lymphedema treatment.
Conclusions: At present time a very strong compression pressure exerted by material with high stiffness seem to be questionable in lymphedema treatment. A low pressure provides the best outcomes in arm lymphedema, while a pressure in the range of 40–60 mm Hg seems to provide higher efficacy in lower limb lymphedema, provided it is maintained overtime. A high stiffness seems to be unnecessary to treat chronic edema. Future clinical trials, including proper description of treatment methodology and adequate investigating instrumental tools, are awaited to possibly corroborate the conclusive outcomes of our review.

Keywords

Lymphedema, compression, bandage, elastic garment

Lymphedema

According to the most recent International Society of Lymphology (ISL) consensus document,[1] "lymphedema is an external (and/or internal) manifestation of lymphatic system insufficiency and deranged lymph transport" or, more simply, "a symptom or sign resulting from underlying lymphatic disease". It can be "primary" when this derangement is due to a congenital lymphatic dysplasia or "secondary" when due to multiple causes such as a "radical operative dissection (e.g., axillary or retroperitoneal nodal sampling), irradiation, or from repeated lymphangitis with lymphangiosclerosis".[1] The central disturbance in lymphedema is basically a low output failure of the lymphatic system, which is characterized by an overall lymphatic transport reduction. More generally chronic edema is defined as an edema lasting more than three months due to a derangement of lymphatic drainage, which becomes unable to remove a chronic fluid extravasation/stagnation depending on several causes. Lymphedema is one of the possible clinical manifestations of chronic edema, specifically related to a lymphatic disease.

The common denominator of all kind of edema is the organic and/or functional impairment of the lymphatic system fluid reabsorption and/or transport, which has fallen below the capacity needed to handle the presented load of microvascular filtrate including plasma, proteins, cells and macromolecules which may leak from the bloodstream into the interstitium.[1] In fact the classical concept according to which the extravasated fluid is reabsorbed in the general circulation by venular capillaries has been convincingly contradicted

[1]Angiology Department, MD Barbantini Clinic, Lucca, Italy
[2]Eurocenter Venalinfa, San Benedetto del Tronto (AP), Italy

Corresponding author:
Giovanni Mosti, Clinica MD Barbantini, Via del Calcio n.2, Lucca 55100, Italy.
Email: giovanni.mosti10@gmail.com

by new research demonstrating that in the extremities fluid reabsorption/drainage is almost entirely due to lymphatic system.[2] This new finding remarks the importance of the lymphatic system in the pathophysiology of every kind of edema.

In lymphedema, the progressive accumulation of fluid, together with the bulk of proteins and micro particles trapped in the interstitial spaces, give rise to "proliferation of parenchymal and stromal elements with excessive deposition of extracellular matrix substances and adipose tissue" in a chronic degenerating inflammatory process which leads to fibrosis and a series of possible tissue changes.[1]

Compression therapy

Compression therapy is an effective treatment in every kind of edema and it is considered the cornerstone treatment in venous edema and lymphedema.

In lymphedema, compression therapy is always applied together with other therapeutic measures such as exercise, manual lymphatic drainage and skin care, in the so-called decongestive lymphatic therapy (DLT), but it has been considered the most effective therapeutical procedure in lymphedema treatment strategy.[3]

Compression therapy helps in symptoms relief, and in the prevention of progression and risk of skin infection. It reduces edema by increasing the interstitial pressure, hence reducing the capillary filtration, increasing the lymphatic reabsorption of interstitial fluid (macromolecules first), increasing the lymphatic flow, shifting fluid to non-compressed areas, increasing the lympho-venous-muscular pump function, protecting the skin and breaking down the fibrosclerotic tissue.[4,5]

Although compression therapy can be considered the most important treatment modality in chronic edema treatment, specific evidences regarding materials, compression pressure and regime are lacking or sparsely provided.

This narrative provides an overview on the data we have on compression therapy in lymphedema.

A literature search was performed in PubMed and Google Scholar, focusing on articles of the last 40 years and using the following headings and keywords: "chronic edema", "edema management", "lymphedema", "lymphedema management", "lymphedema treatment", "compression therapy", "complex decongestive therapy". Intentionally no search was performed on intermittent pneumatic compression, which does not apply to this review.

Our aim is to report the literature data and innovative scientific proposals which could lead to a revision of the classical approach to compression therapy in lymphedema.

What we know

Although compression therapy is always included in the DLT or complex decongestive therapy (CDT), our search highlighted only a few papers specifically dedicated to compression therapy in lymphedema. Moreover, many studies on compression therapy are burdened with several methodological flaws and confounding factors[6,7] making hard to accept even the little data we have. The lack of consistent data is the main reason why we do not have solid recommendations in compression therapy of lymphedema, especially regarding the compression pressure to apply and stiffness of materials.[1,3–5,8]

Many papers and consensus documents "suggest" to apply multilayer multicomponent short stretch bandages in the initial treatment phase[1,3–5,8–18] and conversely to apply elastic, custom-made, garment in maintenance phase to maintain the achieved results and prevent recurrences as formerly shown by one observational[19] and one randomized study.[18] More specifically Yasuhara et al.[19] achieved good results in primary and secondary lymphedema treatment by elastic stockings. No control group submitted to a different compression device was included in this study. In the randomized controlled trial, Badger et al.[18] randomized two groups of patients with leg lymphedema to two kinds of treatment. One group was treated by multilayer bandage (MLB) followed by elastic stockings, and the second group was treated just by elastic stockings throughout the protocol duration. The reduction in limb volume by means of MLB followed by hosiery was about double the edema decrease achieved with hosiery alone and the outcome was sustained over the 24-week period.

This widely accepted clinical practice for limb lymphedema has been practiced in different studies, but mostly as part of a multi-modality treatment and without any specific reference to the exerted pressure and the material stiffness. Up to a decade ago, best practice was still based on a compression where "the optimal sub-bandage pressures for the multi-layered lymphatic bandage systems (MLLB) used in lymphedema have yet to be determined".[9]

Literature reports that almost all authors used in their studies an intensive decongestive treatment based on bandages with inelastic material commonly applied to exert the maximal pressure that can be tolerated by patients. Basically, little if no reference to the technique and especially to the compression pressure is reported in the vast majority of the studies. Usually the application of a strong (that was defined from 40 to 60 mm Hg)[20] or a very strong pressure (that was defined as more than 60 mm Hg),[20] with high stiffness, is reported in the pertinent articles, but the compression pressure was almost never measured and the really exerted

compression range was never assessed. As a matter of fact, inelastic bandages are difficult to apply and the target pressure is rarely achieved even by the expert healthcare personnel.[21–23]

Of great importance, bandage pressure loss has been repeatedly demonstrated in different studies (Figures 1 and 2(a)), which may require a frequent re-adjustment of the bands after a short time,[24] which is not the case with ACW (Figures 3 and 2(b)) and elastic stockings (Figure 4 and 2(c)). In venous diseases, scientific data on the pressure that is necessary to occlude the veins and exert a hemodynamic effect have been published and debated in the scientific community in the past 20 years.[25,26] Conversely, the search for an optimal compression pressure to treat chronic edema and lymphedema led to some scientific studies only more recently; subsequently, a review publication[27] highlighted that venous edema and lymphedema can be treated by a low-moderate compression pressure and do not require a very strong compression.

In addition to compression pressure, a basic feature of any compression tool is represented by stiffness of the used material; stiffness is defined as the pressure increase, produced by a compression device, per 1 cm of increase in leg circumference. Such circumference increase is determined by the calf expansion due to the muscle contraction. More recently, a much simpler method to calculate stiffness, disregarding the circumference increase, was proposed[28,29] and widely accepted by the scientific community. The static stiffness index (SSI) is calculated by subtracting the supine interface pressure from the standing pressure in the medial gaiter area where the tendinous part of the gastrocnemius muscle turns into its muscular part (named point B1). It was proven that the SSI is able to discriminate between the elastic ($SSI < 10$) and inelastic ($SS > 10$) compression devices.[28,29]

Stiffness characterizes the elastic property of a compression device applied on the limb. Inelastic, stiff material opposes to limb volume increase (the limb gives way) and this will cause a much higher pressure increase than the elastic material.

High stiffness resulted in an increased improvement of venous hemodynamics and in maximal comfort of compression device.[30–33] Compression with high stiffness is suggested in lymphedema treatment[3–5,8,9] mainly

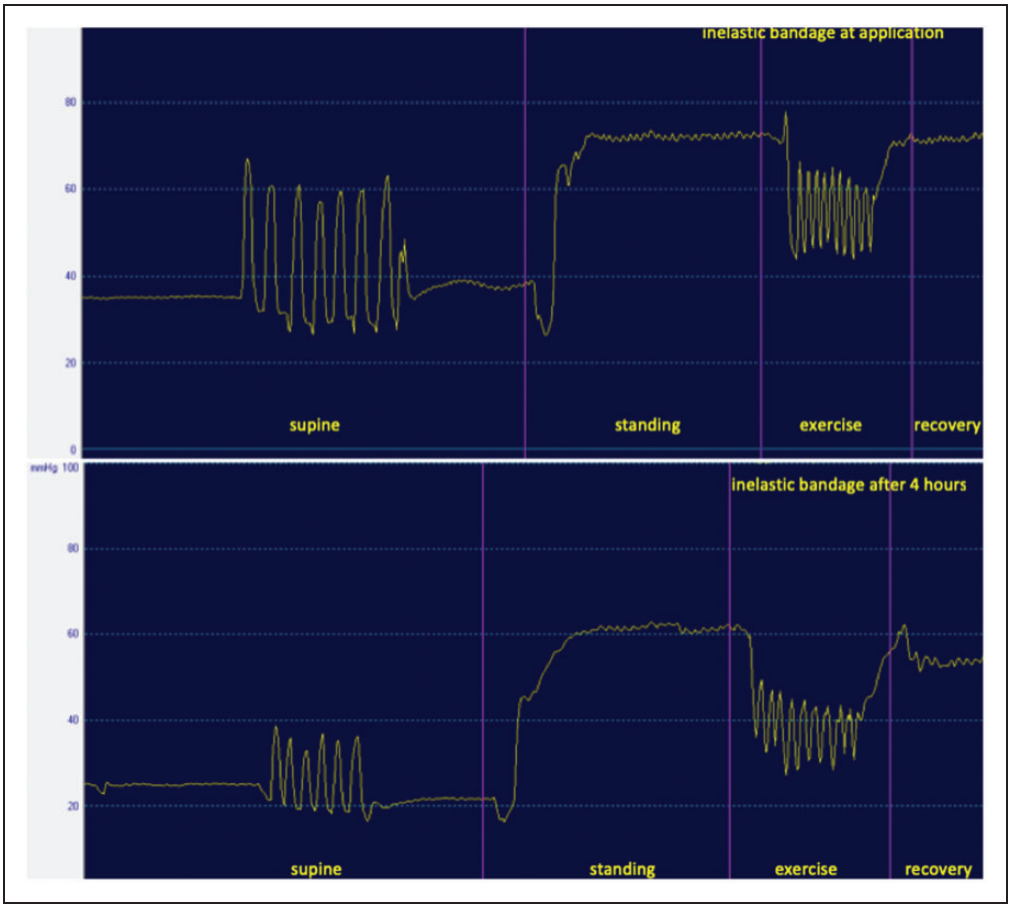


Figure 1. Pressure curves recorded after inelastic bandage showing the significant pressure drop after a few hours.

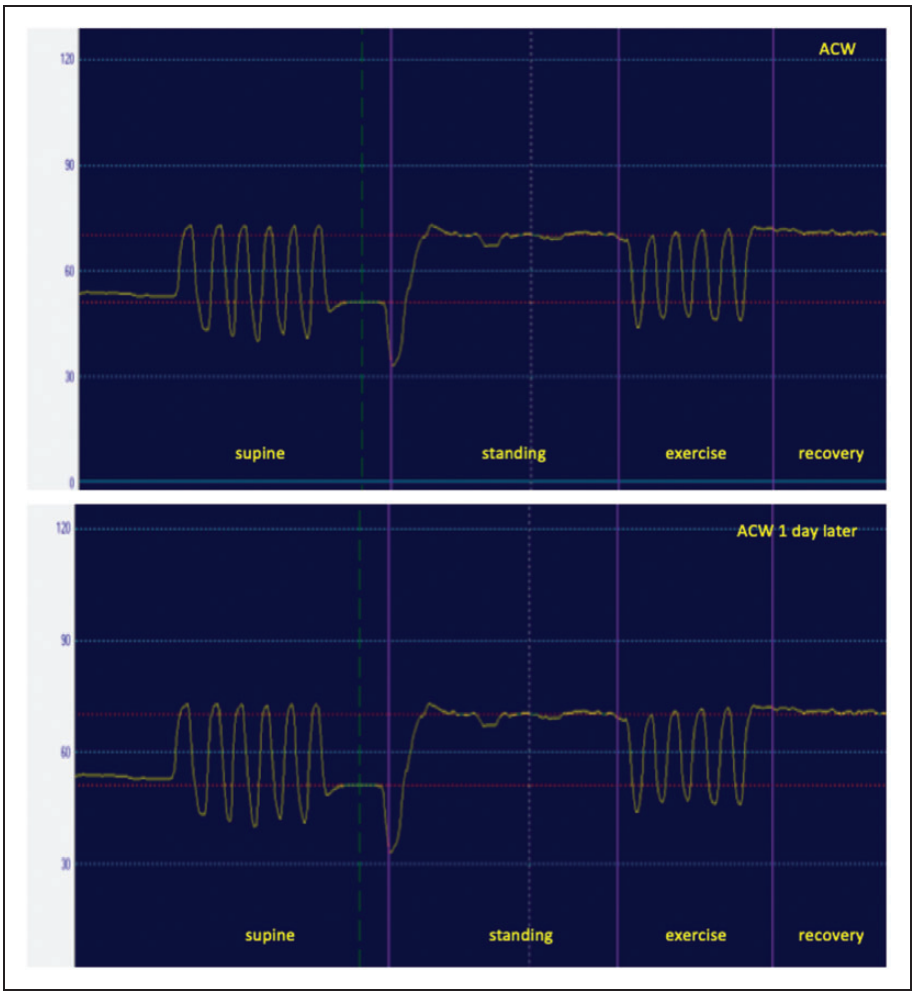


Figure 2. Median pressure values continuously recorded in 3 groups of 20 patients for 2 days. In the first group, inelastic bandage pressure (4A) drops down significantly. In the second group (4B), pressure is well maintained and even slightly increased by applying adjustable compression wraps. In the third group, compression pressure slightly decreases overtime by applying an elastic garment.

for the 'massaging effect' during muscle contractions, which is aimed at improving venous hemodynamics and the rhythmic pulsations of lymph collectors.

New evidence

It became clear that the compression pressure to treat edema may be different when targeting the upper or lower extremity. In contrast to the common belief, it is now well known that a low pressure is more effective and better tolerated than a strong pressure to treat arm lymphedema and this is true both after 2 and after 24 h.[34] This is likely due to the different filtration pressure that is much higher in the leg than in the arm in the standing and sitting position. The possible impaired lymph drainage caused by higher pressures is another proposed explanation.[35] In fact lymphoscintigraphy has shown that in case of arm lymphedema, lymph flow decreases when cuff pressure is reduced to 10 mmHg.[35]

Similar outcomes concerning the efficacy/compliance issue of compression in breast-cancer related lymphedema were highlighted in a recent study,[17] where elastic garments with presumably lower pressure compared to bandages achieved about the same outcomes, but elastic garments were much better tolerated both at 10 days and 3 months ($p = 0.065$ at three months).

As for lower limb compression, when treating venous edema and dependency syndrome (soft, pitting edema that disappear or reduces in supine position), we were able to show that a stocking exerting around 20 mm Hg pressure at the ankle is almost as effective as an inelastic bandage exerting a pressure higher than 60 mm Hg.[36] In our experience, an optimal compression pressure in leg venous edema was around 40 mm Hg at the ankle, especially when maintained

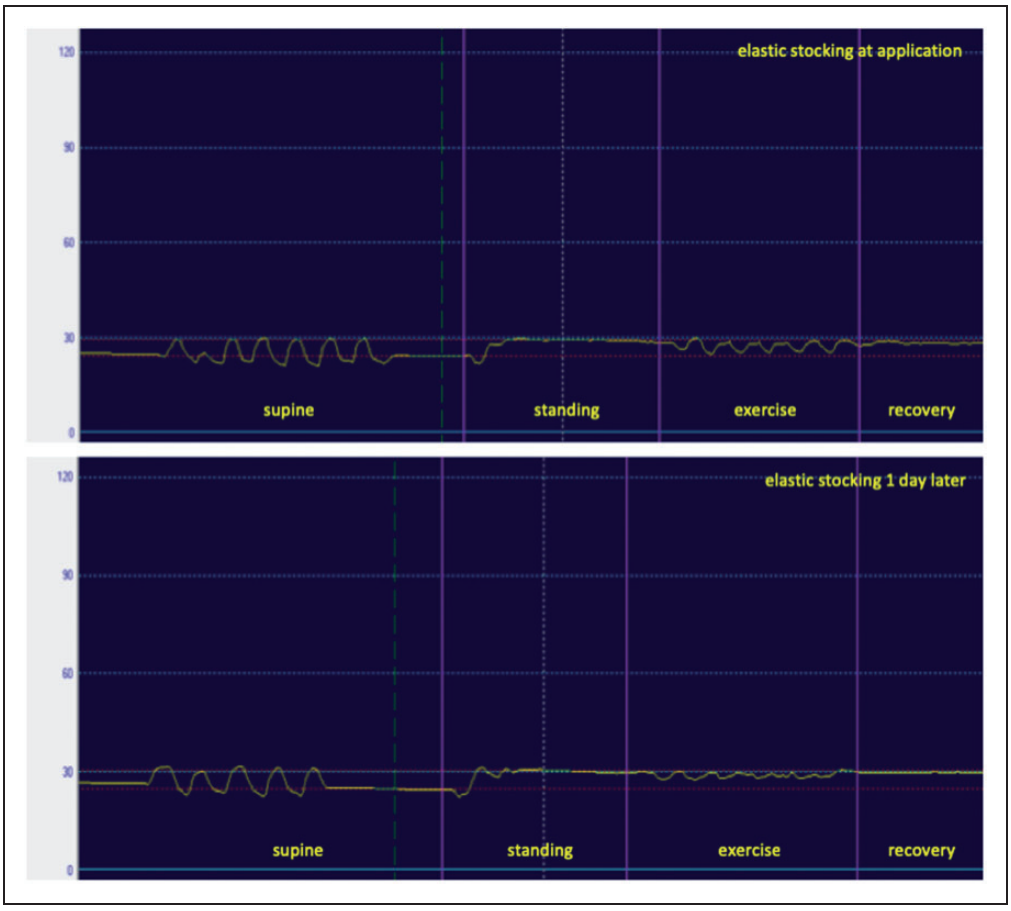
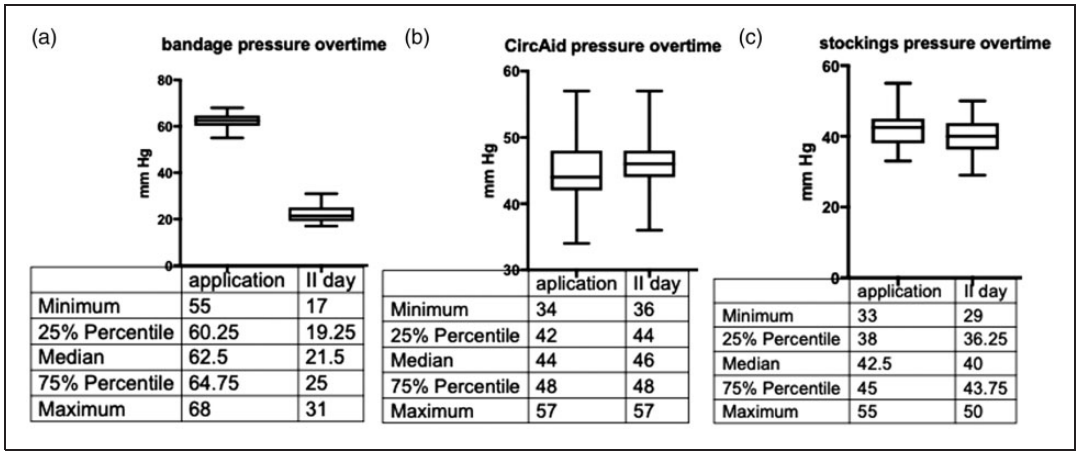


Figure 3. Pressure curves recorded after adjustable compression wraps application showing that the initial pressure is well maintained overtime and even slightly increased after 24 h.



	application	II day
Minimum	55	17
25% Percentile	60.25	19.25
Median	62.5	21.5
75% Percentile	64.75	25
Maximum	68	31

	aplication	II day
Minimum	34	36
25% Percentile	42	44
Median	44	46
75% Percentile	48	48
Maximum	57	57

	application	II day
Minimum	33	29
25% Percentile	38	36.25
Median	42.5	40
75% Percentile	45	43.75
Maximum	55	50

Figure 4. Pressure curves recorded after elastic stocking wearing showing that the initial pressure at application is well maintained overtime.

overtime by means of an adjustable compression device.[37,38] Also in lymphedema, similar outcomes comparing adjustable compression wraps (ACW) and inelastic bandages were shown.[39] It was demonstrated that ACW, even when applied with the same pressure of about 50 mm Hg as inelastic bandages, are more effective in leg volume reduction due to the device self-readjustment by patients leading to a better pressure maintenance overtime.

In leg lymphedema experimental studies (performed through intra-lymphatic pressure and flow measurement), the gradual increase of foot-applied compression up to 40 mmHg, showed an increasing intra-lymphatic pressure while evoking spontaneous lymph vessel contractions. Higher pressures did not result in any additional beneficial effect.[40]

In agreement with literature data, a pressure of about 40–50 mm Hg has been established as a standard value in increasing the lymph drainage in the lower limb: higher pressure is not necessary and potentially counterproductive.[36–39]

Despite of suggestions regarding compression with high stiffness to treat lymphedema, our group showed that elastic stockings exerting 23–32 mm Hg, as well as elastic kits exerting about 40 mm Hg, were almost as effective as inelastic bandages in reducing the lower limb edema.[36,37] The average SSI value of these compression devices was 3 both for elastic stockings and elastic kits. Similarly, ACW static stiffness index value was 7 in our study[38] on venous edema and 2 in the lower limb lymphedema study,[39] both indicating a low stiffness of the material. In contrast, inelastic material had always an SSI value higher than 10[39] and also above 20,[36–38] but this high stiffness did not result in a more effective edema treatment. It is necessary to underline that both elastic stockings and ACW maintained their pressure range overtime very effectively in all these studies, whereas inelastic bandages showed a significant pressure loss already after 24 h. Regarding the comfort of compression devices, inelastic bandages are always reported as comfortable in the examined studies. Both elastic stockings and elastic kits were well tolerated during the day and not well tolerated only overnight. ACWs applied in lymphedema treatment were reported to have a good comfort without any complaint from the patients and without significant differences compared to inelastic bandages.

Lastly other factors, such as patient's mobility, abnormally shaped limbs, coexisting arterial diseases, may play an adjunctive role in the decisional process on the choice of compression material to treat lymphedema. In particular in patients with arterial disease, the compression pressure must be reduced and it should not exceed 40 mm Hg.[41] Elastic material should be avoided as it can be painful in supine position.

Conclusion

Innovative data are being highlighted in the most recent studies applying stockings and ACWs in lymphedema treatment. Analyzing literature data, a revision of the high compression regime is proposed by many experts, as a pressure in the range of 20–30 mg Hg and 40–50 mm Hg seems to be effective in arm lymphedema and lower limb lymphedema, respectively. Similarly, a high stiffness does not seem a basic pre-requisite in lymphedema compression, in view of the interesting outcomes achieved by garments or ACWs both in venous edema and lymphedema. All these data could raise the conclusion that maintenance overtime of a moderate/strong pressure is the main characteristic we need to pursue treating extremity lymphedema; conversely high pressure and stiffness compression devices seem to play a minor role. The issue of a lower patient's tolerance towards low-stiffness elastic garments is possibly overcome by the use of ACWs which have been nowadays reported as effective for intensive as well as maintenance treatment of lymphedema. They allow self-management, with significant costs savings and proved to be well accepted by the patients in terms of wearing and tolerance. The renovated interest of the scientific and industrial community towards compression treatment, specifically in edematous limbs, has led to a series of possible innovative proposals which are currently under scrutiny.[42]

In order to get a higher degree of evidence, more randomized controlled trials on lymphedema treatment by means of different compression medical devices are to be performed.

These new randomized clinical trials should be performed incorporating already well-defined characteristics[43] regarding sample size, inclusion and exclusion criteria, wash-out period, proper duration, details on compression devices properties, compression pressure and compression stiffness that should be measured both at application and before removal of every compression device. Volume measurement is the basic finding and it should be assessed by validated systems. Water displacement, which is considered the gold standard in volume measurement, is easier to use in arm lymphedema then in patients with abnormally shaped lower limb lymphedema. Optoelectronic methods showed to be comparable with water displacement and easy to use in lymphedema patients.[44] Tissue changes assessment should be assessed through. A few instrumental methods, such as bioimpedance spectroscopy and duplex ultrasound/elastography, may complement the traditional volumetry methods,[45,46] so to assess both fluid and tissue changes. Finally, a quality of life questionnaire should be part of a global evaluation of compression effectiveness in patients with chronic edema and the International Compression Club questionnaire,[47] which has been already validated in a few countries, could be a valid tool in these clinical conditions.

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We just perform a literature review. No tests on human beings or animals. Ethical approval not necessary.

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Contributorship

Giovanni Mosti: literature research; writing the manuscript; reviewing Attilio Cavezzi: literature research; contribute to write the manuscript; reviewing.

ORCID iD

Giovanni Mosti http://orcid.org/0000-0001-7639-8463

References

1. The diagnosis and treatment of peripheral lymphedema: 2016 consensus document of the International Society of Lymphology. *Lymphology* 2016; 49: 170–184.
2. Levick JR and Michel CC. Microvascular fluid exchange and the revised Starling principle. *Cardiovasc Res* 2010; 87: 198–210.
3. Lee BB, Andrade M, Antignani PL, et al. Diagnosis and treatment of primary lymphedema. Consensus document of the International Union of Phlebology (IUP)-2013. *Int Angiol* 2013; 32: 541–574.
4. European Wound Management Association (EWMA). Caine S (ed). *Focus document: lymphoedema bandaging in practice*. London: Medical Education Partnerships, Ltd, 2005.
5. Best practice for the management of lymphoedema – 2nd edition: compression therapy: a position document on compression bandaging. International Lymphedema Framework, www.lympho.org/mod_turbolead/upload/file/Resources/Compression%20bandaging%20-%20final.pdf (2012, accessed 26 December 2018).
6. Badger C, Preston N, Seers K, et al. Physical therapies for reducing and controlling lymphoedema of the limbs. *Cochrane Database Syst Rev* 2004; 18: CD003141.
7. Oremus M, Dayes I, Walker K, et al. Systematic review: conservative treatments for secondary lymphedema. *BMC Cancer* 2012; 4: 12–16.
8. Lee BB, Bergan J and Rockson SG (eds). *Lymphedema: a concise compendium of theory and practice*. London: Springer Verlag London Limited, 2011, pp.431–441.
9. Moffat C. *Best practice for the management of lymphoedema. International consensus*. London: Medical Education Partnership (MEP) Ltd, 2006, pp.32–46.
10. Fukushima T, Tsuji T, Sano Y, et al. Immediate effects of active exercise with compression therapy on lower-limb lymphedema. *Support Care Cancer* 2017; 25: 2603–2610.
11. Lamprou DA, Damstra RJ and Partsch H. Prospective, randomized, controlled trial comparing a new two-component compression system with inelastic multicomponent compression bandages in the treatment of leg lymphedema. *Dermatol Surg* 2011; 37: 985–991.
12. Haesler E. Evidence summary: managing lymphoedema: compression therapy. *Wound Pract Res* 2016; 24: 263–266.
13. Franks PJ, Moffatt CJ, Murray S, et al. Evaluation of the performance of a new compression system in patients with lymphoedema. *Int Wound J* 2013; 10: 203–209.
14. Moffatt CJ, Franks PJ, Hardy D, et al. A preliminary randomized controlled study to determine the application frequency of a new lymphoedema bandaging system. *Br J Dermatol* 2012; 166: 624–632.
15. Partsch H, Flour M, Coleridge Smith P, et al. Indications for compression therapy in venous and lymphatic disease. Consensus based on experimental data and scientific evidence. Under the auspices of the IUP. *Int Angiol* 2008; 27: 193–219.
16. Lee BB, Antignani PL, Baroncelli TA, et al. IUA-ISVI consensus for diagnosis guideline of chronic lymphedema of the limbs. *Int Angiol* 2015; 34: 311–332.
17. King M, Deveaux A, White H, et al. Compression garments versus compression bandaging in decongestive lymphatic therapy for breast cancer-related lymphedema: a randomized controlled trial. *Support Care Cancer* 2012; 20: 1031–1036.
18. Badger CM, Peacock JI and Mortimer PS. A randomized, controlled, parallel-group clinical trial comparing multilayer bandaging followed by hosiery versus hosiery alone in the treatment of patients with lymphedema of the limb. *Cancer* 2000; 88: 2832–2837.
19. Yasuhara H, Shigematsu H and Muto T. A study of the advantages of elastic stockings for leg lymphedema. *Int Angiol* 1996; 15: 272–277.
20. Partsch H, Clark M, Mosti G, et al. Classification of compression bandages: practical aspects. *Dermatol Surg* 2008; 34: 600–609.
21. Keller A, Müller ML, Calow T, et al. Bandage pressure measurement and training: simple interventions to improve efficacy in compression bandaging. *Int Wound J* 2009; 6: 324–330.
22. Protz K, et al. Compression therapy: scientific background and practical applications. *J Dtsch Dermatol Ges* 2014; 12: 794–801.
23. Hara H, Hamanaka N, Yoshida M, et al. Variability in compression pressure of multi-layer bandaging applied by lymphedema therapists. *Support Care Cancer* 2018; 7. DOI: 10.1007/s00520-018-4385-9.
24. Damstra RJ, Brouwer ER and Partsch H. Controlled, comparative study of relation between volume changes and interface pressure under short-stretch bandages in leg lymphedema patients. *Dermatol Surg* 2008; 34: 1–7.
25. Partsch B and Partsch H. Calf compression pressure required to achieve venous closure from supine to standing positions. *J Vasc Surg* 2005; 42: 734–738.
26. Partsch H, Mosti G and Mosti F. Narrowing of leg veins under compression demonstrated by magnetic resonance imaging (MRI). *Int Angiol* 2010; 29: 408–410.

27. Partsch H, Damstra RJ and Mosti G. Dose finding for an optimal compression pressure to reduce chronic edema of the extremities. *Int Angiol* 2011; 30: 527–533.
28. Partsch H. The static stiffness index: a simple method to assess the elastic property of compression material in vivo. *Dermatol Surg* 2005; 31: 625–630.
29. Partsch H. The use of pressure change on standing as a surrogate measure of the stiffness of a compression bandage. *Eur J Vasc Endovasc Surg* 2005; 30: 415–421.
30. Mosti G and Partsch H. Measuring venous pumping function by strain-gauge plethysmography. *Int Angiol* 2010; 29: 421–425.
31. Mosti G and Partsch H. Duplex scanning to evaluate the effect of compression on venous reflux. *Int Angiol* 2010; 29: 416–420.
32. Mosti G, Mattaliano V and Partsch H. Inelastic compression increases venous ejection fraction more than elastic bandages in patients with superficial venous reflux. *Phlebology* 2008; 23: 287–294.
33. Partsch B, Mayer W and Partsch H. Improvement of ambulatory venous hypertension by narrowing of the femoral vein in congenital absence of the venous valve. *Phlebology* 1992; 7: 101–104
34. Damstra RJ and Partsch H. Compression therapy in breast cancer-related lymphedema: a randomized, controlled comparative study of relation between volume and interface pressure changes. *J Vasc Surg* 2009; 49: 1256–1263.
35. Modi S, Stanton AW, Svensson WE, et al. Human lymphatic pumping measured in healthy and lymphoedematous arms by lymphatic congestion lymphoscintigraphy. *J Physiol* 2007; 583: 271–285.
36. Mosti G, Picerni P and Partsch H. Compression stockings with moderate pressure are able to reduce chronic leg oedema. *Phlebology* 2012; 27: 289–296.
37. Mosti G and Partsch H. Bandages or double stockings for the initial therapy of venous oedema? A randomized, controlled pilot study. *Eur J Vasc Endovasc Surg* 2013; 46: 142–148.
38. Mosti G, Cavezzi A, Partsch H, et al. Adjustable Velcro® compression devices are more effective than inelastic bandages in reducing venous edema in the initial treatment phase: a randomized controlled trial. *Eur J Vasc Endovasc Surg* 2015; 50: 368–374.
39. Damstra RJ and Partsch H. Prospective, randomized, controlled trial comparing the effectiveness of adjustable compression Velcro® wraps versus inelastic multicomponent compression bandages in the initial treatment of leg lymphedema. *J Vasc Surg: Venous Lym Dis* 2013; 1: 13–19.
40. Olszewski WL. Contractility patterns of human leg lymphatics in various stages
of obstructive lymphedema. *Ann NY Acad Sci* 2008; 1131: 110–118.
41. Mosti G, Iabichella ML and Partsch H. Compression therapy in mixed ulcers increases venous output and arterial perfusion. *J Vasc Surg* 2012; 55: 122–128.
42. Hageman DJ, Wu S, Kilbreath S, et al. Biotechnologies toward mitigating, curing, and ultimately preventing edema through compression therapy. *Trends Biotechnol* 2018; 36: 537–548.
43. Stout N, Partsch H, Szolnoky G, et al. Chronic edema of the lower extremities: international consensus recommendations for compression therapy clinical research trials. *Int Ang* 2012; 31: 316–329.
44. Cavezzi A, Schingale F and Elio C. Limb volume measurement: from the past methods to optoelectronic technologies, bioimpedance analysis and laser based devices. *Int Angiol* 2010; 29: 392–394.
45. Cavezzi A. Duplex ultrasonography. In: Lee BB, Rockson SG and Bergan J (eds) *Lymphedema a concise compendium of theory and practice*. London: Springer, 2018.
46. Suehiro K, Nakamura K, Morikage N, et al. Real-time tissue elastography assessment of skin and subcutaneous tissue strains in legs with lymphedema. *J Med Ultrason* 2014; 41: 359–364.
47. Devoogdt N et al. International compression club compression questionnaire, www.icc-compressionclub.com (accessed 26 December 2018).